SYSTEM DYNAMICS ANALYSIS OF FINANCIAL FACTORS IN NUCLEAR POWER PLANT OPERATIONS

by

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ABSTRACT

Nuclear Power Plants require continuous investment in many areas to maintain high levels of safety and performance. The supply of economic resources through revenues, bond markets, and share holders has considerable impact on almost every measure of performance and safety. How a utility budgets these resources among many competing objectives has just as much control over performance, safety and the future availability of resources. This thesis describes a process for constructing models of the financial influences on nuclear plant performance and safety using the System Dynamics method. This financial model incorporates effects on the utility's performance from budget allocations, Public Utility Commission rulings, Stock and Bond Markets, and competition. Combined with the Plant, Social, Political and Information sectors, (see Simon 1995, Eubanks 1994) this thesis demonstrates that a utility's neglect of such issues as perceived safety, media attention, and perceived plant performance can have long term negative effects upon the utility's ability to raise capital, successfully plead rate cases and compete in a deregulated market.

Thesis Supervisor: Dr. Kent Hansen
Title: Professor of Nuclear Engineering

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1. Introduction

Since 1957, Nuclear Power has produced electricity safely and efficiently in the United States. It has benefited millions of people with a cheap source of power during times of heightened concern over energy resource supplies and environmental pollution. Despite complex technical and managerial hurdles, nuclear power plants have continued to improve both their operational capacities and safety records.

The future safe operation of nuclear power plants (NPPs) depends heavily on utility owners' and investors' continued financial support of nuclear plants and investment in new plants as better technologies are discovered. However, investments are limited by budgets which must also pay for the enormous costs of financing the construction of nuclear power plants. These financing costs are then severely affected by public opinion, nuclear plant perceived safety, regulatory controls, and other utility financial indicators. Utility owners must consider these outside influences when budgeting nuclear plant spending to maintain their excellent safety record and continued improvement in nuclear plant operations.

1.1 Background

A recent poll by the Nuclear Energy Institute indicated that over 57% of Americans favor the use of nuclear energy as one of the ways to provide electricity for the U.S. The Nuclear Regulatory Commission is in the process of licensing three new reactor designs. Despite the current glut of electric power, many large fossil plant will have to be decommissioned in the next ten years. Why have no new nuclear plants been ordered?(Bisconti, 1994)

The answer lies primarily in the financial uncertainty associated with nuclear power. The owner of a utility must take into account two factors when making any investment: the future return on the investment and the riskiness of the investment. As nuclear plant costs increase, the return in investment decreases relative to other investments, such as fossil plants. Furthermore, as the risk of losing the initial investment due to changing political moods or another accident rises, the required return will have to increase even more to account for the elevated probability of losing the invested money.

Since the cost of building a nuclear plant is so high compared to the cost of operation, the utility owner must make a greater investment up front. This greater investment means more capital is at risk before the plant is even operated and more of the cost per kW-hr produced goes to repaying debt. Thus, a change in the riskiness of generating sufficient returns on investment affects the operation of a nuclear utility much more than financial changes at another business or even a non-nuclear utility.

For a nuclear plant to generate the minimum necessary return for a given change in financial riskiness, operations and maintenance (O&M) costs must be reduced by a greater percentage than at a fossil plant. Deregulation will affect nuclear utilities more than fossils since they must reduce O&M costs much more to see the same percentage reduction in total cost to the customer. Nuclear utilities may no longer be able to guarantee a return to their investors if electric utilities are deregulated.

Prior to the 1980s, even as construction and operations costs rose, Public Utility Commissions (PUCs) guaranteed the utility investor a return on their investment through rate proceedings and a pre-determined "fair rate of return." In return for this guaranteed return and a monopoly on local power distribution, utilities pledged service to all local residents. Thus, as long as the PUC decided that utility investments were "prudent," meaning they could defend new plants as being required by projected demand, the utility was reimbursed for its expenses. Even as regulatory burdens, public delays, and lawsuits caused the cost of plants to skyrocket, the electricity prices were adjusted so that the utility investors received satisfactory compensation.(Hahne,1983)

After the oil embargo and the rapid inflation of the 1970s, consumers refused to accept the rapid escalation in utility bills. Consumer activist groups gained widespread popularity as friends of the people verses the Goliath utilities. Investors no longer considered utility stocks as safe as Treasury Bills.

The environment has changed even more in the United States recently. Because of the high likelihood of competition, utilities will no longer be able to guarantee the sale of nuclear electricity. The lowest cost producer will underbid the other plants and sell it's electricity to consumers. Nuclear plant owners already realize that nuclear power costs must be slashed to compete with fossil prices primarily because debt costs are so high. The question is how to cut costs and still maintain safe plants. (California Public Utilities Commission February, 1993)

Cutting costs has other unintended side effects. Of course, the effect on the possible safety of the plant is constantly cited as a reason not to deregulate nuclear plants. However, this contention is countered with the fact that the safest plants in the U.S. are also cheaper to operate. (Sponsor Meeting, April 1994)

This relation most likely does not work the other way around. A plant manager cannot just cut costs across the board and hope to achieve a safer plant. Side effects associated with cutting costs must be predicted and the fat must be trimmed carefully. One way to cut costs is to reduce preventative maintenance. The long-term side effects can possibly lead to increased corrective maintenance, reduced profits and diminished safety. Another way to reduce costs is to reduce manpower, training, information or goodwill spending. All of these reductions can cause long-term increases in costs. A third way to reduce costs is to settle for less than perfect grades on the SALP (Systematic Assessment of Licensee Performance) or INPO (Institute for Nuclear Power Operations) inspections. However, the utility must manage the negative public opinion and increased regulatory burden which can come from these lower scores-again possibly leading to higher costs.

All of these methods can result in increased risks associated with investing in nuclear utilities, or utility owner's investing in nuclear plants. Increased risks lead to increased financing costs. When financing costs increase, the utility has less money to spend on capital equipment, maintenance, and safety programs. Not only does decreased safety of nuclear reactors affect the financial outlook of nuclear investment, it can reduce the ability to make safety improvement investments to restore public and investor confidence.

Understanding the long term impacts of short-term cost cutting requires the manager to evaluate the connections between many variables both inside and outside the utility. Since these relations are very complex and often non-linear, carefully constructed models of these relations can aid the utility manager in determining the most important policy levers. He can then quantitatively evaluate various decisions.

1.2 Utility Financial Issues

Utilities deal with many financial issues which affect the safety and performance of their nuclear plants. Not only are financial resources limited and need to be budgeted by the utility managers, but outside agencies control the availability of funds needed by the utilities to operate their nuclear plants safely. These agencies include the state Public Utility Commission, Bond Raters, and Stock Market. Additionally, outside agencies impose costs on the utilities on top of normal operating costs which can reduce the amount of funds available. The costs include regulatory costs, lawsuit costs, and delay costs. The utility manager must take into account the effects operations decisions have on these outside agencies.

1.2.1 Regulatory Costs

Regulatory Costs have risen considerably since the economic peak of nuclear power construction in the early 1970s. Many nuclear managers attribute most of the increase in O&M (Operations and Maintenance) costs since the 1970s to the constant need to fulfill NRC (Nuclear Regulatory Commission) requirements. An examination of the breakdown of costs reveals that many nuclear plants' costs have risen many fold even in cases where the regulatory burden has leveled out. Thus, nuclear managers need to investigate other reasons for high costs of building and operating.(Boston Edison 1994, Hansen et. al 1989)

We can not underestimate the burden regulations have had on the nuclear industry. The accounting of many regulation costs do not include rework costs, or personnel costs associated with work that would not have occurred if the regulation had not been imposed. An example is a design change late in the construction of a nuclear power plant. The additional costs imposed because of rework and schedule changes can be seven times the initial cost of the required design change.(Bespolka, et al., 1994)

Additionally, utilities have been continually imposing requirements on themselves beyond the regulations of the NRC. Just like a driver stopping his car ten feet short of a stop sign, just to be sure, these actions have imposed additional costs on utilities.(David Morey, 1994)

1.2.2 Capital Costs

Building a nuclear plant has historically cost, in 1994 dollars, between 500 million for the early plants to a high of over 10 billion for the TVA and Vogtle 2 plants. The huge debt servicing requirements to build a nuclear plant require the utility to charge rate payers from 3-4 times as much for loan payments than for Operations and Maintenance.

It behooves the utility to control these costs by whatever means are necessary. For example, during the low interest rate period of 1994, Boston Edison refinanced their entire bond and loan structure to take advantage of the lower financing rates (Boston Edison, 1995). Although this restructuring cost millions of dollars, the savings to Boston Edison involved tens or even hundreds of millions of dollars over the lives of these loans.

Refinancing loans is well-known practice. However, the effect of public outcry, perceived safety by regulatory and financial institutions, and investors on bond ratings and bond prices can also lead to costs in the tens of millions of dollars over a period of time. These costs, instead of appearing on the balance sheet as outflows of income, are reflected in the share price of the utility, interest rates it must pay and bond prices it can charge. Again, since these costs are about 75% of the costs involved in running a utility, they can be more important than the cost of labor, parts or additional regulatory requirements.

One of the major reasons for the escalating costs of nuclear power plants during construction was the cost of interest during the delays. Each day a billion dollars sits waiting to be paid for, over $280,000 must be paid out in interest costs with a 10% interest rate. With a one year delay (many utilities' projects were delayed for many years such as Seabrook and Shoreham plants) compounded interest alone amounts to over $105 million. Since no principle is paid on this debt, because of the delay in construction, the debt continues to accumulate. In addition, utility interest rates continue to climb for the financing of new debt as well as debt taken out to pay for the interest charges which the banks usually require the utility to pay periodically.

Of course many other factors were involved in the explosive growth of nuclear plant construction cost such as rework, labor prices, inflation, inventory problems, lawsuits and several other production factors. Even without these factors, with just a delay alone of a few years, a utility can end up doubling or tripling the debt servicing costs. (Bespolka et. al., 1994)

After construction was complete, the resulting price of selling electricity increased to pay for this massive debt accumulated over greater than ten years. Since this cost controls the price the utility must charge so heavily, the factors which change these costs over time must be analyzed to see the their multiplicative effects.

For example, if society perceives nuclear plants as unsafe, so will investors. If these investors believe that their investment in nuclear utilities is more risky, the return on their investment the utility must pay will be higher, and the bond rating institution's rating will be lower-which translates into higher interest rates. Even though the interest rate allegedly only affects new debt, Boston Edison's consolidation of debt demonstrated the amount of money saved if the utility can lower its interest rate.

1.2.3 Equity Costs

Two additional costs, although less obvious than debt costs, is the cost of raising new capital and maintaining share price. When the utility's share price drops, the utility must sell more shares to raise additional capital, thus dropping the share price even more. To counter the drop in share price, the utility must raise dividends or raise the cash through debt instead. The inability to raise equity translates into dividend costs, or loss of value to the utility reflected in the stock price.(Boston Edison, 1994)

Unfortunately, since the price of a utility's stock does not represent a direct payout by the utility the day it occurs, this effect is often just referred to as "paper losses." However, these costs are real; the utility must account for them when they occur. These losses are directly reflected in the current stock price. The potential costs to the utility of having a lower stock price may be even larger than the change in stock price because of additional interest charges or smoothing of dividend forecasting which investors calculate.

Utilities pay out dividends regularly to maintain a high share price in a zero or very low growth environment. Investors perform a Net Present Value calculation of projected dividend payments over their time horizon to determine the current value of holding this stock. The stock price is then modified by estimated growth and relative risk of the stock compared to zero risk investment rate or return. As public outcry, perceived risk of a reactor, regulatory burdens or other factors which affect investment risk increase, the utility must increase dividend payments or face a lower stock price.(Brealey and Myers, 1988)

Since dividends are governed by the amount of profit the utility makes, the problems which affect investment risk occur utilities' profits are also dropping. So, the utility can easily enter into an "equity slide." This slide is similar to the debt spiral.

1.2.4 Control by Public Utility Commissions

In return for being a guaranteed provider, utilities are granted a local monopoly on production and distribution of electricity and a guaranteed "fair rate of return" to its investors. Thus, as the return to investors drops, the utility can raise the price of electricity automatically so that they can maintain the rate of return provided by the PUC. This process is automatic in between rate proceedings but is based on the PUC's perceived prudence of the utility. The return on investment they allow the utility can be changed. In fact, the same factors which affect the riskiness of investing in a utility also affect the perceived prudence of the utility.(Hahne and Aliff, 1983)

The reason for utilities' continued survival even in the midst of debt crises is due to the PUC's guaranteed minimum return on equity. If a utility's bond rating drops sufficiently, the utility cries to the PUC and the PUC generally raises the allowed return on equity so that the utility can raise the price of electricity further.

The feedback from the public when the utility raises the price of electricity causes the PUC to reduce the allowed return on equity so this escalation must stop somewhere. In reality, a dynamic compromise is reached where the utility pleads, the PUC reacts, the public complains, the PUC reacts and so on until an equitable rate is reached. It is not a harmonious process.

One of the key problems after the inflationary period of the 1970's was the utilities' rapidly escalating prices The public was not willing to accept additional increases in electric bills. Public activism resulted in Public Utility Commissions' reducing the "fair rate of return" to utilities.

The dynamics of the PUC, public interest groups, and utility owners are very complex. They involve many "soft" relations-political relations related to public perceptions, the political affiliations of the PUC members, attitudes of the utility owners towards negotiation with hostile opponents, and the power of public activists who often distrust the utilities and PUCs. The result of this complex system is much confusion and most often a misunderstanding of how the process affects the ultimate rate-payer.

An excellent example is the one that occurred in many states during the 1980's, especially in states with more activist PUCs. Citizen activists decried the huge profits the utilities were making in dollar figures and the huge costs associated with building new power plants. The activists cited surprising amounts of waste in spending by fat utilities, and multi-million dollar expenses to contracted firms since the utilities were reimbursed automatically for expenses related to construction.

Although the examples of waste and overspending were well known, the PUC was powerless by law to control how the utility spent its money. Thus, a simple cut on Return or Rate Base (which has the same effect as cutting Return on Equity) was enacted by the PUC. The result, instead of the cuts in waste the activist groups and rate payers desired, was an increase in borrowing by the utilities. The final result was a requirement to raise the Return on Equity a few years later to pay the increased financing costs. While it is true that that some utilities cut costs significantly in other areas, financing costs often increased, thus hurting the rate payer. (CA PUC, 1994)

1.3 Method of Solution

The problems the utility manager faces are primarily relational. Most cause and effect structures outside the utility plant are undocumented and often completely ignored by utility managers. However, long term profitability or even survival depends on attention to these problems.

The death of the nuclear industry, if it occurs, will not be due to technical problems. It will be due to political, social and regulatory problems. It is these problems which the nuclear manager is least equipped to face. System Dynamics provides the interrelation tool to measure the impact and provide 'what if' scenarios for decisions he must make in light of the current social/political problems nuclear power faces.(Hansen et. al., 1995)

A System Dynamics model of the nuclear industry's external factors and a nuclear plant has been developed to examine the interrelationships among these factors. The model has five different sectors as shown in Figure 1.3-1. The model uses over 1200 variables to analyze the complex relations involved in plant maintenance, financial planning, government, society and information sharing among utilities.

Each of these sectors was built individually and then connected to the other sectors. They can be run and tested individually. Once connected to the rest of the model, nonlinear feedbacks and delayed responses quickly make the model difficult to analyze by intuition. The experimental method running different scenarios then provides an excellent tool to learn how this system operates.

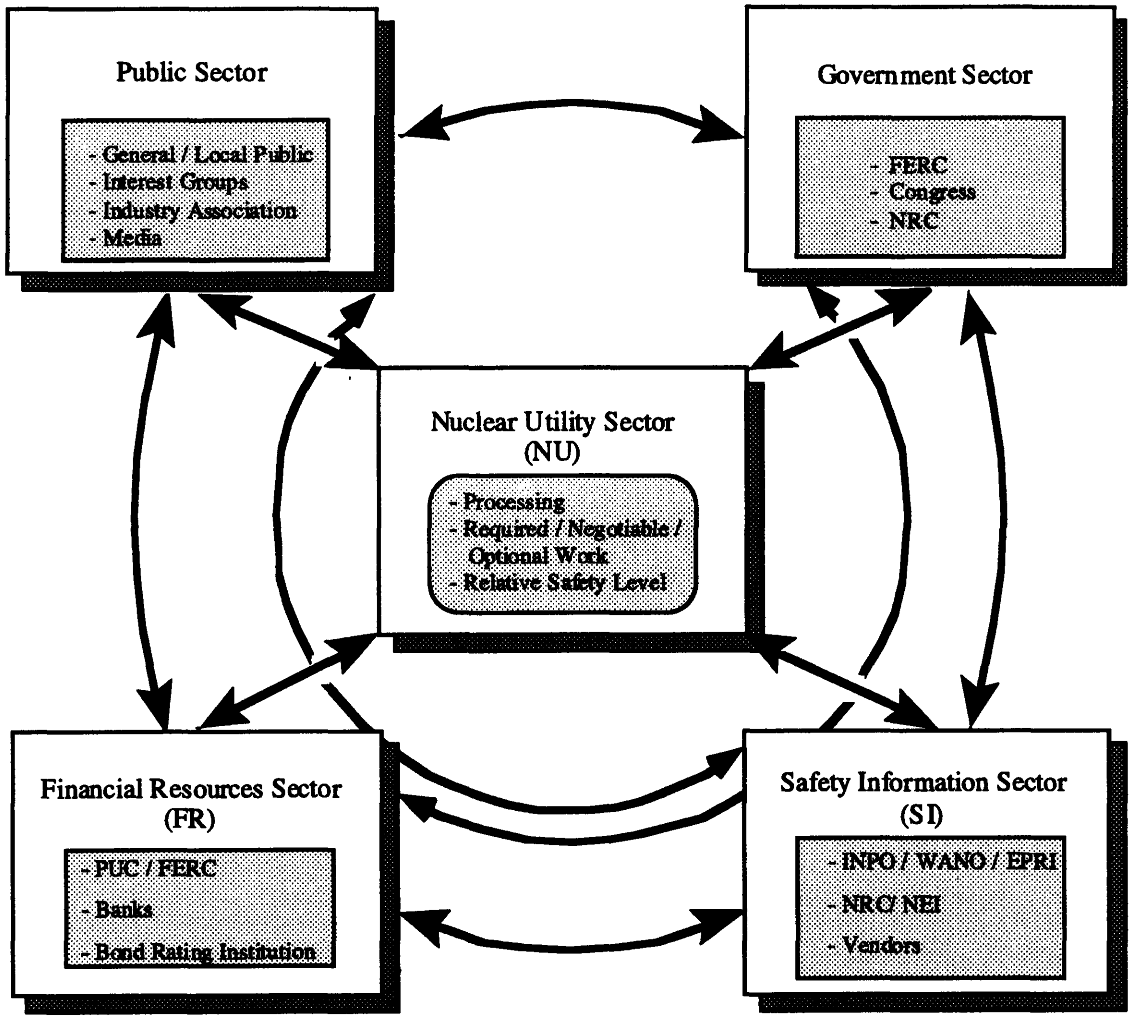

Figure 1.3-1 Overview of System Dynamics model of nuclear industry environment. It includes Utility Plant, Financial, Social, Governmental, and Information Sectors.

Additionally, System Dynamics provides dynamic modeling. Most human thinking is static. When reviewing the descriptions, it behooves one to think of the effects occurring over time. Time delays and delayed feedbacks are present throughout the model. One obvious example is spending on information. Often, this spending is viewed as wasted money. Over the first few months, the only results of spending are negative as scarce resources are diverted. However, over a number of years, accumulated learning improves plant performance, especially in the case where an accident occurs at another utility. (Forrester 1961, Simon 1995))

The model has been run to analyze many strategic decisions which nuclear plant managers face. Several counter-intuitive results have been found, and reasons for poorly understood processes have been examined. For example, in the case of a nuclear accident at another utility, the model suggests that a utility might want to cut back on preventative maintenance shortly after the accident to free up short-term resources to deal with the onslaught of investigations and public scrutiny. This finding and other counter-intuitive results show the power of System Dynamics to aid in management forecasting.

In the case of PUC proceedings, System Dynamics consistently models the long-term effects of the PUC, activist, and utility dynamics. Most other components of the utility financial picture: the balance sheet, stock pricing model, debt costs, and internal costs have been previously modeled using other methods. The intergroup relationships of the fight for return on equity are best represented with a system dynamics strategy. Since many of the mental models of the rate case procedure are 20 years old or more, most financial experts concentrate on presenting the correct utility cost requirements and cost of capital requirements to the commission and ignore all together the long term dynamics of the social and regulatory stakeholders.

2. System Dynamics

> "Industrial [System] dynamics is the study of the information-feedback characteristics of industrial activity to how organizational structure, amplification (in policies), and time delays (in decision and actions) interact to influence the success of the enterprise."
>
> Jay Forrester (1961, p. 13)

2.1 Background

Jay Forrester, an electrical engineer, was an expert in control system theory and feedback. He and others decided to use control theory to analyze industrial systems in the late 1950's. Since then system dynamics has been used to analyze industrial, economic, social and environmental systems of all kinds. System dynamics has been put to use wherever there existed complex feedback. (Eubanks 1995, Forrester 1961)

The system dynamics approach is based on the following framework taken from Jay Forester's book:

- Decisions in management and economics take place in a framework that belongs to the general class known a information-feedback systems.
- Our intuitive judgment is unreliable about how these systems will change with time, even when we have good knowledge of the individual parts of the system.
- Model experimentation...can show the ways in which the known separate system parts can interact.
- Enough information is available for this experimental mode-building approach without great expense and delay in further data gathering
- The "mechanistic" view of decision making implied by such model experiments is true enough so that the main structure of controlling policies can be represented.
- Our industrial systems are constructed internally in such a way that they create for themselves many of the troubles that are often attributed to outside and independent causes.
- Policy and structure changes are feasible that will produce substantial improvement in industrial and economic behavior...(Forrester, p. 14, 1961)

Within this framework system dynamics develops a simulation method which managers and policy makers can use to conduct experiments with different strategic decisions. Analytic solutions of complex, non-linear, human systems are not possible. Through model building and experimentation, certain optimization schemes can be derived in a fraction of the time it takes to experiment in the real world. For example, the nuclear utility model can run a ten year simulation comparing three different strategic decisions in less than 30 minutes on a Macintosh Quadra 800 Computer. (Eubanks 1995, Hansen et. al 1994))

Many uses for system dynamics modeling have been found during its 30 year history. Some famous examples include the Industrial Dynamics Model, the world economics model, and more recently the "Boom and Bust" model. Additionally, many consulting firms and companies use system dynamics as a primary management tool. Organizations using system dynamics include: Pugh Roberts, Exxon, Motorola, the Department of Energy and Ford.(Senge 1994, Sterman 1991)

One powerful use for System Dynamics is to overcome prejudices and force consistency when trying to deal with a problem in a human organization. In the Boom and Bust model developed during the system dynamics class, acute shortages of the product appear as it becomes popular. Marketing personnel are often ill-prepared to enact one counter intuitive solution to short supply: raising the price of the product. Not only do price increases reduce demand but they supply sorely needed capital for the company to expand production. A prejudice against hiking prices much above marginal cost prevents most business owners from raising prices. Then, he finds himself with chronically short production output while competitors are rapidly entering the field.(Sterman, 1991)

With respect to a nuclear utility plant, owners need a method to maximize long-term revenues in light of social fears, regulatory burdens, changing PUCs, production pressures to reduce scheduled maintenance, and competition. Without including all of the time delays and feedbacks involved, a utility manager will not be effectively using all of the resources available and operating the correct policy levers to optimize decisions. Like the inventory problem described by Jay Forrester, the manager can become short-sighted and over react to current problems if he does not account for time delays. In the case of the inventory model, large cyclic inventory over-shoots occur because of production delays. If one adds to this problem a manager's overreacting to current events, the time delayed effects can be even larger. (Forrester, 1961 pp. 21-29)

Essentially, utility managers need a tool to provide "what-if" scenarios to better manage their spending in light of the long-term feedbacks which are peculiar to nuclear energy. Most of the relations between stakeholders and effects on nuclear plants are highly non-linear and the connections are very complex. Thinking about three or four relations at once is next to impossible; for a thousand variable simplified model of the a nuclear plant with the current social/political environment, thorough mental analysis is impossible.

The building of System Dynamics models is very similar to building computer models of physical systems. Just as one models a car as mass/spring/damper system, human systems can be approximately modeled. Anything that accumulates over time such as paperwork, public opinion, regulations etc., can be modeled as stocks or energy storage devices such as the height above the ground of a car or the mass of water in a bathtub.

When feedback occurs to effect a change in a stock, this effect is modeled in System Dynamics as an auxiliary. In physical systems auxiliaries are usually energy translational devices such as springs. The spring imparts a force on a car which results in an acceleration. Acceleration flows into velocity and velocity flows into car height. An example of these auxiliaries in the utility model would be the effect of electricity price on customer satisfaction.

The damping effects, or delays in increases of stocks are modeled as flow restrictions just as energy dissipation devices are modeled in physical systems. These dampers delay the accumulation of stocks; they are analogous to a shock absorber reducing motion of a car or the nozzle on a shower. The damper of a car delays the effect the road surface has on the car height by counteracting the acceleration force of the spring. Similarly, in the model, the time to convene PUC hearings delays the impact of needed revenue by the utility on an allowed return on equity.

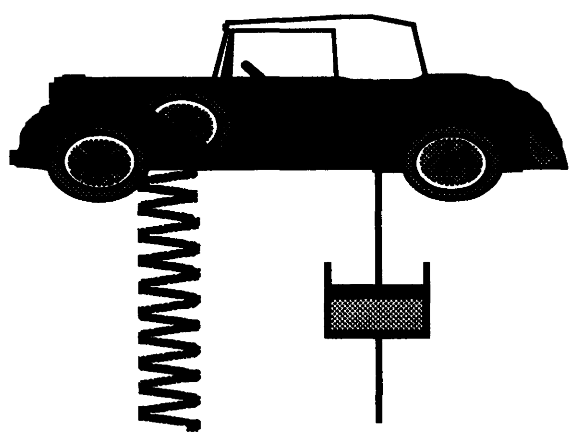

Figure 2.1-1 The simplified model of the car as a mass/spring/dashpot system.

2.2 Model Structure

The development of a model for a social/political system is similar to the development of the model for a physical system. However, since social/political systems are often vastly more complex with many difficult to define variables, the effort at modeling must be more carefully executed than physical models. However, the benefits of modeling social/political systems is that, just as one can tune the shock absorber and spring of a car, one can also tune social/political systems.

Understandably, since many of the variables involved in social/political systems are poorly defined or inaccurately measured, the tuning will be much more approximate than the tuning of a car. However, the modeling process can provide more insight into the processes of the human system and the dynamics of the interactions than can be gained through other investigatory processes.

Returning to the case of the car to demonstrate how System Dynamics models physical systems, the method for developing a model will be detailed. The steps one normally follows are(Goodman and Karash 1995, Richardson and Pugh 1981)

1. Define the problem
2. Draw graphs of behavior over time (current and desired)
3. Focus the issue to help determine the most important path to solution
4. Based on the Focusing statement develop the structure of the problem
5. Develop and present causal loop diagrams to the stakeholders
6. Develop Quantitative Relations
7. Connect the relations in the entire model
8. Present graphs over time of model dynamics to stakeholders
9. Validate model

Define the problem. In the case of the car, this involves determining that we would like to have a smooth ride over a bumpy road surface. We do not want to feel every bump but we also do not want to gyrate forever after hitting a pothole.

The graph of a step input in road height followed by various car responses is shown in Figure 2.2-1. The preferred response is the small overshoot and return to normal known as critical damping. In order to model the system one needs to focus the development further.

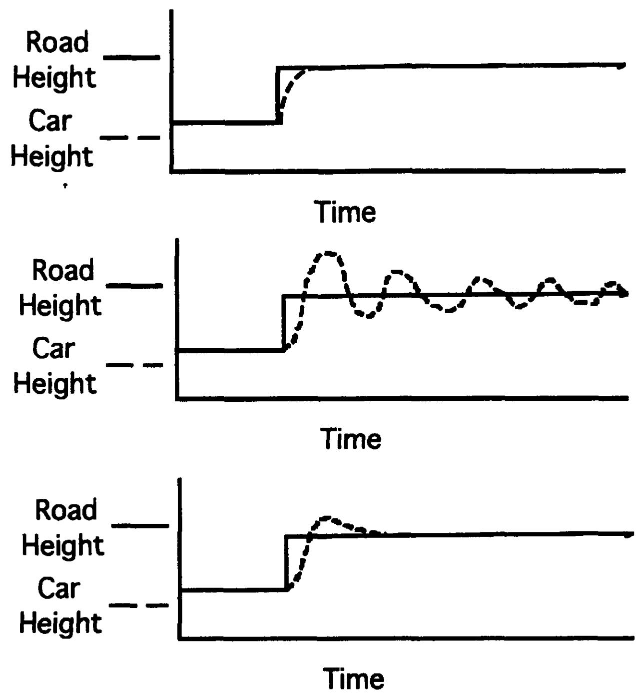

Figure 2.2-1 Behavior over time graphs for the car. The top represents overdamping, the middle underdamping and the bottom critical damping.

The critical issue for this simple system is determining which variable can be adjusted to achieve the critical ride. Assuming the mass of the vehicle is constant, only the characteristics of the spring and shock absorber can be changed. Thus, it is these variables which we will explicitly model.

The relations between the variables can now be demonstrated in a causal loop diagram with the concerned variable, Car Height at the top of the loop. See Figure 2.2-2. Car height is compared to Road Height. The difference from initial values determines the spring force. At the same time Car Velocity is compared to Road Velocity. This difference translates into a counter-force by the shock absorber which mitigates the spring force on acceleration. Acceleration translates to car velocity and then to car height.

The negative sign in the middle of the loop shows that this system is self regulating or a negative feed back system. It gradually decays to steady state. The time it takes to reach steady state is obviously dependent on the damper and spring constants.

The next step is to model the system and quantitatively determine relations between the variables. In this case, the issue is fairly easy because this system has been modeled before.

The spring force is based on the difference in heights; damper force is based on the difference in velocities; and the acceleration is based on the sum of the forces divided by the car's mass. In human based systems the modeling of these variables is much more difficult.

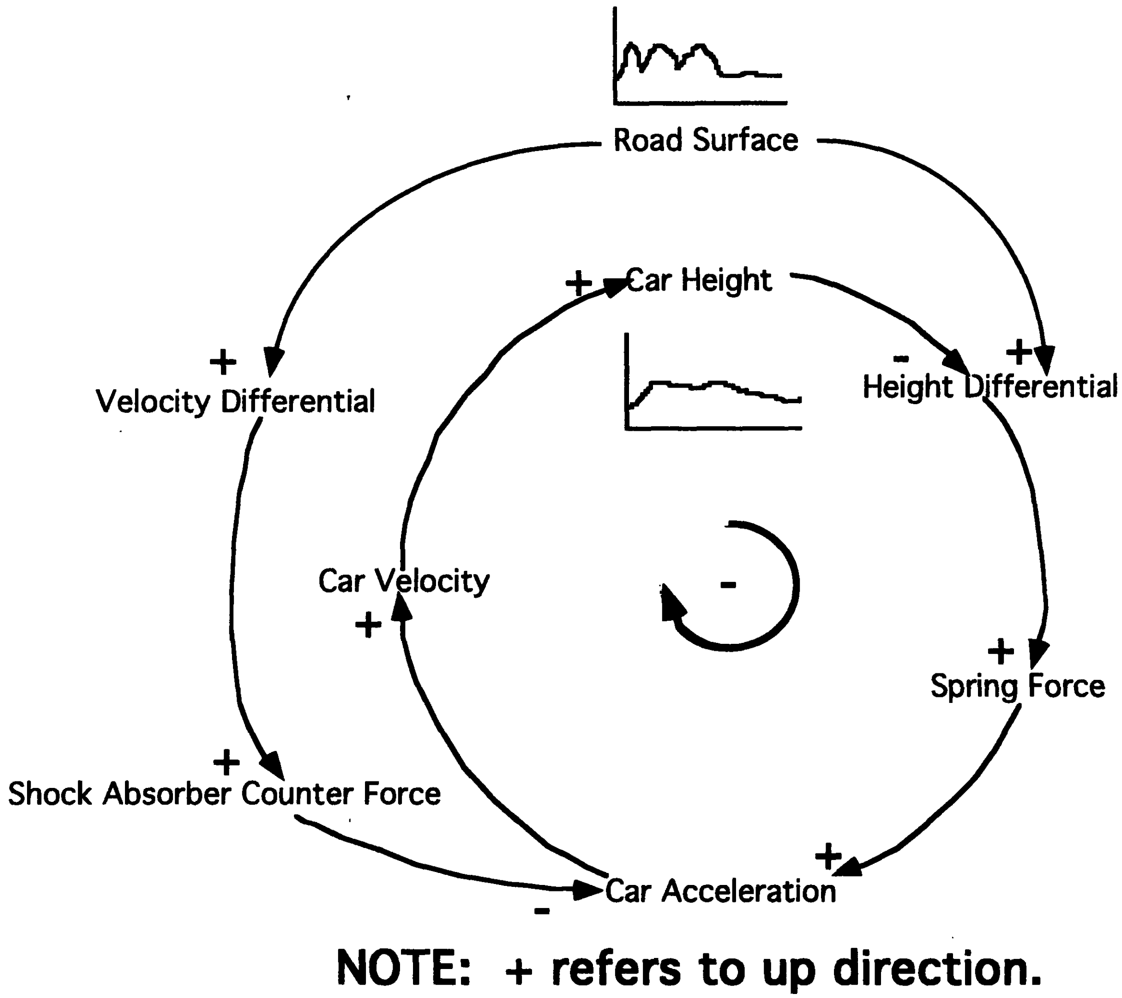

Figure 2.2-1. System Dynamics causal loop description of a physical system. In this case, a car with a spring and shock absorber. The desired effect is shown in the inset graphs.

Translating the causal loop diagram into a Stella® model involves taking these quantitative relations and attaching them. Since the relations between the stocks such as velocity and height are already known, they can easily be modeled. The entire model is shown in Figure 2.2-3.

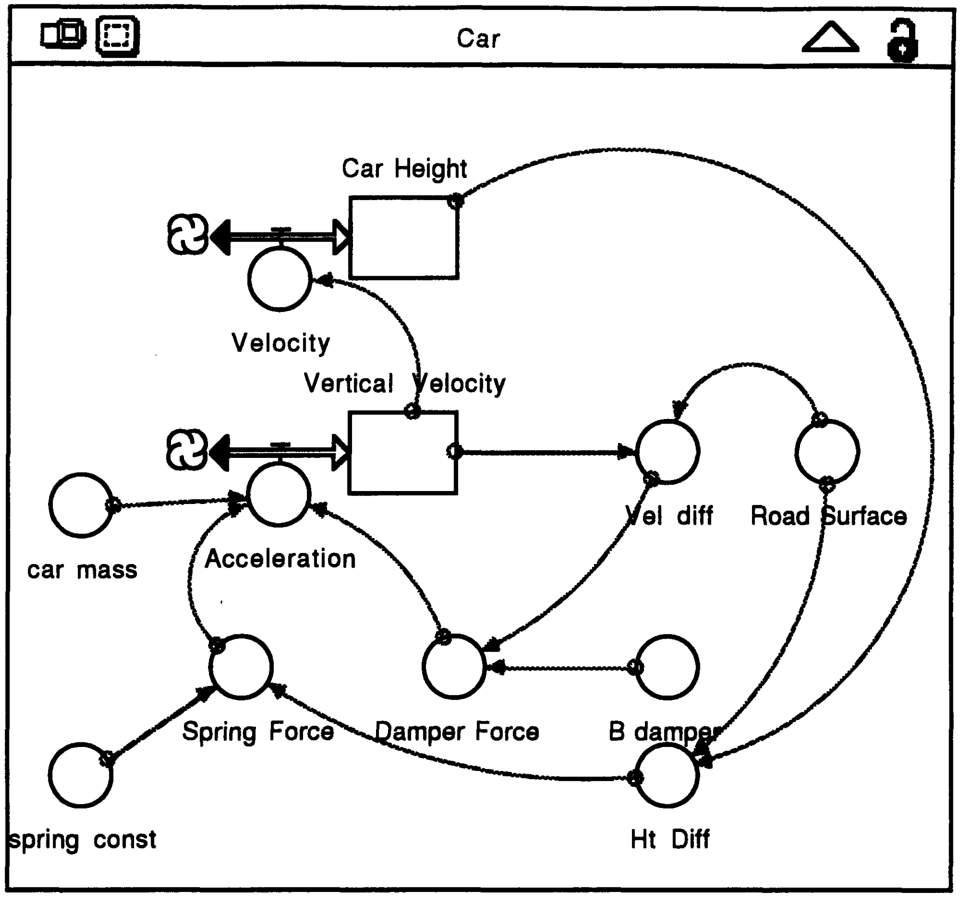

Figure 2.2-2 System Dynamics Model of a Car. It includes the mass of the car, spring and shock absorber.

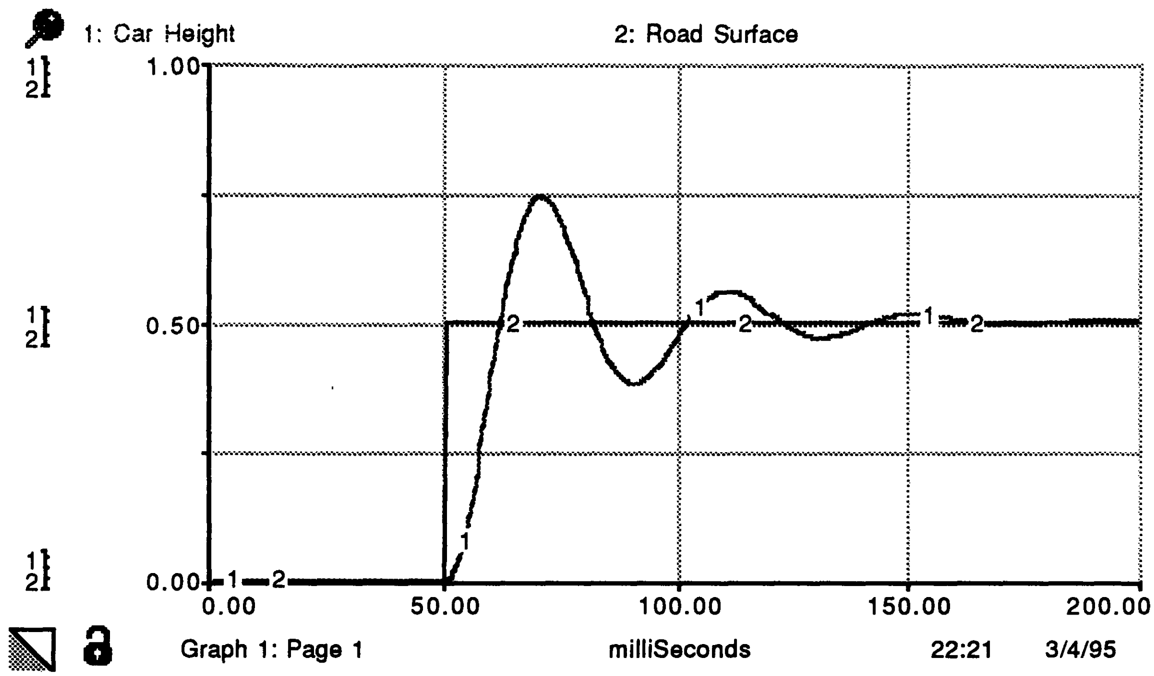

Figure 2.2-3 A graph of relative road height and relative car height over time. This car needs new shock absorbers, which would damp the vibrations more. These same effects are also evident in human systems.

By inspection, the car in Figure 2.2-4 is underdamped. In the case of the simplified car example, the differential equations can easily be solved to reveal the necessary damping and spring constants to achieve the desired ride. However, when dealing with non-linear human systems such as a nuclear utility and the politics which surround it, the many ordered differential equations are impossible to solve analytically. The methodical approach System Dynamics uses in this case provides insight into the system that analytical equation solving cannot.

Model validation also takes place by inspection for the car. In the case of management systems several other methods of validation must be employed. The example of the car demonstrates the compatibility of System Dynamics with physical systems.

2.3 Model Validation

The methods for model validation in System Dynamics can be very different from physical systems. However, the essential elements of the scientific method are still used. In the model of the car, the experimental laboratory is a ride on a road to test whether the model has predicted the performance of the car.

For system dynamics models, validation is much more difficult because of the complex, non-linear, and unpredictable nature of human systems. A system dynamics model can predict simplified performance only within the confines of the model parameters. The car model does not attempt to predict how the car will react to an icy road; for the same reason the inventory model does not attempt to predict inventories if the product is made illegal, or a new product comes to market.

Several methods are currently used to validate system dynamics models. The methods that are particular to the nuclear utility model include: Structure verification test, parameter-verification test, boundary-adequacy test, and dimensional consistency test. Additionally, a test which includes all of the above tests is "transferring confidence to persons not directly involved in model construction." (Forrester and Senge p. 209, 1980)

The structure verification test, made easier with STELLA®, is performed two ways. The first is comparing the model relations through causal loops and STELLA® diagrams to literature. The second is presenting the relations to policy stakeholders and experienced system dynamics modelers. The structure test is probably the most important test since all other tests follow from it.

The dimensional consistency test is part of turning the structure into a quantitative model. It is performed by the model builders while developing equations to relate the variables contained within the model.

The parameter-verification test compares the model results with historical data. This test, the experimental validation of the model, is the test which most closely matches tests for physical systems. However, this test must be conducted understanding the limitations of the model.

Presenting the model to experienced managers and policy makers during each step of model verification is crucial. Interviews with these policy makers also satisfies the boundary-adequacy test to ensure during each step of model building the size of the model is adequate to answer the intended policy questions.(Forrester and Senge, 1980)

3. Nuclear Plant Model Sector

The nuclear plant model develops all of the processes inside the nuclear plant that control the performance and safety of the nuclear plant. Nuclear power plants can be broken into subsectors such as personnel allocation, budgeting, and maintenance. Individually these subsectors control the flows of workers, money or materials and broken parts. When connected, these subsectors then show the dynamic operation of a nuclear power plant with respect to capacity, safety, and revenue generation. (Carrol et. al. 1993, Sterman et. al, 1992)

The following subsectors of a nuclear power plant are represented in the nuclear plant sector.

1. On-line capacity calculations
2. Equipment Flows
3. Defect Flows
4. Defect Sources
5. Learning & Training
6. Scheduled Work Flows
7. Unscheduled Work Flows
8. Safety and Radiation Risk
9. Planning
10. Mechanics Time Allocation
11. Maintenance Staff Hiring
12. Engineer Hiring & Allocation
13. Manager Hiring & Allocation
14. Mandatory and Discretionary Inspections
15. Materials Specifications & Stores Inventory

Since this model is much simpler than an actual nuclear power plant, several factors have been aggregated in each sector. For example, engineers have been divided only into maintenance, planning, design and information categories. The maintenance engineer allocation system does not need to be further disaggregated to achieve the desired level of accuracy since the primary goal of the model is to estimate overall capacity. The flows of broken equipment through the maintenance processes are similar across functions. So, they can be aggregated into average values.

3.1 Description

The nuclear plant subsector was originally a model built by DuPont to determine the reasons for low capacity factors at chemical plants. DuPont used the plant model to determine the value of preventative maintenance (PM) and to test methods for gradually implementing a successful preventative maintenance program (PMP) with limited resources. We have modified the model extensively to incorporate many of the attributes particular to nuclear plants. The subsectors are described below.(Sterman et. al, 1992)

3.1.1 Equipment flows and Capacity Calculation

The equipment flow subsector controls the total pieces of equipment either fully functional, broken down, or taken down for PM. The equipment flows and capacity calculation subsector is shown in figure 3.1.1-1. The flows among the three states is controlled by the other sub-sectors within the plant such as equipment repair rate, inspection rate, and breakdown rate.

The capacity calculation is a graphical function based on the percentage of equipment broken down or taken down by maintenance personnel. If equipment is taken down, it is expected that some prior planning has occurred so that it does not affect capacity as severely. The chance that broken equipment will cause a forced outage is accomplished with a probability function. As more equipment breaks the probability of one of those pieces causing a forced outage increases. Periodic outages also effect capacity in this subsector.

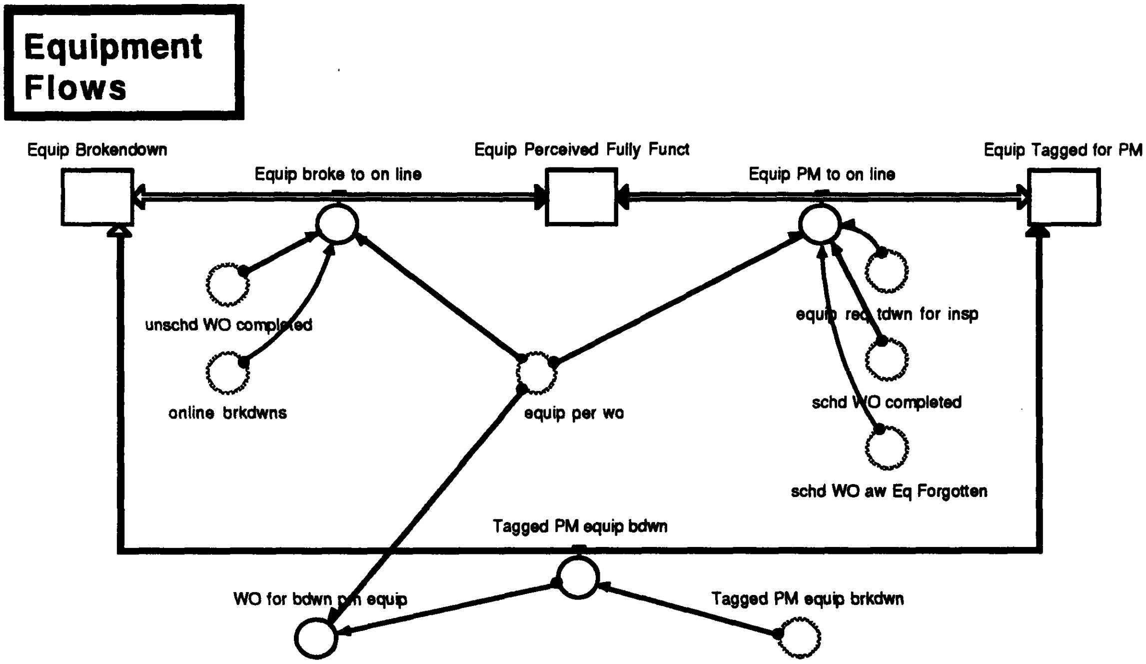

Figure 3.1-1A STELLA® representation of equipment flows at the nuclear plant.

Equipment is either Fully Functional, Broken down, or Tagged for PM. Flows between these three states represent equipment breaking, being fixed, being taken down for inspection, breaking during PM inspection, or being sent to the PM system while broken down.

3.1.2 Defect Flows and Defect Sources

The defect flows subsector generates defects, produces breakdowns, and eliminates defects through repair. Defects are generated several ways:

1. Normal Operation
2. Worker Repairs
3. Defective Parts
4. Breakdowns of other equipment

The defects then stay in the equipment until they are identified or cause a breakdown. If they are not identified through inspections, a defect will cause a piece of equipment to breakdown in an average of twelve weeks. Likewise, even after mechanics identify a defect, it must be repaired through scheduled maintenance. Otherwise, it will eventually cause the equipment to breakdown as well.

Defect generation is reduced as plant operators learn how to reduce stress on components, and wear on components declines due to break-in. As mechanics accumulate repair hours, they make fewer mistakes. As personnel inspect more equipment, their inspection skills improve. The model does not yet include severe end of life characteristics of the bathtub effect since it runs for only ten years.

3.1.3 Learning Curves

Learning curves are also included which reflect the reduction in defect generation over initial plant life. Information and training impact the plant sector most through this sub-sector. As training hours increase, the learning curves improve. As the utility invests more in information the learning curves also improve. Learning curves are also generated for forced outage frequency due to operator errors, event report rate and parts inspections.

3.1.4 Flows of Unscheduled Work Orders

This sub-sector accounts for repairs of all broken equipment. Once equipment breaks. its repair is simplified since it does not need to be inspected or scheduled first. However, since worker productivity is lower when fixing broken equipment, equipment stays down longer. Also, since equipment cannot be taken down at desirable time, such as during a periodic outages and ordering parts consumes more time, each down piece of equipment has a greater impact on plant capacity.

The flows of the sub-sector include work order creation, engineer and manager review, material acquisition, partially functional equipment take down (a percentage of broken equipment), and work in progress. Once, the broken equipment flows out of "Work in Progress," it is considered fully functional. However, new defects could have been introduced during the repair process.

3.1.5 Flow of Scheduled Work Orders

This sub-sector controls PM repairs. Inspections determine necessary repairs. They are then scheduled, reviewed, and performed. Meanwhile, plans are created and materials are acquired for the job. The whole process is more efficient since the work is scheduled in advance. Additionally, workers introduce fewer new defects into the equipment and the taken down equipment has reduced effect on plant capacity.

The goal of the utility is to eventually place all equipment in the PM program. However, one of the balancing acts in the model is allocating workers and engineers between the unscheduled and scheduled maintenance programs. If managers allocate too many people to PM then the broken equipment will not be repaired.

3.1.6 Maintenance Staff, Hiring Allocation and Overtime

This subsector is the heart of personnel allocation. The designs of Manager and Engineer allocations are similar; only the functions of the personnel are different. Based on the budgeted allocation of resources, various fractions of maintenance workers either work on maintenance, perform inspections, train or plan work orders. Other overhead type jobs are assumed to be an equal part of all the above jobs. If there is a shortage of workers, overtime results. As overtime increases, hiring increases. However, there are time delays and feedbacks that affect worker productivity. As overtime increases, worker productivity drops substantially. Alternately, if workers are under-utilized, their productivity will drop to fill the available time. Thus, it is difficult to see the fat without layoffs and the ensuing consequences, good or bad.

3.1.7 Mechanics' time allocation

The division of mechanics' time between scheduled and unscheduled maintenance is assumed to occur automatically. The way the budget allocator controls an increase in preventative maintenance is by increasing inspections. The mechanics react to the incoming workload each week by assigning the required number of mechanics to the work. If there are too few mechanics, broken equipment receives priority. However, they will attempt to do all the required work, based on the backlog, by increasing overtime.

The number of backlogged work-orders controls the capacity of the plant. This backlog represents the pieces of equipment that were not fixed at the end of the week. The pieces that are still broken reduce capacity.

Training effects a reduction in time the mechanics spend on actual maintenance. It is a good example of a delayed benefit.

3.1.8 Planners

The delay in performing a work order often comes down to time spent waiting for a correct plan for the job. If a plan for a job already exists in the library, the job is expedited. Otherwise, the worker must wait for a plan to be written and reviewed.

3.1.9 Mandatory and Discretionary Inspections

In this sub-sector the budget allocator has the greatest direct impact on plant performance. The budget allocator can control the of discretionary inspections by assigning more mechanics. The Nuclear Regulatory Commission (NRC) can also effect more scheduled maintenance through mandatory inspections. As mandatory or discretionary inspections increase, the number of defects found increases and the number of scheduled work orders increases.

3.1.10 Materials Specifications

To work a job a mechanic needs repair parts. The budget allocator must allocate some money to maintaining a proper inventory. They can also invest money in new capital equipment or improve specifications of existing equipment and repair parts in this sub-sector. Improving parts quality specifications reduces the number of defects per part. Buying all new equipment reduces the average age of equipment in the plant, reducing operations defects in that equipment.

3.1.11 Engineer Allocation

The model allocates engineers similarly to Mechanics. They are hired and laid-off. They are allocated to maintenance, planning, design, operations, and information. They also work overtime with lower productivity. The budget allocator can allocate engineers among the different functions.

3.1.12 Management Allocation

Managers are allocated similarly to Engineers. They are also hired and laid-off. They are just more expensive and there are fewer. Their functions are finance, maintenance, operations, information, and other.

3.1.13 Safety

The Safety sector includes calculations of Man-Rem, Forced Outage Frequency and Estimated Core Melt Frequency. The Man-Rem estimate is determined by multiplying the amount of maintenance done by an average Rem per work order. The Forced Outage frequency is a probabilistic calculation based on the current average forced outage frequency for nuclear plants multiplied by a ratio of broken equipment and operator astuteness. Operator astuteness is determined primarily by training and information.

The Estimated Core Melt Frequency is determined by multiplying the current base core melt frequency {1/(20,000 Reactor-Years)} by operator astuteness, broken equipment, and forced outage frequency factors. This calculation is not rigorous, but it provides a consistent simplified effect on overall core safety by the model.

3.2 Connections to Finance Model

There are numerous ways in which the financial operations of a utility impact the nuclear operations. Among these, the most important are through:

1. Personnel Hiring and Allocation
2. Capital Investment
3. Parts and Supplies Purchases
4. Training Costs
5. Inspection and Preventative Maintenance Program Costs
6. ALARA (Person-Rem Reduction Program) Costs

Each of these operations or programs require investment by the utility to perform the needed tasks. The utility decides how much money to spend on these programs by budgeting the available money gained through revenues to each area. Any shortfalls are made up through incurring debt, selling equity or by possible reimbursement through a rate hike. In any case, the utility must decide how and when to spend the available resources to best support each of these areas.

3.3 Financial Limitations

Many financial constraints are placed on a utility. Especially as competition approaches, wise budgeting of money is required to best use the generated revenues to maintain a high capacity and safety rating next month as well as ten years from now. The model prescribes the number of maintenance workers available to do corrective and preventative maintenance based on how much of the budget is left after other required outlays. If not enough revenues are available the model gives the user the option of cutting everything evenly, or choosing which sectors to reduce spending on. One can hurriedly layoff a few managers and save much money in the short run, but cause long work delays, or perhaps cut back on training and layoff a few maintenance workers, but cause an increased defect generation rate.

The power of the model is in this role playing that the user can perform to see 'what if.' "What if I change the amount of information sharing, cut dividends, and increase inspections." "What if I spend more money on reducing regulations, parts quality and engineer hiring" Each of these scenarios can be played out in about ten minutes.

4. Social/Political Sectors

Most of the social and political model was developed by Keith Eubanks who also connected it to the plant model. The Social and Political sectors represent much of the environment outside the nuclear plant. Understanding these sectors is crucial to optimizing the operation of a nuclear power plant. (Eubanks, 1994)

4.1 Social Sector

4.1.1 Overall

The Social Sector includes the local public, the national public, the media, and interest groups. Each sub-sector provides a positive feedback on the other sectors leading to rapid saturation during the simulated accident. The social model represents the agitation which follows a TMI type accident and the long term attention to operations, forced outages, SALP scores, and government feedback which the social and political stakeholders experience.

The Political Sector concerns the actions of the national government. It includes the NRC, Congress, and SALP Ratings. The public influences the Congress to pass laws and influence the NRC. The NRC responds by conducting investigations and developing new regulations. These new regulations then appease the public and interest groups somewhat who then reduce their influence on Congress.(Eubanks, 1994)

4.1.2 Local and National Public Concern

Local Public Concern represents the public in the community served by the nuclear power plant. Local public concern is capable of being much more variable than national public concern depending on the operation history of the reactor, local goodwill efforts, and local politics. The local public has a direct effect on the Public Utility Commission (PUC), local media, stock prices, and interest groups.

National Public Concern represents the public at large. Although, its concern does not change as rapidly, its effect on the local utility can be greater financially through more inspections, regulations, interest group lawsuits and media activity than other financial factors. Although local concern is heavily influenced by national concern, the effect of an accident at another plant on the local nuclear plant is not as great if the local utility has performed well.

4.1.3 Media

The media monitor interest group activity, government reaction, utility operations and public concern. Based on these measures, the media produce reports and follow-up stories that influence the above groups again. This effect can cause a strong positive feedback.

4.1.4 Interest Groups

Anti-nuclear interest groups are constantly at work monitoring utility operation, government actions and public concern. They need funding, however. As public interest grows, more people contribute to interest groups. These contributions improve their ability to wage lawsuits, demonstrations and lobbying efforts. These groups also have considerable influence on some PUCs.

4.2 Political Sector

4.2.1 Nuclear Regulatory Commission

The NRC controls inspections, regulation and much of the information transmission between utilities. After an accident the NRC steps up investigations considerably, researches and produces regulations. The effect on the utility is increased mandatory inspections and workload in the information sector. This sector provides regulators with an opportunity to gauge effects of new regulations and inspections. Thus, they can determine the best path of action to derive the intended results-increase safety and capacity.

The utility can also influence the NRC by investing in abandoning regulations, conducting its own inspections or improving its SALP scores. The model provides a good method for testing the return on investment in each of these areas.

4.2.2 Congress

Congress is influenced by public concern, media, interest group lobbying, utility lobbying and NRC response. As public concern increases, the number of concerned lawmakers increases. More concerned lawmakers then compel the NRC to conduct more investigations and write more regulations.

The actions of the NRC work to assuage congress, the media, the public and the interest groups. Congressional concern also has a natural decay factor as other issues enter the political field.

4.2.3 SALP

Systematic Assessment of Licensee Performance sub-sector represent the calculation of the utility's SALP score based on Engineering, Maintenance, Operations, and Support. The engineering score is based on engineer workload, and quality design specifications achieved for parts. The maintenance score is determined by mechanics workload and broken equipment. Operations is based on training, forced outage frequency and operator astuteness. Support is based on Manager workload. The model does not calculate all of the factors that enter into SALP scores such as operator drill performance, security, or safety analysis performance. These additional factors are assumed to average out and have the effect of reducing the range of the SALP somewhat.

4.3 Connections to Finance Model

The utility can spend money on the social/political models directly by enhancing local goodwill, lobbying Congress, attempting to reduce regulation, or spending more on SALP preparation. However, since perceived safety of the reactor and reactor operations have such a significant impact on the social/political sectors, every dollar spent on those two factors in the plant and information sectors improves the performance of the plant in the eyes of the public, media, interest groups, congress and the NRC.

4.4 Financial Limitations

Again, the financial limitations to the utility in influencing the public and other social stakeholders are strong especially with coming competition. With fewer dollars to spend, the utility must ensure that it is maximizing the return on each investment. The model demonstrates that some money spent on goodwill is required to maintain a low local public concern,. However , the best way to achieve favorable public attention is through good operations.

5. Information Sector

5.1 Description

5.1.1 Overall

The information sector of the model is primarily concerned with the effect of knowledge sharing activities and associations. Essentially, the information sector helps to reduce plant problems and breakdowns through procedure revisions, training, and plant modifications. The information sector was developed by Loren Simon independently and then connected to the rest of the nuclear utility model (Simon, 1995)

5.1.2 Sources of Information

Within the model, the main source of information is minor events, site alerts and emergencies at other nuclear power plants. These alert the plant to other problems that may not be apparent in ours. With the model the main source of problem processing is INPO, because in our opinion is it the most influential organization for information exchange within the industry today. Problem and research reports can also come from the NRC, WANO, EPRI and vendors.

5.1.3 Utility Information Response

The utility screens, evaluates and performs corrective actions for the newly found problems to reduces its own problem occurrence rate. This reduction helps to improve plant performance significantly.

5.1.4 Interactions with NRC

One other important aspect of the information sector is the interactions with the NRC for new regulations. The utility will screen and perform technical analyses on the regulation, which allows quicker implementation of the required corrective actions in the regulation. In addition to this, the utility can work with NEI to abandon regulations in development at the NRC. This interaction uses a significant amount of engineers to create detailed analyses for NEI and the NRC. This use of engineers can lead to short term losses in plant performance, because other work may not be getting done. However, it can lead to long term gains because regulations are not added to the NRC books.

5.1.5 Information Personnel Allocation

The information sector is implemented by allocating managers and engineers to work within it. As with the majority of the model, allocation of people for information is a key aspect. Information is limited in its ability to improve plant performance, so the correct allocation must be made between information usage and engineer planning and reviewing of maintenance work in order to optimize plant performance. The model can show that correct allocation of the professional staff can improve performance, without having to hire extra engineers or managers.

5.2 Connections to Finance Model

The most important connections from the finance model to the information model is through allocation of safety engineers to work on gathering, sharing, evaluating and training on information from utilities, INPO, WANO, NEI and the NRC. If a utility budgets more money to using information then more will be processes by the utility, more and better training will occur and workers' and operators' learning curves will improve, meaning they will reduce their defect or event production rate more quickly.

6. Financial Model

The financial model develops the relations which lead to limiting utility resources. In order to correctly determine how public opposition, PUC decisions, or increased regulation affect the utility's ability to budget spending for safety, a financial sector of utility operations is required. The public, NRC, interest groups, and plant operations all affect a utility's ability to raise cash to invest in safety and performance goals.

This system dynamics model was created using the same methodology as for the car example given in section 2. A problem statement was developed and focused using behavior graphs. Then causal diagrams were constructed and shown to utility stakeholders to determine if the most important relations were included. A quantitative model using STELLA® software was built and run to reveal some results a utility manager can use to improve long-term Nuclear Power Plant operations.

6.1 Development

The Financial model was developed using the System Dynamics procedures described above. The model took approximately 14 months to construct, connect to the larger utility model and test. The model is currently beginning validation, with one utility sponsor volunteering to provide the necessary data to fit the model to an operating nuclear power plant.

6.1.1 Defining the problem

The problem statement, "How can a utility owner maximize equity while maintaining nuclear plant safety in the face of many social, political and internal problems?" required that the following areas of utility financial operations be modeled: Internal Accounting, Public Utility Commission, Stock Market, Bond Rating Institutions, Safety as perceived by financial analysts, Economy, and Budgeting. To focus this problem, our development of the utility model focused on the how limitations of financial resources are caused by social, political and other outside factors. The financial model was then developed to show how these limitations affect safety and operations, and also as an interface to allow the utility manager to adjust budgets.

6.1.2 Behavior over time graphs

Typical behavior over time graphs are shown in figure 6.1-1. They show expected response by a utility's revenues, stock price, and PUC agreeability after a poor SALP rating. After the rating, the revenues stay constant but the stock price drops. Eventually the PUC agreeability drops and then revenues drop making the stock price decrease again. These behaviors were garnered from interviews with utility financial experts and plant managers.

The problem the utility owner faces in this case is how much should he spend maximizing SALP scores to prevent the stock price from dropping, since spending too much also causes the stock price to drop. In order to determine how much safety, or perceived safety in this case, is economically worth while, all of the relations must be constructed and analyzed.

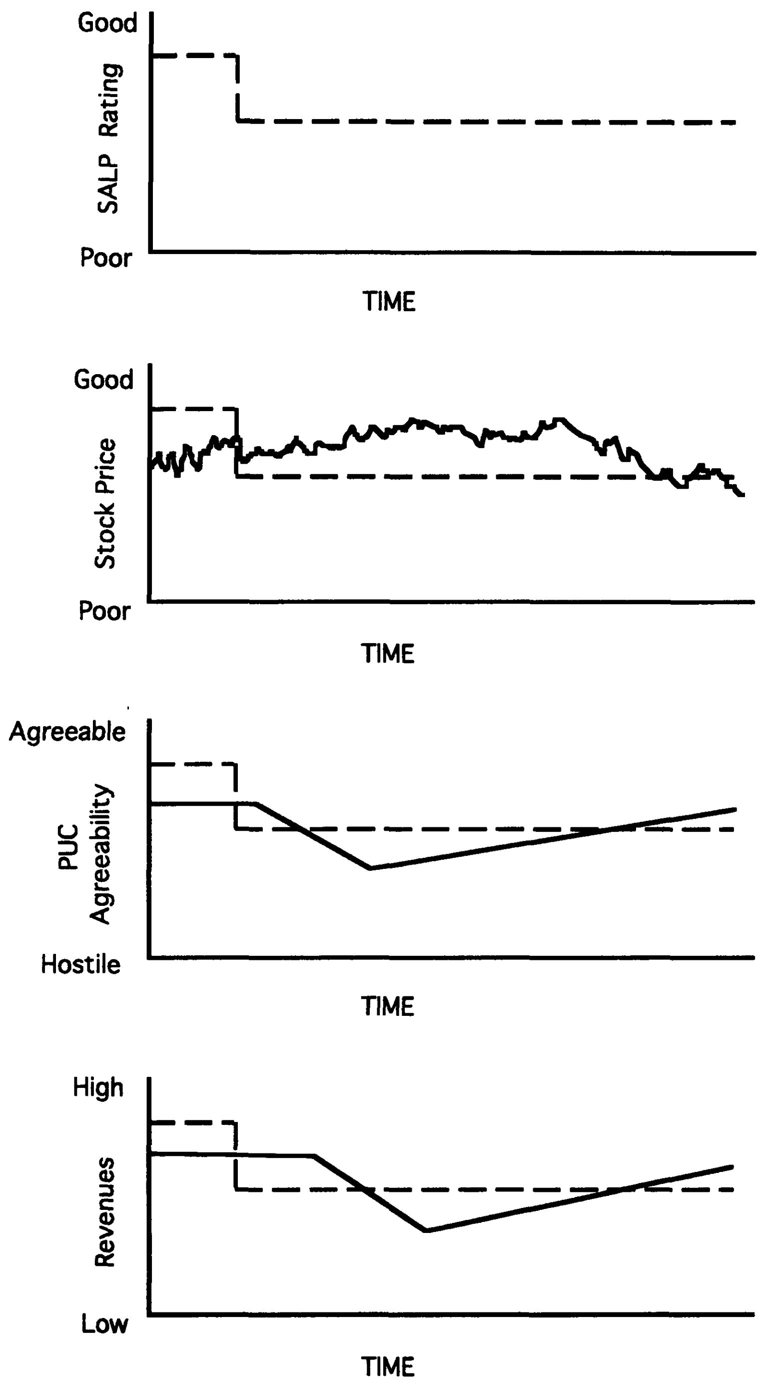

Figure 6.1-1 Expected behavioral graphs of various utility financial variables to a change in SALP rating.

To test the predictions of figure 6.1-1, one need only look at the revenues and stock price of Boston Edison after the poor reviews by the NRC in the mid 1980s on Pilgrim 1. Obviously, Pilgrim 1 is a severe case. However, it was mitigated by the fact that Boston

Edison had a diverse power generation base. Even so, it's nuclear plant had a severe effect on the company as a whole.

Figure 6.1-2 Boston Edison's stock price from May 1986 to May 1994. The effect of the poor SALP scores at Pilgrim 1 had a strong effect on Boston Edison even if other economic factors are considered.

Looking at figure 6.1-3, one can see the effects of a nuclear accident at another utility on this utility. Although public concern and interest groups have some effect on the stock price of a utility shortly after the event, the real effects are seen many weeks later from increases in regulation and revenue losses due to PUC reductions in prudence and reductions in capacity.

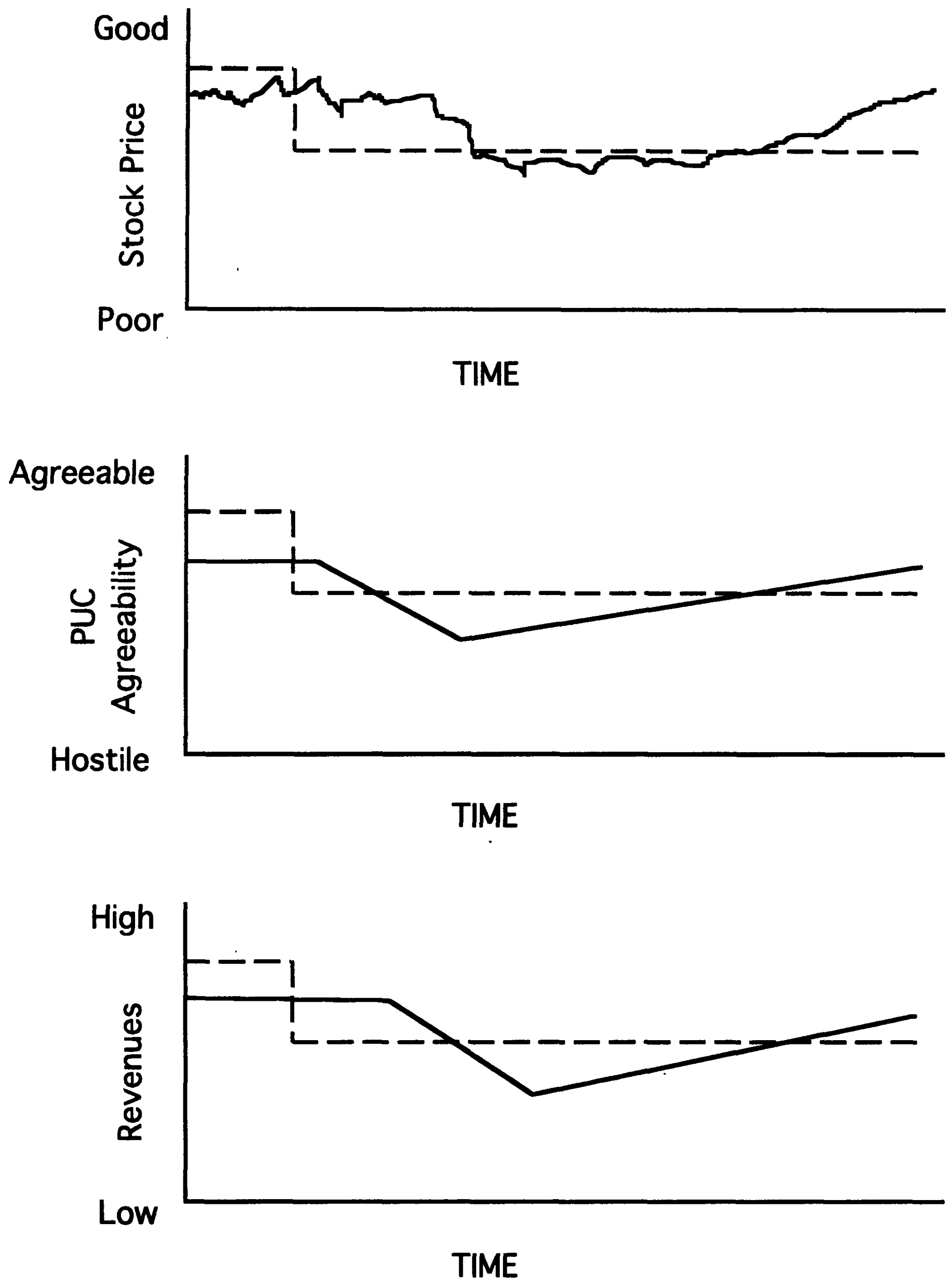

Figure 6.1-3 Expected behavior graphs for a nuclear accident at another utility.

The effects in history from the accident at Three Mile Island can be seen in figure 6.1-4. It is these effects that the model will attempt to capture. In the case of these utilities however, it must be noted that they are not only nuclear. Much of their generating capacity is unaffected by the NRC regulation increases. So, one must compare the more nuclear utilities with the less nuclear utilities to see the effect.

Also important is the effect the economy has on the stock market in general. The utility stock prices must be compared to the Dow Jones Industrial Average (DJIA). For example, if the DJIA increases rapidly and the utility stock does not, then the utility stock is actually dropping in real terms. For this reason the DJIA is shown in comparison. Starting around June 1980, the stock market rises considerably, but the nuclear utilities are staying constant. The model should predict this delayed, real reduction in stock price.

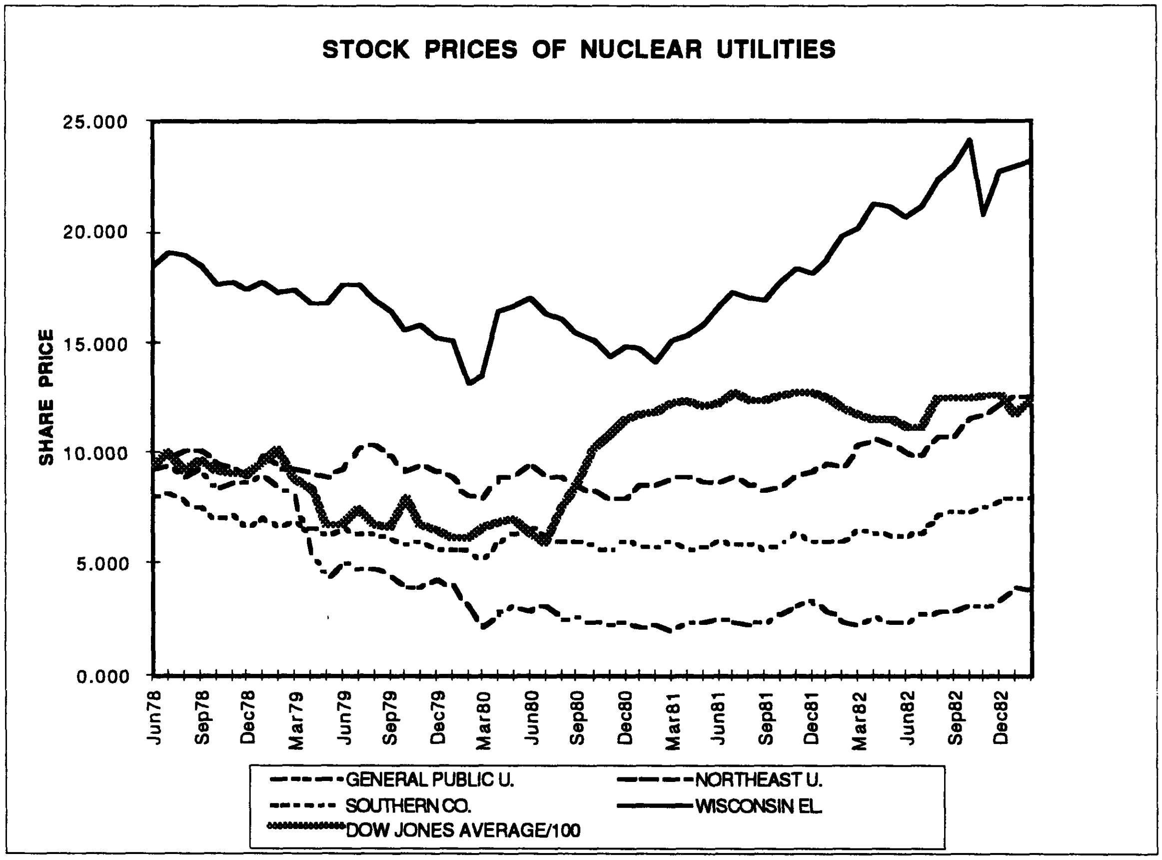

Figure 6.1-4 The stock prices from June 1978 to December 1982 of 4 nuclear utilities, including GPU who owned TMI. The effects from TMI (March 1979) were delayed.(Standard & Poor's Compustat 1994, WSJ March 1995)

6.1.3 Model structure

Policy influence paths (Figure 6.1-3) were constructed and presented for structural analysis to utility financial experts. The policy influence paths represent the most important relations of the model. It will aid in breaking down how the causal loops are turned into a computer model of the financial relations a utility must confront.

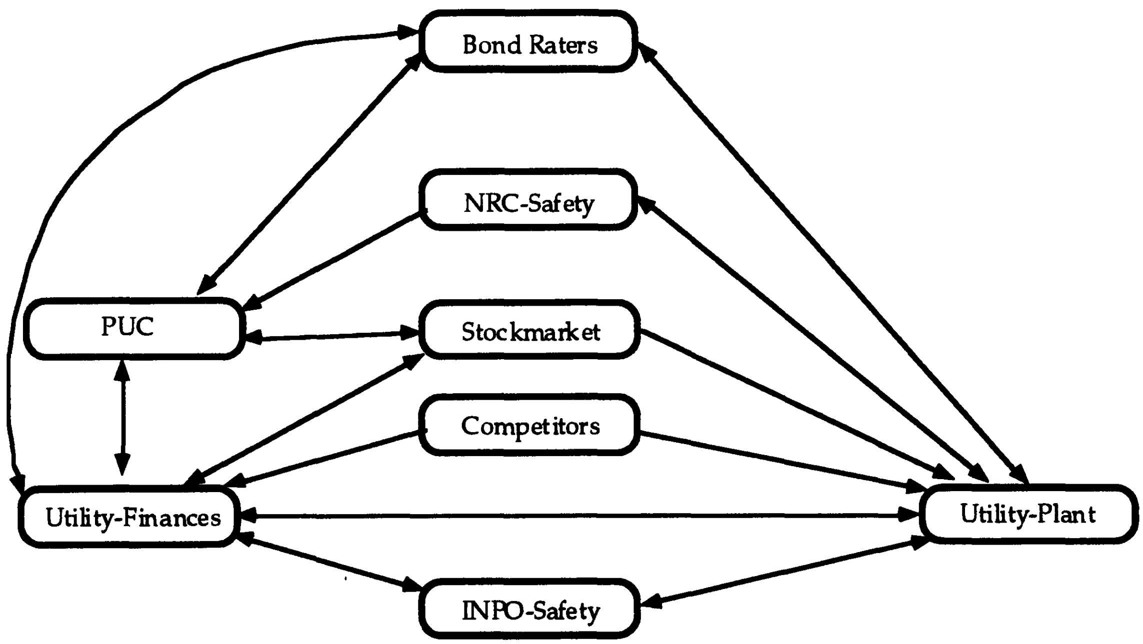

Figure 6.1-5 The policy influence paths of the financial model.

Numerical relations for the generic utility were based primarily on Boston Edison's published financial data and standard accounting and financial textbook relations. Once the structural model was built, the predicted results of various financial relations were presented to stakeholders at various utilities to measure overall reaction.(Hahne 1983, Brealey 1988, Boston Edison 1994, 1995)

Although much model validation must still take place, the essential method of System Dynamics, consultation with stakeholders, has been used to achieve a model whose structure has been verified by many different parties. The model at this stage can be used as a template. A utility can insert data, test it and revise it if required.

6.1.4 Causal Relationships

After defining the problem, the next step is to develop causal loop diagrams (Figures 6.1- 4 & 5). With stockholder's return on equity at the top of the causal loop, the most important relations which affect the return on equity were developed and presented to utility stakeholders for their review.

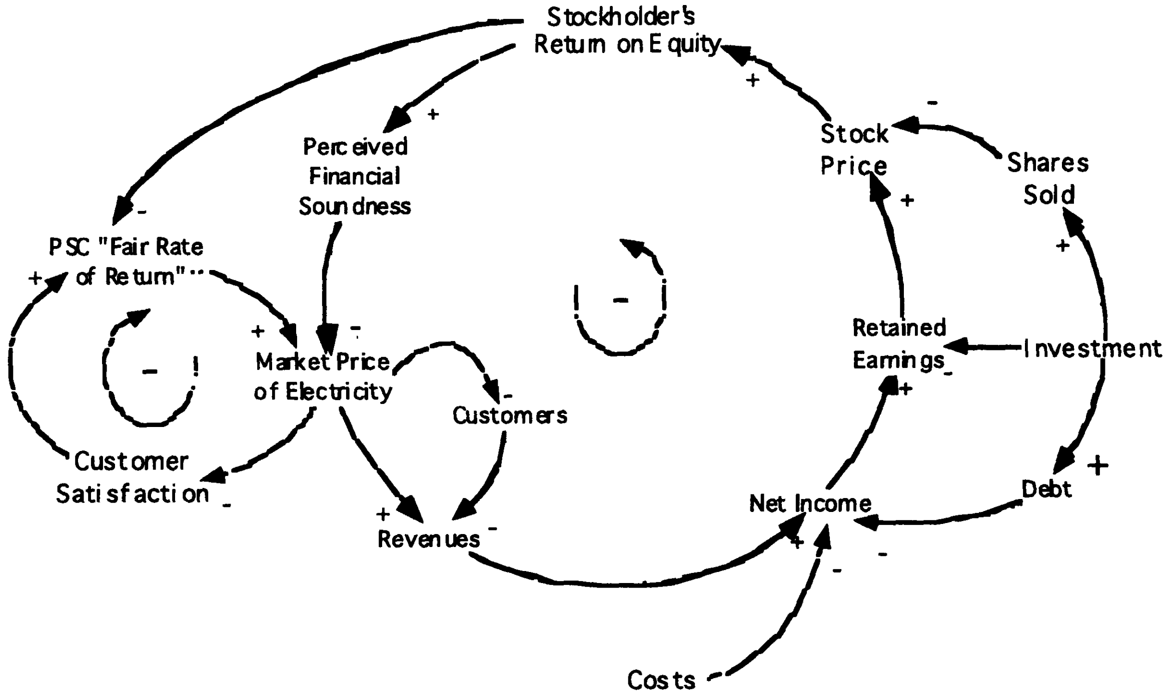

Figure 6.1-6 The basic loop which affects return on equity. The PUC controls the negative feedback loop limiting the owner's return on equity to a "fair return" in exchange for the utility's guaranteed delivery of electricity.

In the causal loop arrows show the direction of effect and the '+' or '-' signs indicated whether the effect is positive or negative holding all other variables constant. In this case, Stockholder's return on equity positively affects perceived financial soundness. Under regulation, an increase in perceived financial soundness leads to the utility's lowering the market price of electricity, based on the PUC's "fair rate of return". If the market price is lowered, revenues must drop, which causes net income to decrease. As net income drops, dividends and retained earnings drop. Decreasing retained earnings and dividends causes the stock price to drop which causes the Stockholder's return on equity to drop, thus completing the major loop.

The relationships shown in Figure 6.1-4 are actually more complex, as shown in Figure 6.1-5. As customer satisfaction decreases, rate cases will be determined less in the utility's favor, thus requiring them to lower their market price for electricity. Also, as the utility invests more money, it must incur more debt, or sell shares. Incurring debt decreases net income, and selling shares reduces the stock price directly.

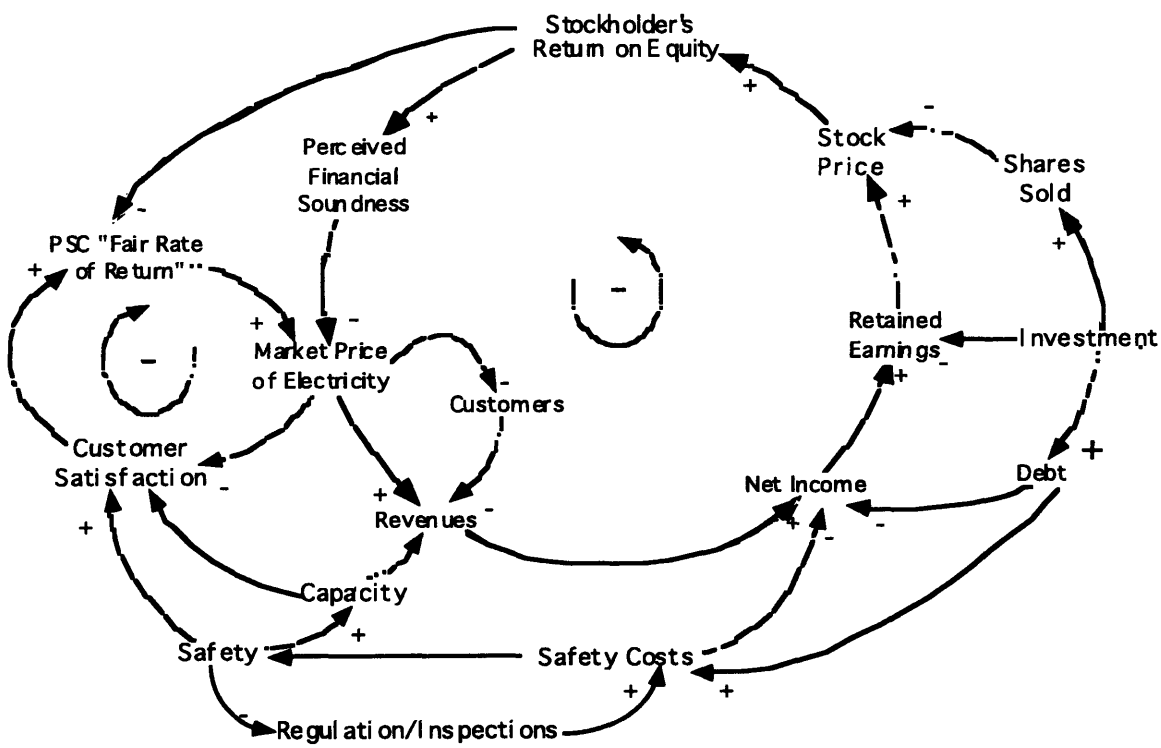

Figure 6.1-7 Return on equity causal loop including utility spending on safety.

The second causal loop diagram of the utility finances includes spending on safety represented as "Safety Costs." Safety spending can either be self imposed, or required by regulation or required inspections. This causal loop was developed with the assumption that safety spending has a positive impact on safety and perceived safety, both represented as "Safety" on the diagram.

As safety improves, capacity improves overall since less equipment is broken. However, this relation can be negative if the utility takes down too much equipment or extends an outage to improve estimated safety. In the U.S. the safest plants, by many measures, most often have the highest capacities. Safety also improves customer satisfaction, as the local public is less concerned about the utility's operations. Finally, safety has a negative effect on regulations and required inspections. As SALP ratings improve, the NRC requires less safety spending by the utility.

All three of these effects by safety and perceived safety can have the overall effect of increasing net income by reducing costs and raising revenue. Safety spending has its own cost, however. A utility owner must balance the spending with the return on the investment. This problem of optimization requires the quantification of different types or safety spending and the return on investment the utility owner can expect.

Once the causal loop diagrams were agreed upon by the utility stakeholders, a quantitative model was developed which attempted to answer this question. The sub-sectors of the financial model were developed to provide the necessary links to support these causal loop diagrams and determine how much effect the variables presented have on each other.

6.2 Descriptions

The Financial Sector includes all aspects of utility monetary operations. It includes Internal Finance Balance Sheets, the Public Utility Commission, the Stock Market, Bond Rating Institutions, Economic Effects, Perceived Financial Safety of Nuclear Plant, Budgeting and Allocation of resources, Capital Investment, and Debt.

This section presents a discussion of most of the variables in the financial sector of the model. The entire model structure is presented in Appendix A, Utility Model. Quantitative relations and detailed descriptions of each variable are located in Appendix B, Equations. Appendix B also contains an alphabetical glossary organized by sub-sectors which describes each variable in detail.

6.2.1 Internal Finance

Cash flows and the overall balance sheet are determined in this sub-sector. Costs are summed each week and subtracted off of revenues to determine the gross margin. Investment, property taxes and then income taxes are subtracted. The remaining, net income minus dividends are forwarded to retained earnings. An asset, liability, and retained earnings comparison is then made.

This model uses cash based accounting. Each dollar flows in and out each week for simplicity. This format will be important when understanding Net Income representation. Under accrual accounting which is normally used, on a quarterly basis, the utility does not show the huge loss from an outage because costs are matched with the revenues later generated. In the model, outages are presented as a large loss in income.

6.2.1.1 STELLA® Structure

The Balance sheet structure is shown in figure 6.2.1.1-1. The structure follows the Statement of Income, Balance Sheet, and Statement of Cash Flows standard accounting format. Revenues enter into Liquid Assets. Liquid Assets are then distributed to Costs, Taxes, Dividends, Investment and Net Earnings in that priority. If outflow exceeds revenues, the difference is made up with Cash Provided by Financing Activities and incorporated into debt. Since this format is for a dynamic model, the cash flows are determined on a weekly basis.

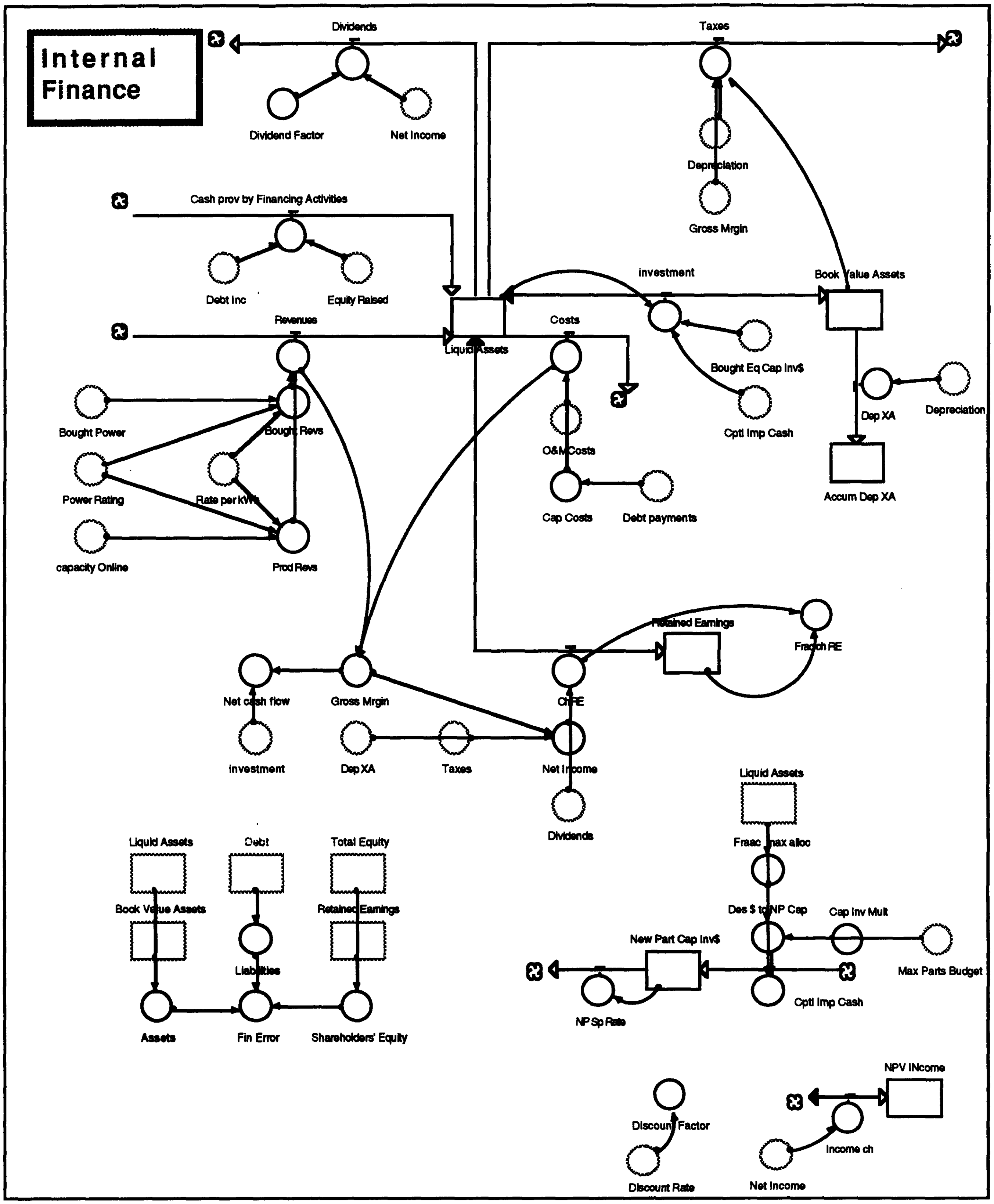

Figure 6.2-1 The balance sheet portion of internal finance.

Starting on the left side of the diagram with Revenues, a description of the Balance Sheet portion of the Accounting Sub-sector follows. Complete details of each variable can be found in Appendix B: Model Equations. Only the major variables and flows will be discussed below. The first mention of a variable will be enclosed in double quotes ("").

"Revenues" are generated based on "produced revenues" and "bought power revenues". "Capacity on-line," "Rate per kWh," and "power rating" determine produced revenues. "Bought power," "power rating" and "Rate per kWh" determine bought revenues. The penalty for using bought power comes in the cost of bought power for the utility under "costs."

The weekly revenue stream flows into "Liquid Assets" as cash. Meanwhile, costs flow out of Liquid Assets. "Operations and Maintenance Costs (O&M)" and "Capital Costs" are combined to determine overall costs. Shortfalls in liquid assets and utility capital investment are made up by "Cash Prov. By Financing Activities". Cash Prov. By Financing Activities is made up of debt incorporation or selling of shares. Most utilities use a 50%/40%/10% Debt, Common Stock, Preferred Stock ratio of funding. Since this model does not include preferred stock, a 50%/50% split between equity and debt is used.

Utility capital investments are made through "investment." Investment by the utility can be made by improving the quality of parts and design through "Cptl. Imp. Cash" or by buying all new equipment (such as Steam Generators) through "Bought Eq Cap Inv$." Investments made by the utility, unlike costs, go into "Book Value Assets" which then depreciate into "Accum Dep XA."

Other flows out of Liquid Assets include "Taxes," "Dividends," and "Retained Earnings" in that priority. Taxes include property taxes and income taxes. Property taxes are a mill rate multiple of the "Book Value of Assets." Income taxes are based on the corporate income tax rate times "Gross Margin." The utility's gross margin is determined by subtracting weekly costs from weekly revenues. Dividends are determined by multiplying "Net Income" by the utility's "Dividend Factor." Net Income is just Gross Margin minus taxes and depreciation. Retained earnings absorb the remaining cash after all other expenses are complete. The rest of the Balance sheet calculates the "Assets," "Liabilities," and "Share Holders Equity" columns which are found on the utility's annual balance sheet

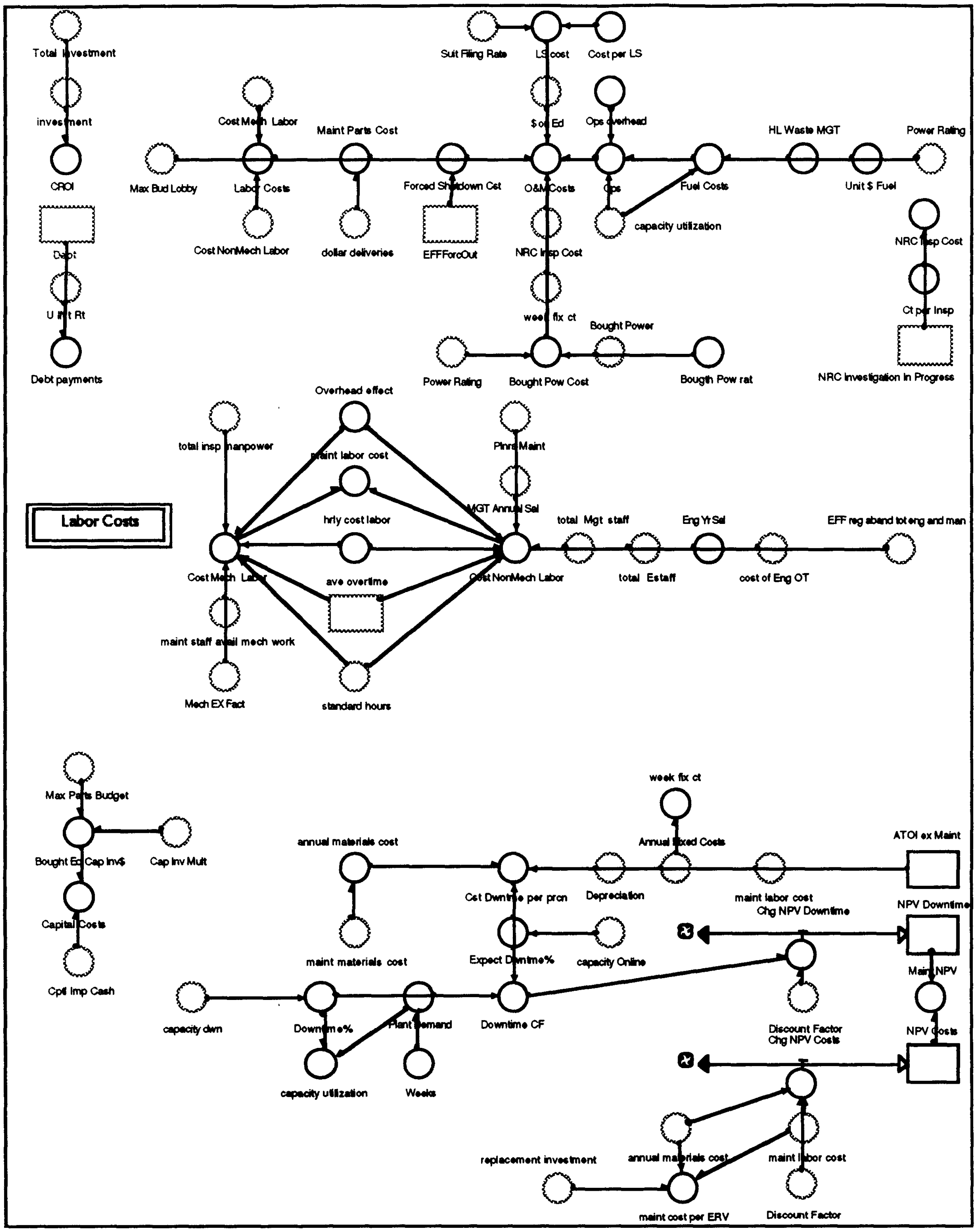

Figure 6.2-2 The cost portion of internal finance.

Utility costs derivation is shown in figure 6.2-2. "O&M Costs" are determined by adding all of the individual weekly costs together. The individual weekly costs are grouped into "Ops," "Labor Costs," "Week fix ct," and other costs. Operations includes "Fuel Costs," "High Level Waste Mgt," and "Ops Overhead." Labor Costs include the cost of maintenance personnel, engineers and managers. Weekly fixed costs are just the additional costs of operating a nuclear plant such as grounds keeping, security, distribution, which are not affected by other areas of the model.

Other costs include "NRC Insp Cost," "Bought Pow Cost," "Force Shutdown Cst," "LS cost (Lawsuit Costs)," "Max Bud Lobby (Lobbying Costs)," and "$ on Ed (Public Education Costs)." NRC Inspection costs include only the direct expense of NRC personnel onsite. Additional Labor costs by utility personnel are covered by labor costs. Bought power costs are the additional cost of buying power from another utility. When the plant is shutdown, the utility must buy all of its power. During a forced shutdown, additional costs on top of normal labor costs are incurred which include investigation costs, rapid repair costs and additional training costs. Lawsuits by interest groups incur large legal costs, as well as greater administrative costs. Lobbying costs include money spent to influence lawmakers and support industry lobbying groups such as NEI. Public Education costs work towards goodwill by lecturing the public, taking school groups on tours, and getting involved in the community.

Also calculated in this section are new parts buying, Net Present Value of Maintenance and Downtime, and "Debt Payments." Investment in new parts is included in capital costs and, divided by the average cost per new part, to determine the number of new parts bought. The Net Present Value calculations aid in determining the dollar costs and overall value of performing preventative maintenance. Debt Payments are calculated by determining a payment schedule based on "Debt" and the utility's average interest rate.

6.2.2 Public Utility Commission

The Public Utility Commission, influenced by customer satisfaction, utility performance, interest groups and political ideas opine their view of the prudence of utility financial decisions. This prudence translates into an allowed return on equity and an allowed rate base. Once the allowed return on equity is determined, it is translated into a cash value and compared with the utility's requested return. Combined with pass through costs such as fuel and NRC regulations, a PUC price is determined after a delay to account for the time between rate case proceedings.

If there is competition, this price represents only a legally allowed price. The price the utility must actually charge to maintain its customers is the competitor's price multiplied by a small augmentation based on proven reliable service.

If the PUC grants an excessive price increase, customer satisfaction drops impacting PUC prudence. If utility financial indicators drop too much, the PUC will approve rate increases to prevent the utility from going bankrupt.

The Public Utility Commission Subsector is shown in figure 6.2-3. The "PUC Prudence" determination is modeled by comparing the current perceptions of the PUC members with a current indicator of how they would feel about the utility given enough time to analyze all of the inputs into "Cur Ind of Prud." Included is a time delay for the perceptions of the PUC to change. Even if a member of the PUC changes creating a harsher or more benevolent climate for the utility, the change in PUC perceived prudence takes time to evolve as new members gain influence in the commission.

The following effects control the behavior of the PUC's decision that the utility's actions are prudent: the ratio of forecasted capacity to actual capacity, "EffCaprel frcst," Customer Satisfaction, "EFFCSPUC," public interest group activity, "EFFPIPUC," Perceived Safety of the nuclear plant, "EffPSPUC," and the political hostility with which the PUC perceives utilities (in the eyes of utility financial analysts), "Evilness." In addition, the PUC uses financial indicators to determine if the financial markets believe the utility's actions are prudent. These include the bond rating, "EffBRPUC," and Stock price, "EFFSPPUC."

The "PUC perc Prud" determines two other variables, "Rate Base," how much of the utility's capital base the owners may use to determine the allowed return on equity, and the "Allowed ROE." If the PUC does not believe the utility's actions on investment are prudent based on a combination of the indicated variables, it will disallow a rate base adjustment and the utility will have to pay for the investment with out increasing charges to rate-payers. If the PUC believes in general that the utility is making more money than a "fare rate of return", it also reduces the allowed return on equity. The allowed return on equity is constantly compared to the utility's cost of capital however, so that economic changes and interest rates do not severely affect the utility.

To determine an actual average rate the utility charges rate payers, several calculations must be made and a delay for the time between rate cases must be incorporated. During a rate case, the utility calculates a requested rate structure, "Utility Req Total," based on future cost estimates. The PUC compares the request with its allowed return on equity for investment and a "Test Yr $/Kw-hr" cost comparison to determine an allowed charge for non-pass-through costs. Other costs, "Pass Through," are automatically charged to the rate-payer without dispute. These costs include fuel costs and NRC regulation costs. The final "Puc Rate" is the maximum legal cost per kilowatt-hour that the utility may legally charge customers. Of course, if competition is present the utility must charge a rate consistent with maintaining customers. After adjusting for this competition, the actual "Rate per kWh" is derived.

To determine customer satisfaction, a comparison of the utility's rate for electricity to customers' perceived relative rate for electricity is also calculated in this subsector. As the price of electricity increases above inflation, customer satisfaction drops rapidly. This drop influences the PUC and prevents further price increases. This effect drove the hostility of rate proceedings after the oil shock of the 1970's and the nuclear construction costs of the 1980's.

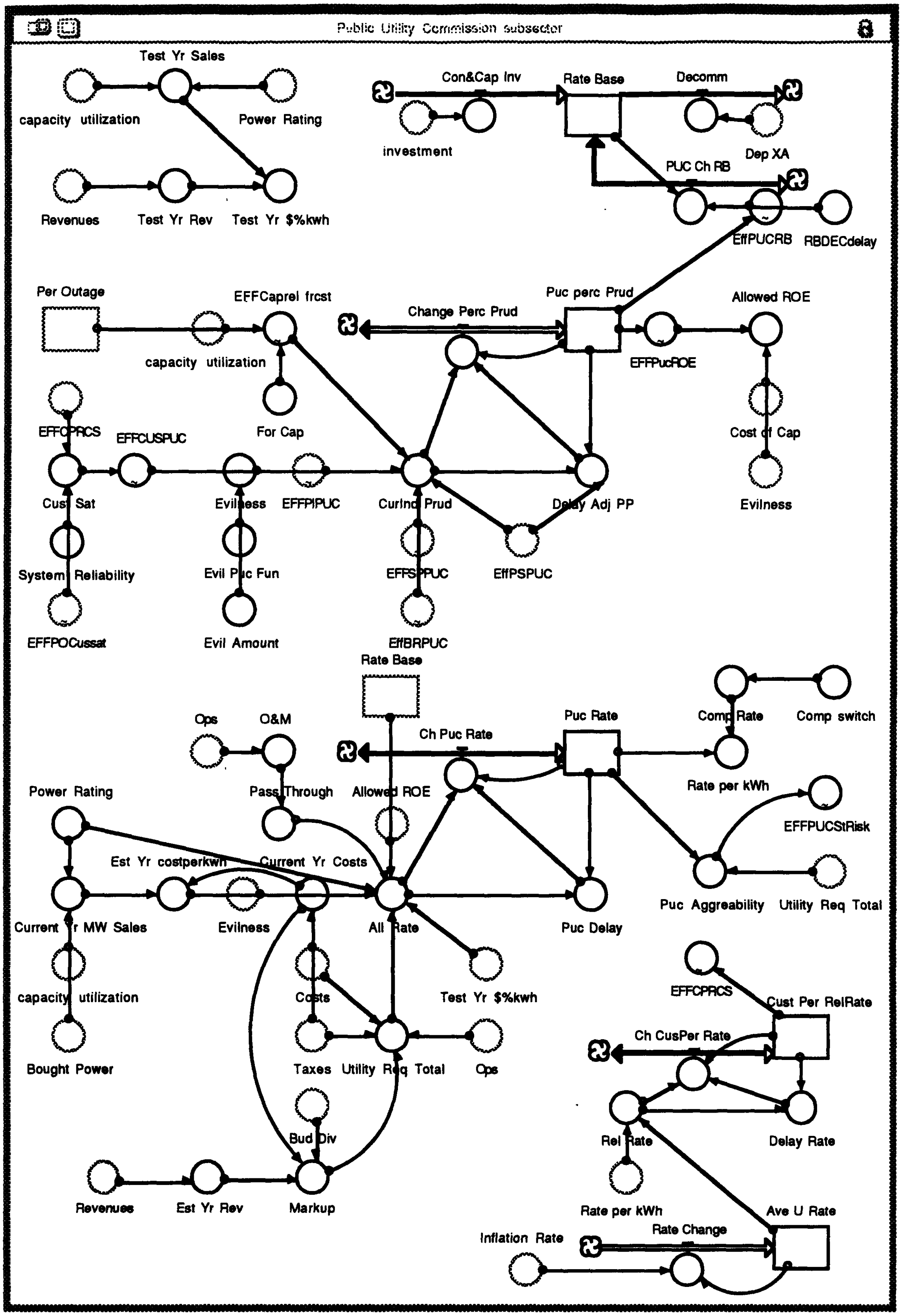

Figure 6.2-3 The Public Utility Commission Subsector is composed of Prudence Determination, Rate Base Determination, Allowed Rate Calculation and Customer Satisfaction Determination

6.2.3 Budgeting and Allocation

A manager using the model to analyze strategic decisions would use the Budgeting and Allocation subsector most frequently to test spending decisions. Utility operations are controlled through allocation of dollars. The utility manager can change spending on inspections, capital equipment, information, personnel, goodwill or lobbying.

The subsector is shown in figure 6.2-4. The layout is similar to costs. The subsector has only auxiliaries which calculate weekly allocations of resources. Starting with "Test Yr Rev", "Required Costs," which are based on "Budgeted Taxes," "Des Weekly Profit," operations, fixed, debt payment and bought power costs, are subtracted off. The "Discretionary Budget" remains to be sliced into various spending pieces. Based on allotment, the maximum allowed number of maintenance workers, engineers, planners, and managers is determined. Also determined is the amount of the budget spent on discretionary inspections, "Fr Lab bud All Disc insp." This fraction determines how much of the labor budget is spent on preventative maintenance. Additional spending decisions are made in training, lobbying, layoffs, dividends, parts, and overall cutbacks.

Other computations this sector performs include a message in case the utility is losing all of its profits, and an allocation block to allot engineers and managers to various areas. The actual allocation takes place in the Engineer and Manager allocation subsectors.

6.2.4 Equity

The stock market is represented by a Capital Asset Pricing Model. The risk of investing in the utility is compared to Treasury Bills and the Dow Jones index. This results in a cost of capital, which is the required return on equity by an investor. This cost of capital is compared to the present value of estimated future cash flows of dividends to estimate a stock price. Combined with random variations and economic effects, this estimated stock price is converted into daily stock price.

The derivation of share price starts with the "Anal Ut Risk," which is derived from the utility's Debt to Equity Ratio, "EFFDEStRisk," National Public Opposition, "EFFPOStRisk," Perceived Safety, "EFFPSStRisk," PUC agreeability, "EFFPUCStRisk," and Local Public Opposition, "EFFLPOStRisk." Then a cost of capital factor called "Beta AST" is derived. Combined with a factor for "Beta Debt," which is derived from the bond rating, "EFFBRStock," this factor becomes "Beta Eq."

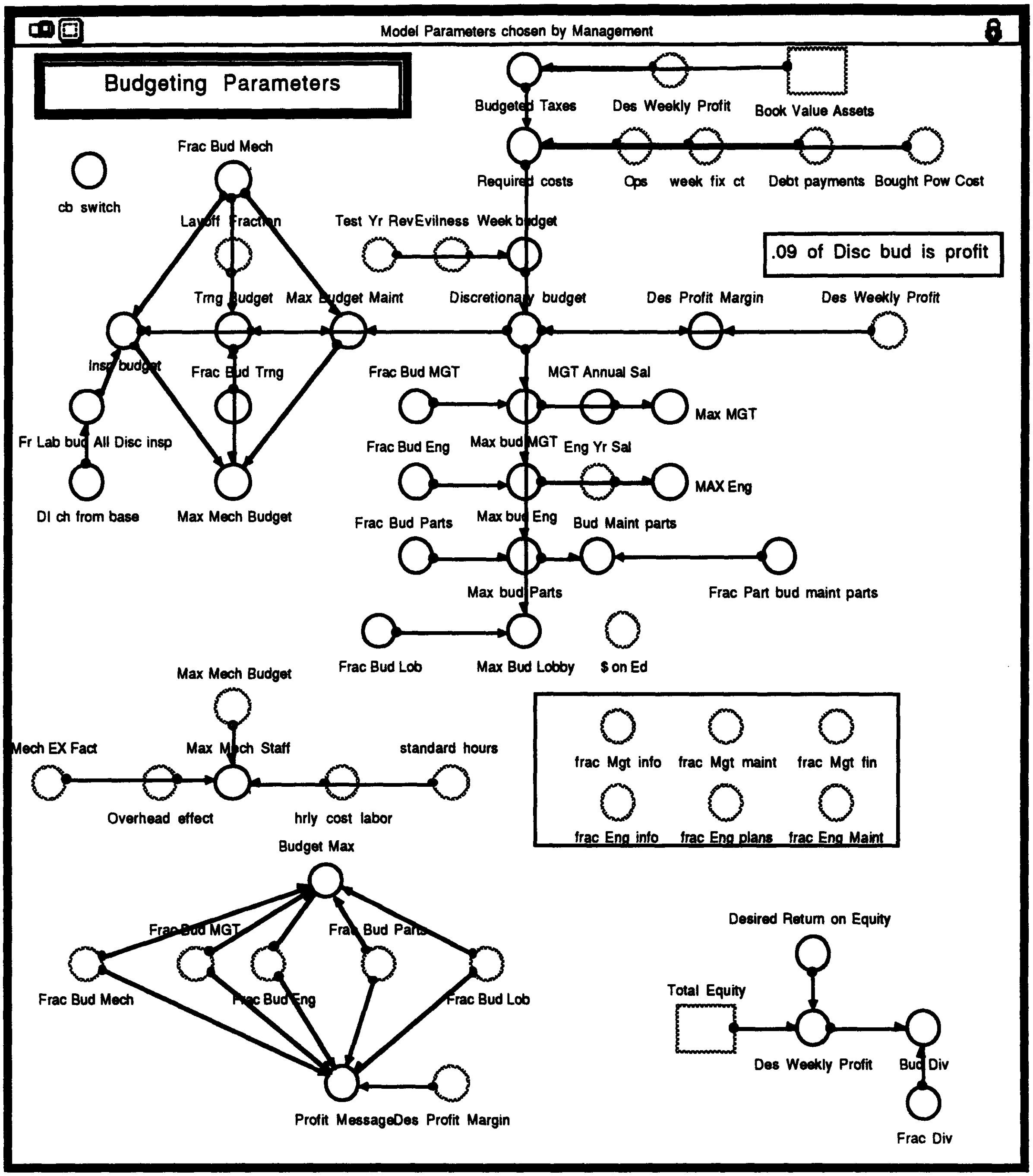

Figure 6.2-4 The budgeting subsector includes budgeting, desired profit calculation, and some personnel allocation.

This Beta represents the relative risk of investing in the utility. This risk is compared to the interest rate of zero risk securities such as T-bills and relatively risky items such as the rest of the stock market to obtain the stock discount rate. This rate is the required interest rate the stock should pay to compensate investors for overall riskiness.

To determine the current stock price two other factors must be considered, "Dividends" and "Rel Growth." If the utility pays dividends, the estimated future dividend payout annuity is converted to present value. This value increases the current price of the stock. If the utility is growing then the investor accounts for this growth by estimating the future return similar to dividends. When combined in the following equation according to the Capital Asset Pricing Model, these factors estimate the current value of the utility's stock (Brealey and Myers, 1988):

$$\text{Value of Stock}=\frac{\text{NPV(Dividend\_Forecast)}}{\text{(St. Dis Rate\%-Exp Growth\%)}} \quad \text{(Eq. 6.2.3-1)}$$

where the numerator is the net present value of the forecasted dividend payments. The denominator includes the annual expected growth in percent and the Stock Discount Rate in percent. This equation provides a good estimate of the current value of holding the utility's stock within a certain range. (Brealey and Myers, 1988 and Hahne and Gregory, 1983)

Obvious problems arise if the expected growth of the stock approaches the discount rate, which is not a problem with most utilities, or if the dividend forecast approaches zero. In that case a different estimate of stock value would have to be used. For utilities, since dividends are paid reliably, at least in the past, this equation provides an excellent estimate of stock prices. The Capital Asset Pricing Model has been used for many years to gauge the value of many stocks. The "Ind of Market Value" is then corrected for time delays for stockholders to analyze financial indicators and multiplied by speculative and economic effects to arrive at an "Actual Share Price"

In parallel to the stock price determination, the "Book Value per Share," is calculated. This is the total assets of the utility divided by the total number of shares. The "Market to Book Ratio" represents the ability of the utility to raise cash by selling more shares. If the market to book ratio is very high the utility can sell more of itself based on investors' belief that their payoff in the future warrants paying a price greater than their share of the assets of the company.

As the utility sells shares, its equity builds based on the market value of the shares when they were sold. This equity is combined with retained earnings to arrive at the total of "Shareholders' Equity." This calculation completes the balance sheet equation of:

$$\text{Assets} = \text{Liabilities} + \text{Shareholders' Equity} \qquad \text{(Eq. 6.2.3-2)}$$

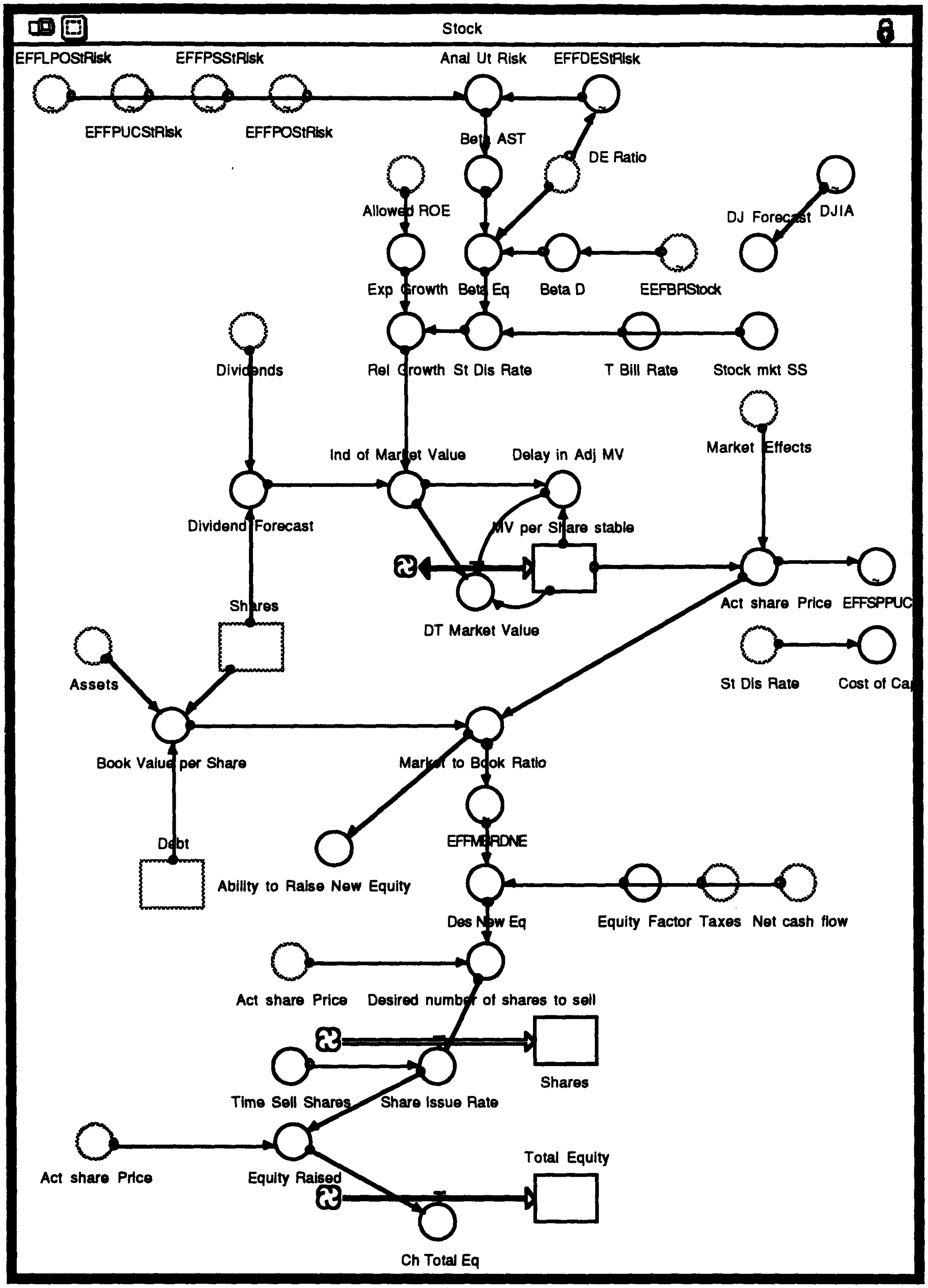

Figure 6.2-5 The Equity Subsector represents the stock market, capital costs and the utility's ability to raise equity through sales of shares.

6.2.5 Bond Rating Institutions

Bond Raters constantly monitor the financial position of utilities to determine their ability to repay long-term notes. The bond rating is on 1-12 scale from Default to AAA+.

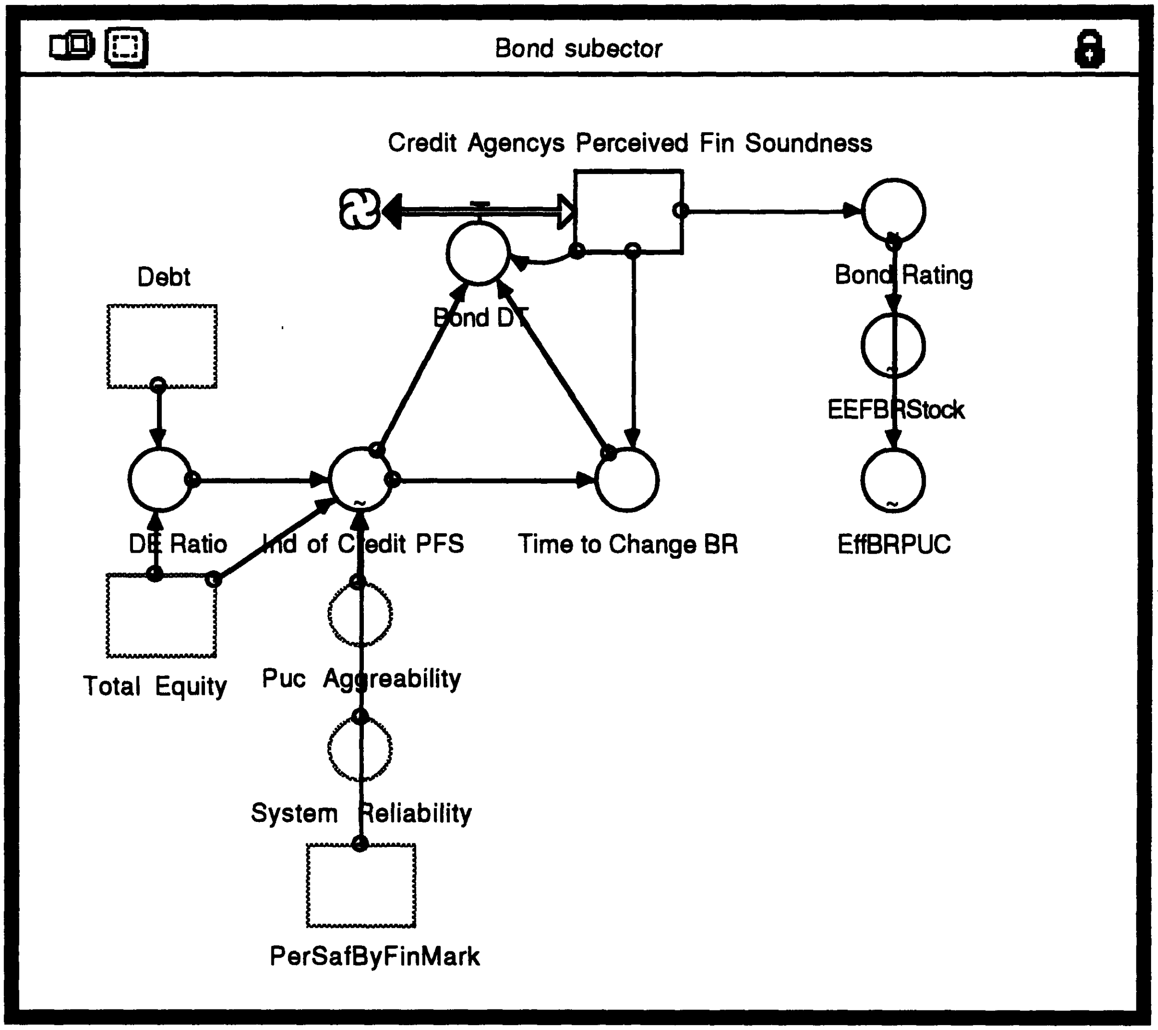

Figure 6.2-6 The Bond Subsector determines the bond rating of the utility.

The indicated bond rating, based on current financial elements, "Ind of Credit PFS," is derived from several factors based on financial indicators which bond rating institutions use to rate companies. The most important of these is the utility's Debt to Equity Ratio, "DE Ratio," which is based on the total liabilities owed compared to the market value of the utility's stock. Additional factors included in the model include

"System Reliability," "PUC Agreeability," and the perceived risk of losing the reactor plant due to a catastrophe, "PerSafBy FinMark."

The Bond rating is delayed by the interval between doing bond rating analysis, unless a financial calamity strikes the utility. The "Credit Agency's Perceived Financial Soundness" is adjusted to fit on a 1-12 scale which represents the utility's bond rating from CCC to AAA. (Duff and Phelps Credit Rating Co., 1994)

6.2.6 Economic and Random Effects

This sub-sector inserts recessions, interest rate hikes, inflation and random effects onto the utility. It is used to incorporate speculation, "Speculation Factor," random stock market actions, "Random Effects," and "Economic Cycles" into the utility's share price. It also calculates the utility's interest on debt from its bond rating. Inflation has been turned off in the model for simplicity but may be reinserted.

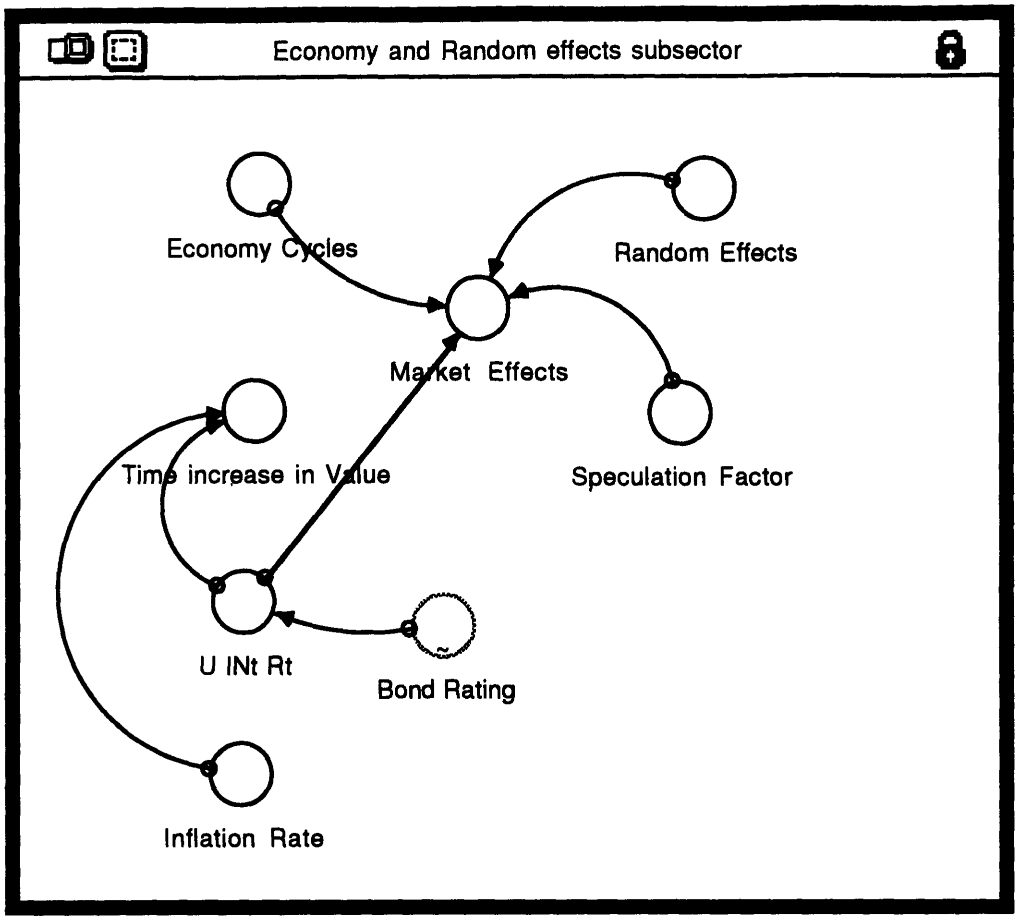

Figure 6.2-7 The Economic Effects Subsector adds economic cycles, speculation and randomness to the stock market.

6.2.7 Perceived Financial Safety

This sub-sector represents an investor's perceived risk of losing investment due to a major accident at the nuclear plant. This risk influences the total risk of investing in the utility and affects the bond rating. It is determined by monitoring operations, SALP scores and forced outage frequency. Risks due to the PUC and economy are determined in the stock sector.

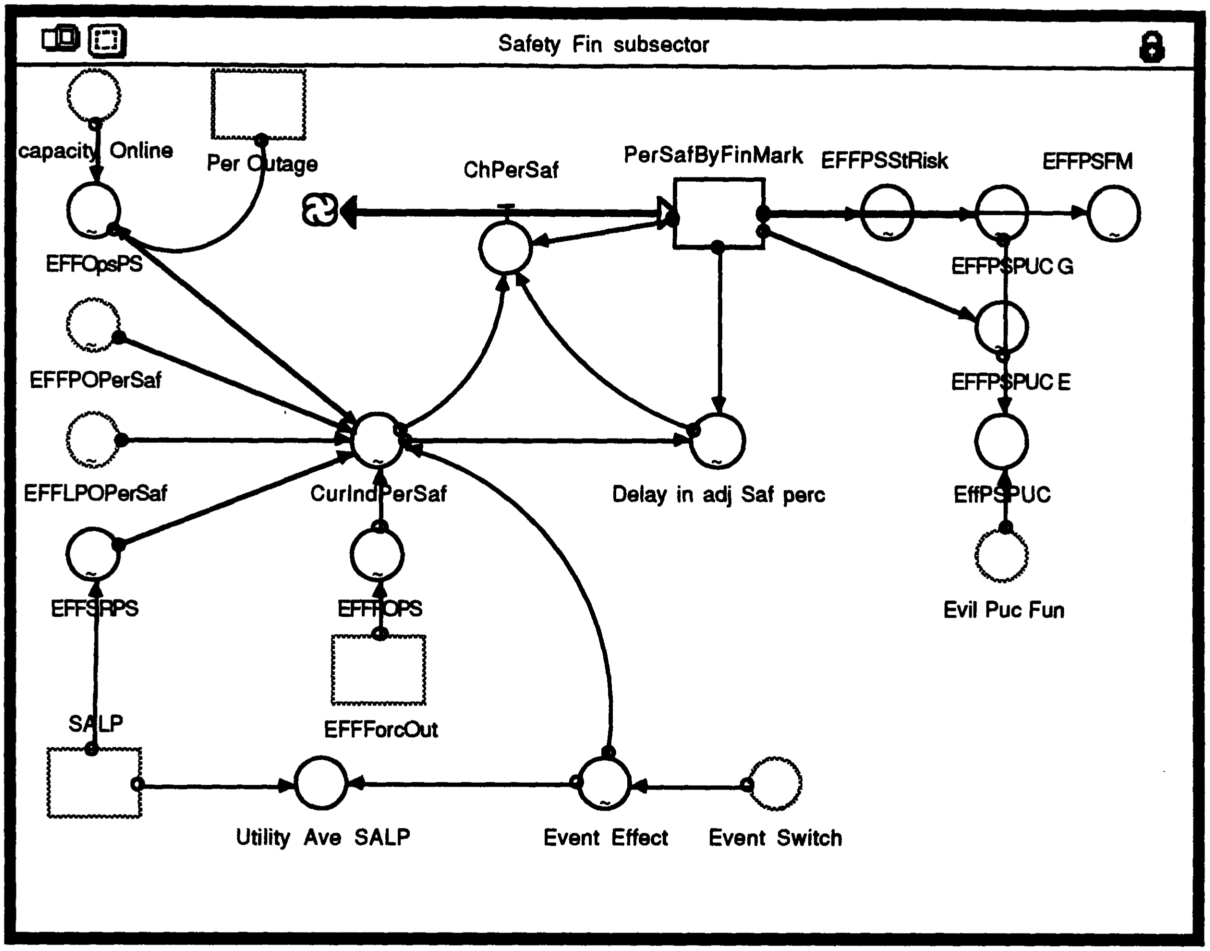

Figure 6.2-8 The Safety Financial Subsector calculates a perceived risk for the investor of losing the investment in the plant due to a core melt accident.

6.2.8 Capital Investment and Debt

The utility manages cash shortfalls and capital investments by financing 50% through long term debt. Since so much debt is incorporated during construction of the plant, approximately 70% of costs go to debt payments in the model. If a utility consistently overspends, it will enter a death spiral of debt.

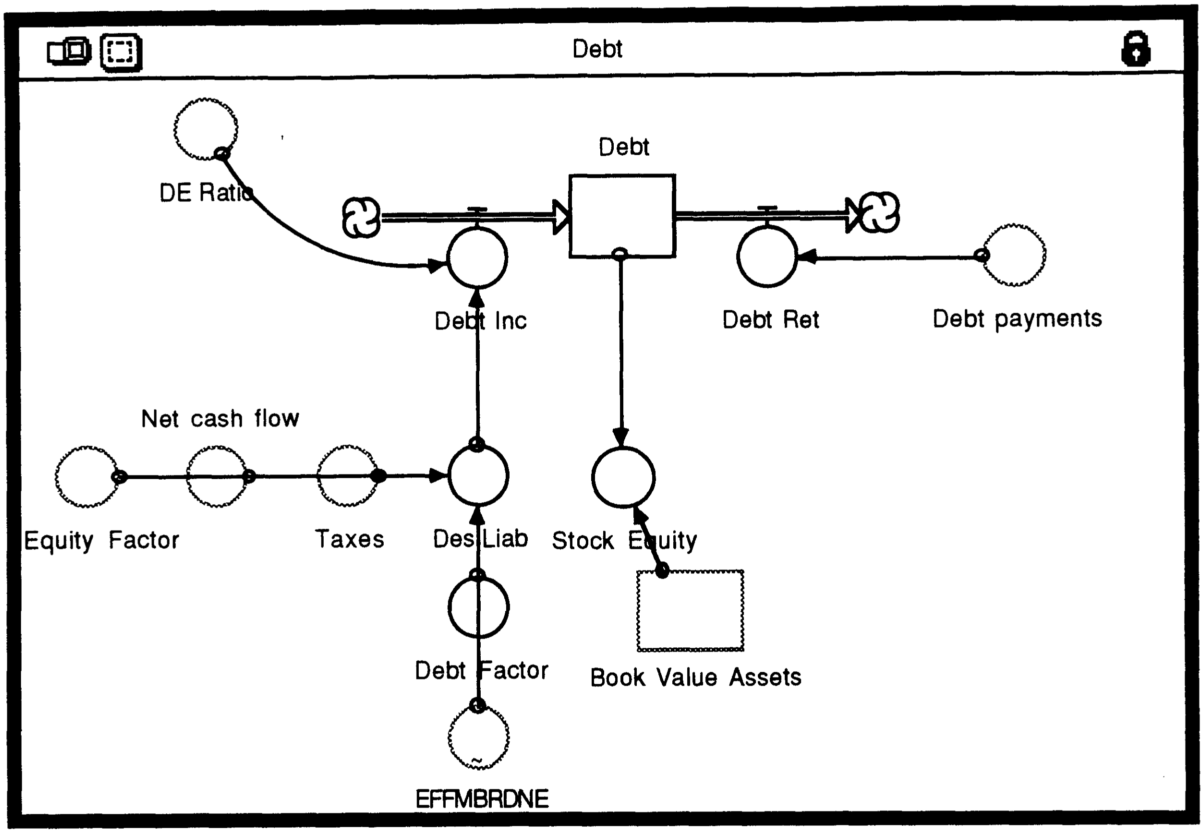

Figure 6.2-9 The Debt Sector determines long term debt and debt payments.

"Debt" is incorporated when Net Cash Flow is negative, requiring the utility to borrow money or sell equity. Based on the "Debt Factor," the utility will raise 50% of the shortfall by incurring more debt. Also, if the total "DE ratio" becomes too large, the utility will stop incurring more debt, and the model will pause to prevent the manager from going bankrupt.

7. Financial Model Simulations

Several simulations have been performed to test the structural validity of the model and present results to stakeholders. Important information has been gained by running the overall model to ensure consistency of equations, and show some interesting results that are valid even for a generic utility. These results, such as showing the value of preventative maintenance, present the power of System Dynamics as a learning, financial planning, and performance improvement tool.

The runs, which are shown below, test various budgeting decisions with and without a significant accident at another utility and the value of training. Value is reflected both in capacity rating but also in net income. Other variables such as bond rating, stock price, or PUC perceived prudence are also important indicators of future plant performance. However, experience running the model has shown that these variables track capacity and net income. Historical capacity is the largest factor in perceived safety and net income over time is the most important factor in determining the financial health of the utility. Additionally, poor bond ratings or PUC attitudes towards the utility result in a drop in net income, so outside changes are evident through net income anyway.

7.1 Steady State and Accident-Baseline

One of the steps to validating a model is running the model in steady state to determine if it realistically represents the normal flow of events in the organization it is trying to emulate. For the Nuclear Utility Model, we optimized many factors to make the model run a smoothly as possible. All of the sectors are connect for this run and some principle financial indicators are shown for comparison. Steady state is represented as Case 1 in figures 7.1-1 through 7.1-6.

The next step in validating a model is to test the model's reaction to a known historical event. Case 2 in figures 7.1-1 through 7.1-6 represent the scenario where a nuclear accident occurs at another nuclear plant occurs in week 156. The resulting public outcry, congressional concern, increased regulation, financial community risk perception and PUC reduction in perceived prudence all severely effect the performance and estimated safety of the plant.

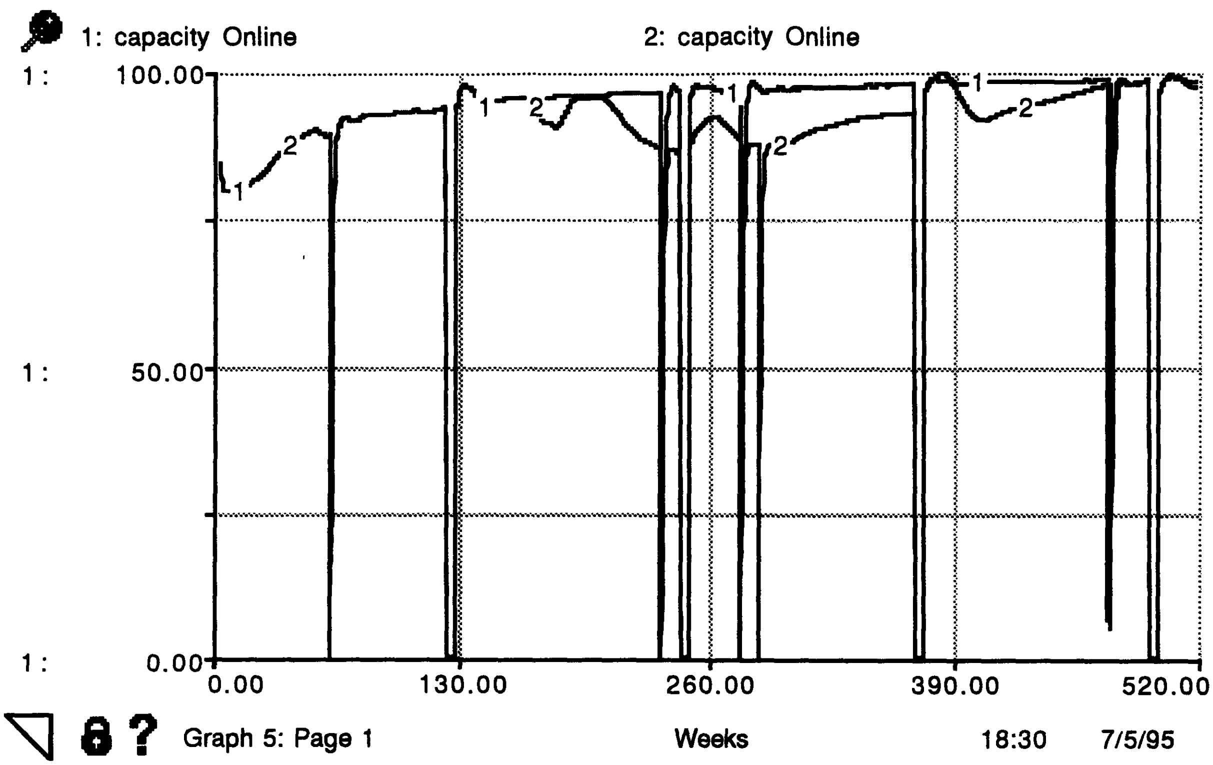

Figure 7.1-1 Capacity on-line for Steady State (1) and an accident at another utility (2). The dips every 120 weeks represent periodic outages. The sharper dips are forced outages.

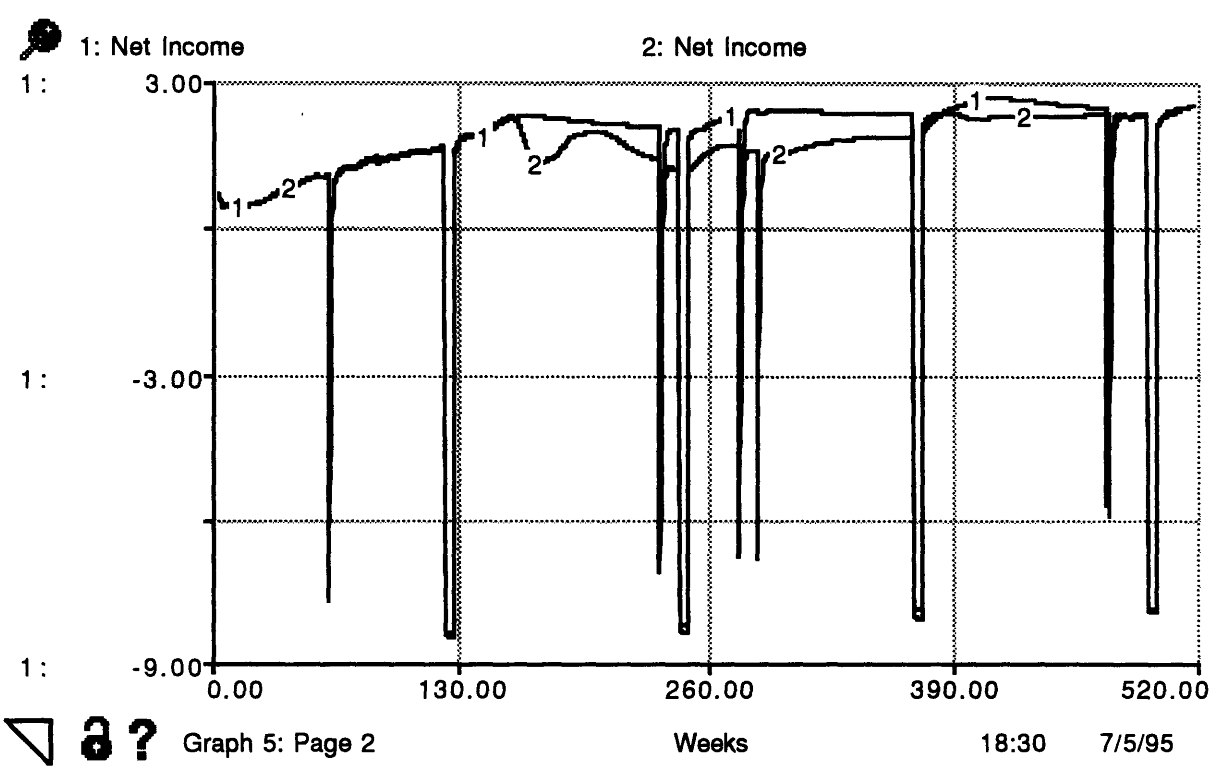

Table 7.1-1 Net Income for Steady State (1) and an accident at another utility (2).

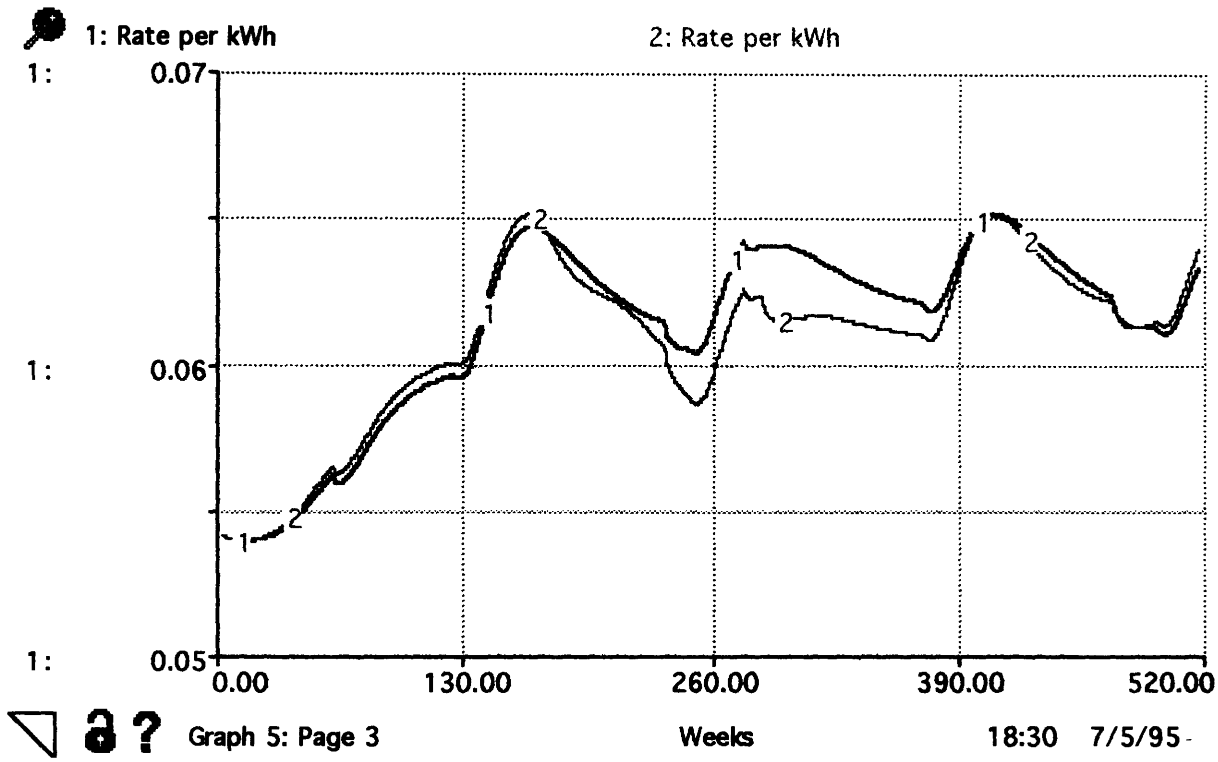

Table 7.1-2 Rate per kW-hr for Steady State (1) and an accident at another utility (2).

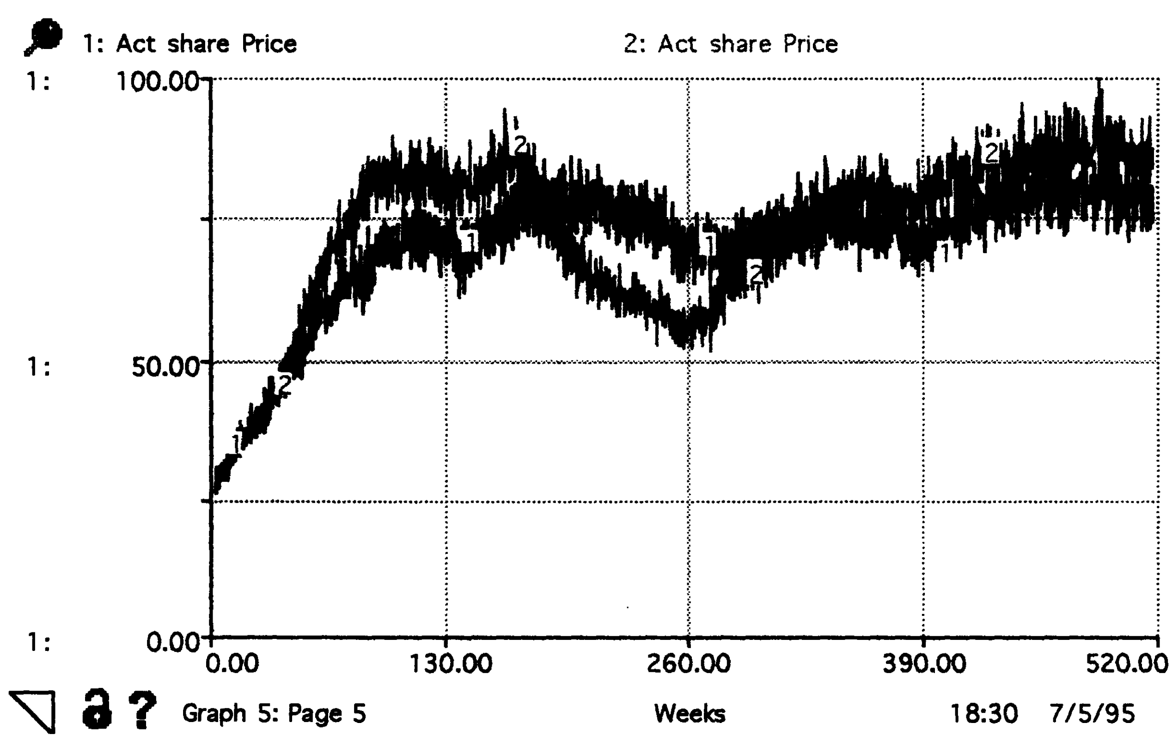

Table 7.1-3 Actual Share Price for Steady State (1) and an accident at another utility (2).

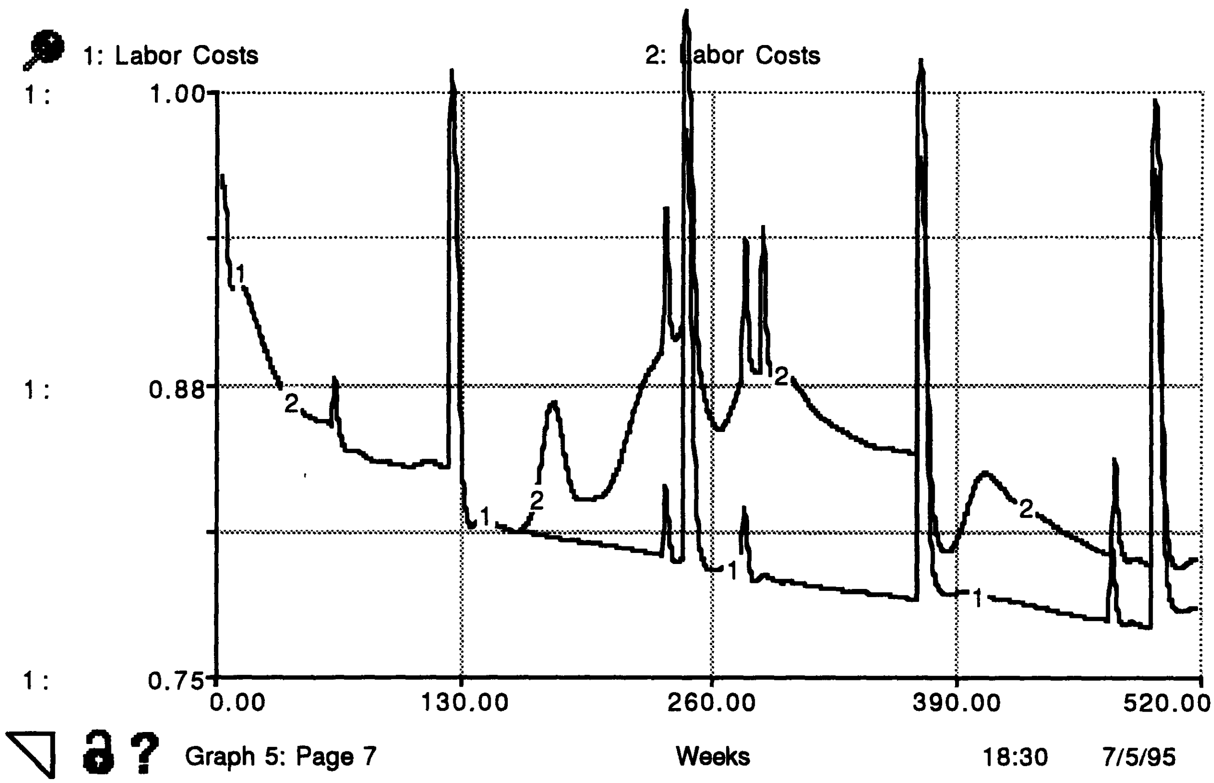

Table 7.1-4 Labor Costs for Steady State (1) and an accident at another utility (2).

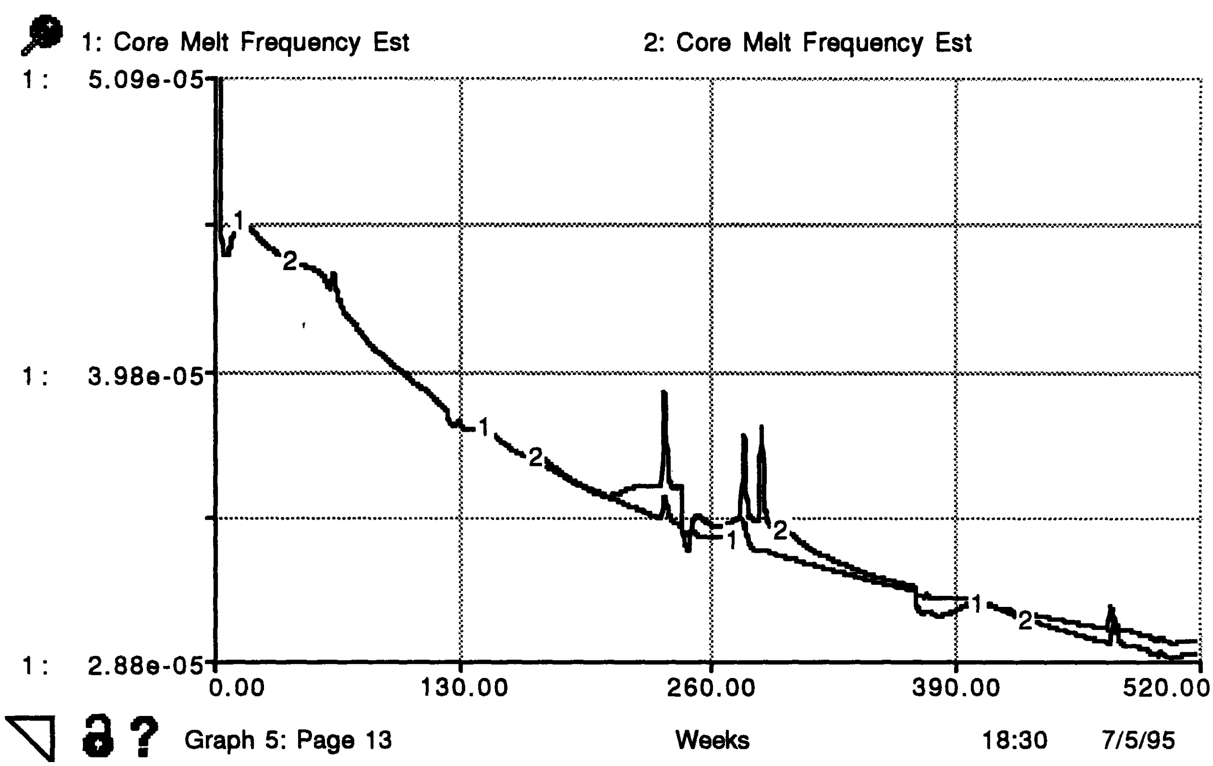

Table 7.1-5 Estimated Core Melt Frequency for Steady State (1) and an accident at another utility (2).

The results of this run show that the monetary costs of an accident at another nuclear plant are very large. The Net Present Value of Net Income for the base case is $ 698 million; the NPV of NI for the accident case is $566 million for a difference of $132 million. These dollars are very real, albeit only a rough estimate of the cost of enduring the negative publicity, NRC regulation, and litigation involved in operating a nuclear plant after a nuclear accident.

Since this model is based on the historical data after the Three Mile Island Accident (TMI) accident, if the societal reaction to another accident is greater, the effects on the utility are greater. $132 million is a large number to think about when considering if nuclear plants in the U.S., indeed the world, are hostages of each other.

Comparing the stock price data in figure 7.1-4 to figure 6.1-3 (excluding the random fluctuations which are not included in figure 6.1-3), one can compare the gradual reduction in stock price, which is similar to figure 6.1-3. Although the model shows somewhat more immediate effect, the slow reduction continuing a year later is consistent with history.

Also shown is labor costs which shows where much of the increased costs come from that severely affect the utility's finances. Labor costs increase significantly after the accident to support increased requirements from the NRC.

The final graph shows the estimated core melt frequency. An interesting result of all these additional labor costs is that reactor safety is not improved. Shortly after the accident it is even reduced (meaning core melt frequency is increased). Because of all the additional workload from post accident reactions, and the reduction in resources the utility has available, training, information usage, and corrective maintenance are reduced. Reducing these programs leads directly to reduction in safety.

7.2 The Value of a Preventative Maintenance Program

The value of preventative maintenance has long been debated in the nuclear power industry. Detractors have complained of the extensive effort required to take down perfectly good equipment for inspection and the possible added defects when a young worker opens a package for the first time. Although many utilities have followed the U. S.

Navy's example and implemented detailed PM programs, the quantitative benefits of their work often is poorly documented.

The model provides a tool to compare, and possibly optimize the plant's preventative maintenance program. Two cases are examined: steady state operation, and post event operation. The results show that a constant inspection budget of about 10% of the total maintenance budget optimizes net income and capacity. Since capacity represents broken equipment for the most part and broken equipment are the main contributor to safety of the plant, this scenario also closely optimizes safety at the same time.

The second case shows a method the plant might use to free resources after a nuclear accident at another utility. By reducing its PM program somewhat after an accident, the plant can actually improve its performance.

7.2.1 Without Accident

The steady state case shows a useful model function: optimizing a budgeting parameter. Since resources available to the plant manager are necessarily limited, optimal budgeting decisions must be made that maximize plant performance while not sacrificing safety. In this case, the model shows a way the manager can optimize PM planning on a limited budget.

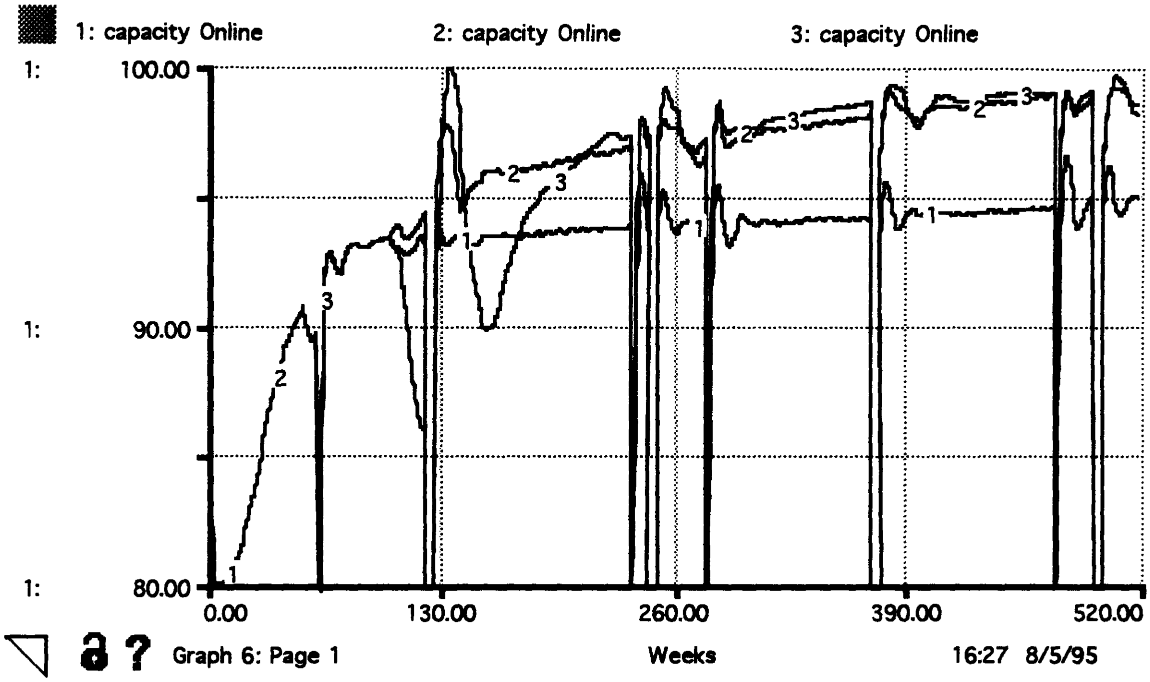

Figure 7.2-1 Capacity On-line for 3 different cases of spending on Preventative Maintenance. Case 1: 0% allocation of labor budget to PM after week 100, Case 2: 10% allocation of labor budget to PM after week 100., Case 3: 20% allocation of labor budget to PM after week 100.

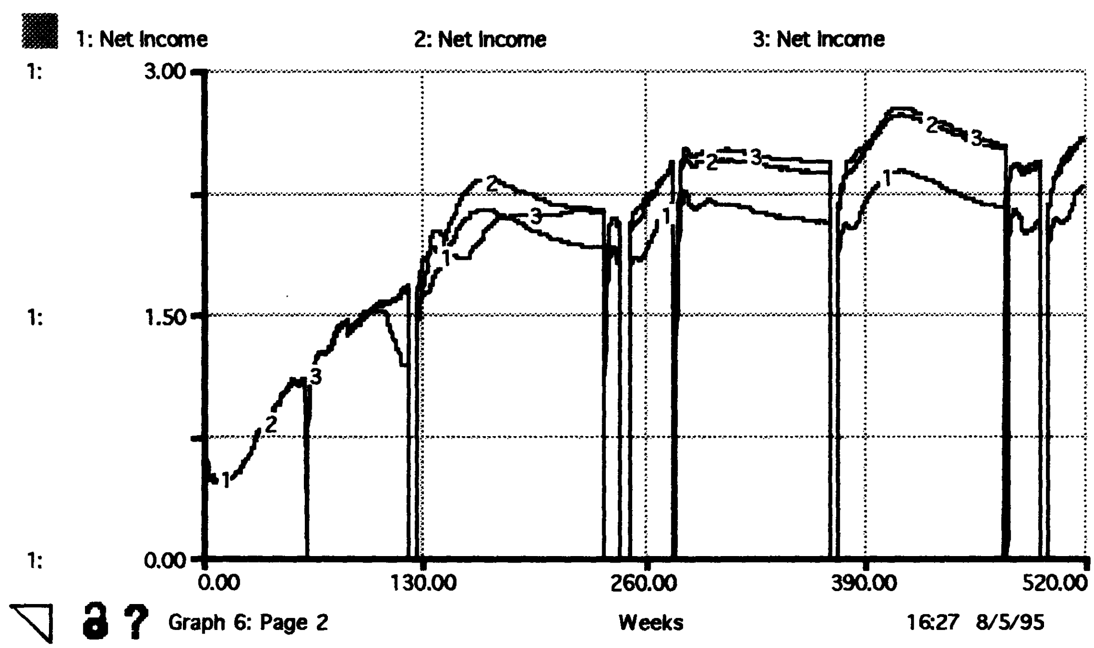

Figure 7.2-2 Weekly Net Income for 3 different cases of spending on Preventative Maintenance. Case 1: 0% allocation of labor budget to PM after week 100, Case 2: 10%

allocation of labor budget to PM after week 100., Case 3: 20% allocation of labor budget to PM after week 100.

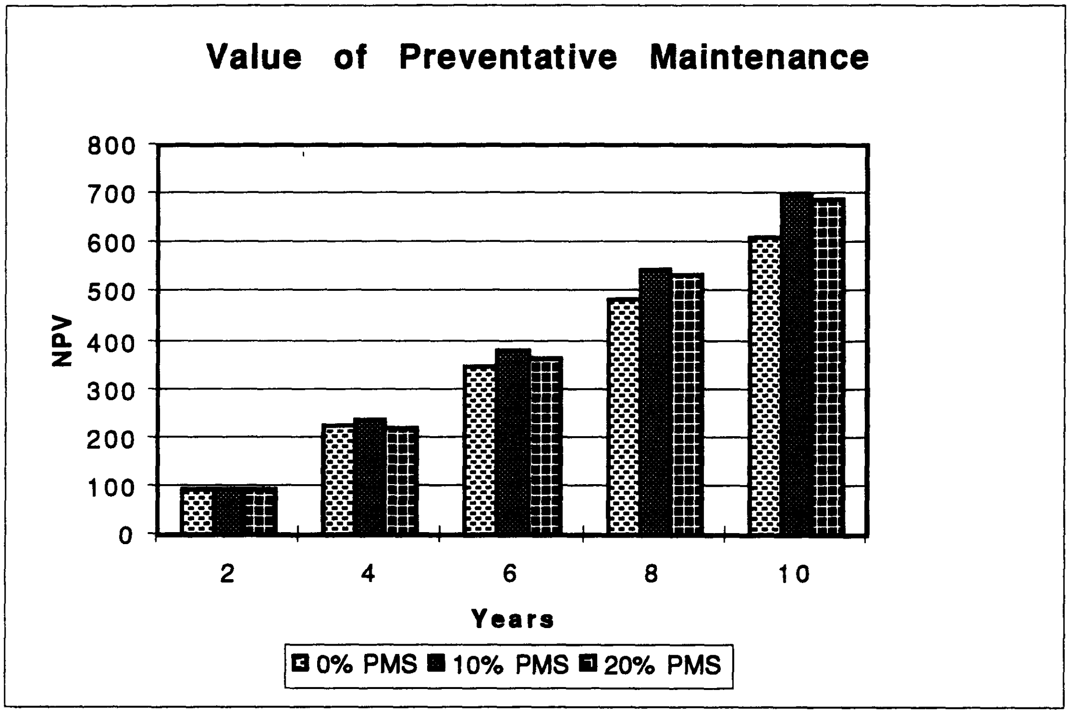

Figure 7.2-3 Net Present Value of Income for 3 different cases of spending on Preventative Maintenance. Case 1: Case 1: 0% allocation of labor budget to PM after week 100 , Case 2: 10% allocation of labor budget to PM after week 100., Case 3: 20% allocation of labor budget to PM after week 100.

Case 1's NPV after 10 years is $ 84 million less than the base case presented in section 7.1. Case 2 is $86 million more than case one and $ 2 million more than the base case. Case 3 is $ 76 million more than Case 1 but $ 6 million less than the base case. Thus spending more on Preventative Maintenance has a positive effect at 10% but will hurt the utility if it spends too much as in Case 3.

7.2.2 With Accident

This run of the model examines a Preventative Maintenance scheme to improve the plant's performance in light of an accident occurring at another plant during week 156. Several strategies were analyzed including additional preventative maintenance before the accident, no preventative maintenance before the accident, and a strong preventative maintenance program which is discontinued shortly after the accident. For better clarity, periodic and forced outages have been removed from this scenario. Net Income is thus adjusted upward by the same amount for every model run.

The resulting "best method" to maximize long term net income is initially counter-intuitive. The best strategy tested was to have a strong preventative maintenance program before the accident, but cut back the utility's discretionary preventative maintenance program shortly after the accident to free up valuable resources to handle the NRC imposed workload, and because much additional required NRC inspections are taking place. The utility preventative maintenance program merely duplicates much of the NRC effort and only results in more equipment being taken down.

All four different strategies are compared in Net Present Value format in figure 7.2-4. The best method is then compared to the baseline strategy of keeping PM constant throughout the run in figures 7.2-5, 6 and 7. The cases represented are described in table 7.2-1:

<u>Responses that Better Post-Event Performance</u>

1 - Base Case (10% maint. Staff allocated for disc. Insp. for entire run.)

2 - 5% Increase in maintenance staff at week 160

3 - Maint. staff allocated for disc. inspection: 5% (160-389), 10%(390+)

4 - 10% eng. staff added to process information

Table 7.2-1 Description of strategies in response to accident.

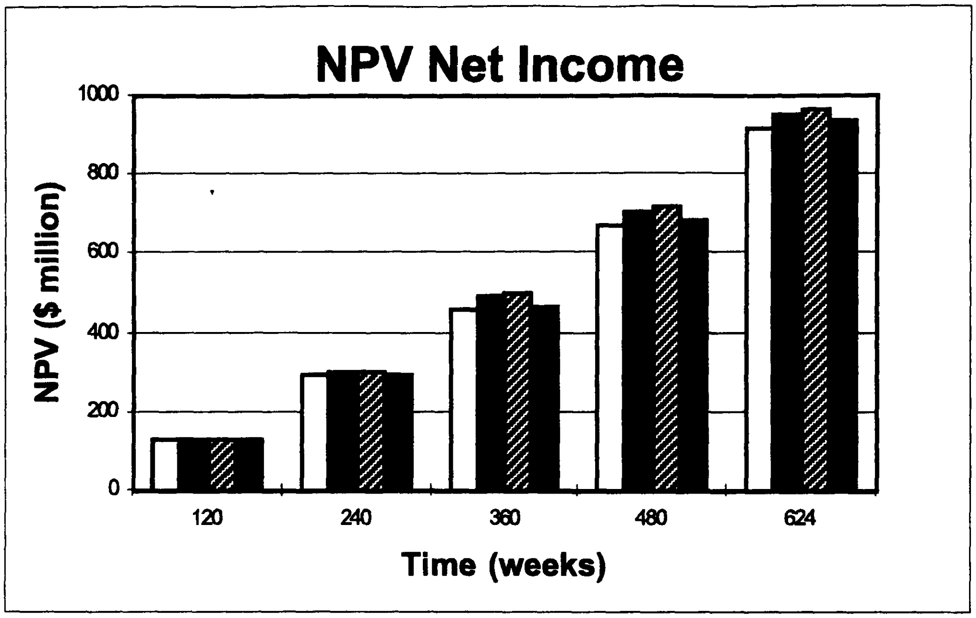

Figure 7.2-4 NPV comparison (from left to right) of cases 1-4.

From 7.2-4 it is evident that case 3 is the best strategy for preventative maintenance for an accident occurring at another plant. To examine why case 3 provides better net present value compared to the base case, it is necessary to look at figures 7.2-5 through 7.2-6. In figure 7.2-5, capacity on-line, the big difference between case 1 and case 3 is about 2 months after the accident. During this time the NRC is conducting intensive investigation, developing regulations and requiring the utility to perform many more mandatory inspections of equipment and to process large amounts of paperwork.

Both of these activities use much manpower. If the utility frees up some workers and reduces its own inspection program shortly after the accident, it can assign more mechanics and engineers to unscheduled maintenance and paperwork processing than it can in the base case. Additionally, since the NRC is requiring more inspections, the plant does not need to do as many to maintain its PM program intact.

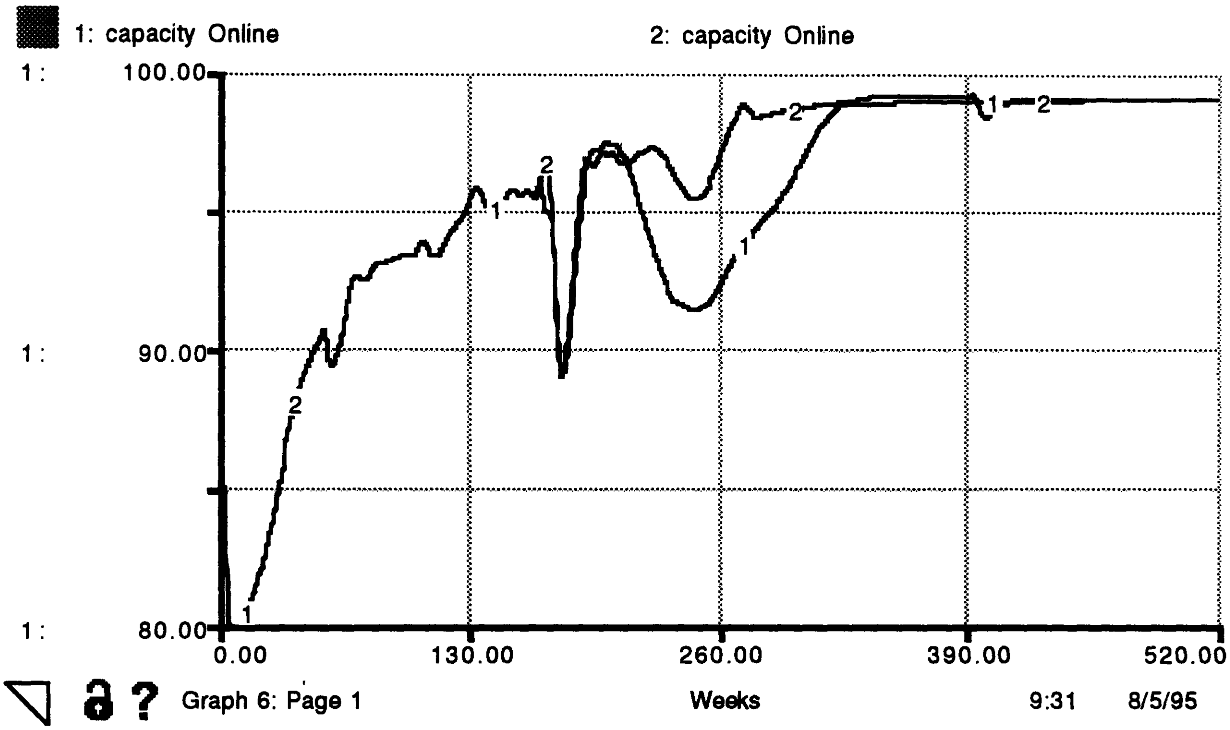

Figure 7.2-5 Capacity on-line for case 1(baseline) verses case 3 (run 2).

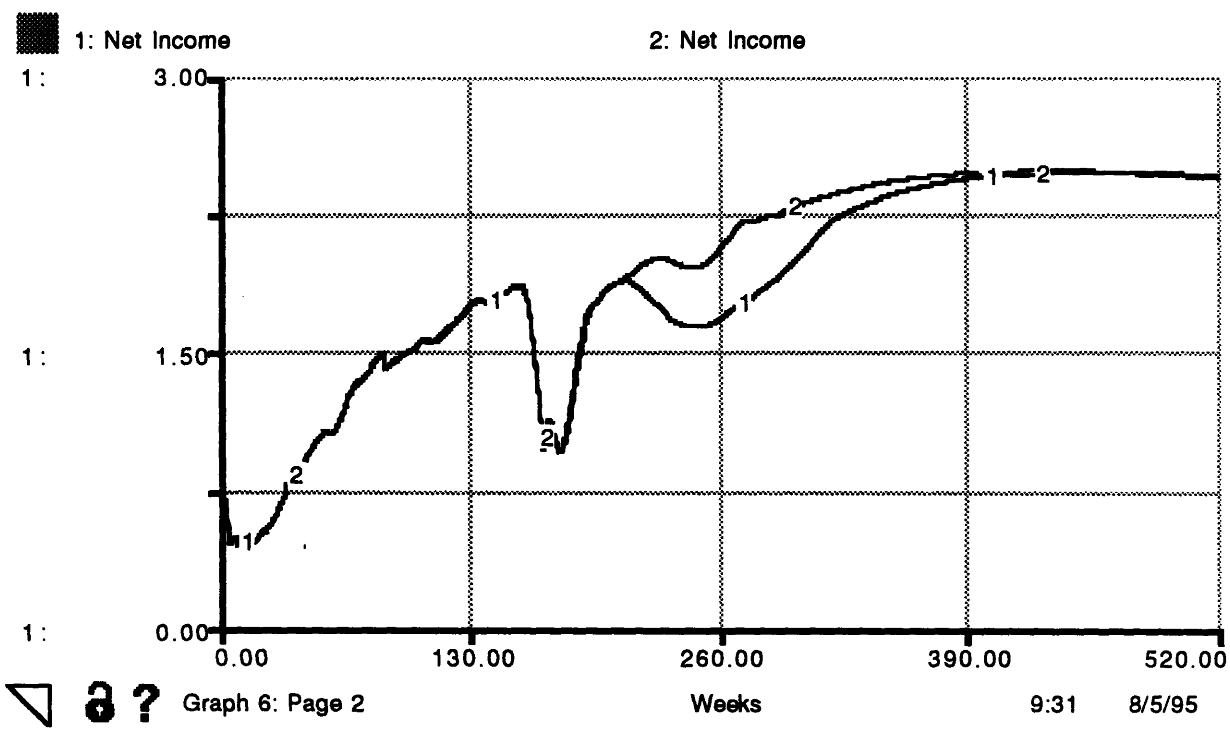

Figure 7.2-6 Net Income comparison for Case 1 (baseline) versus Case 3 (run 2).

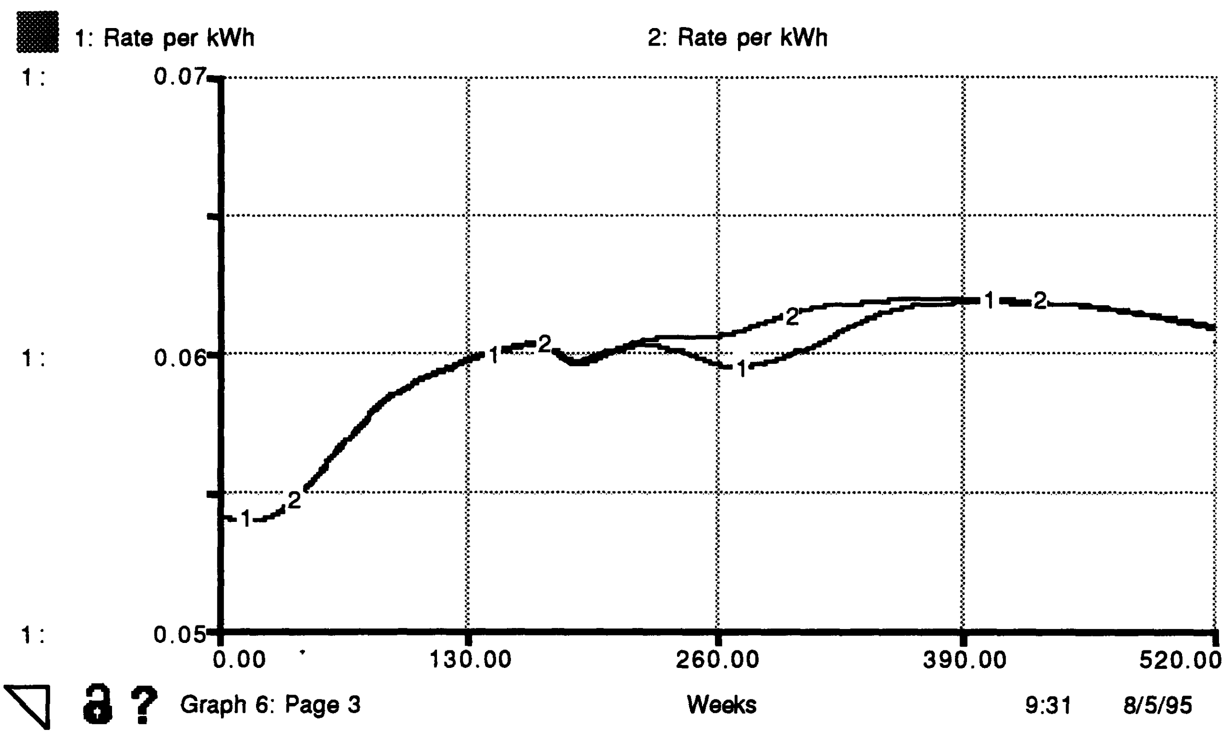

Figure 7.2-7 Rate per kWh for Case 1 (baseline) verses Case 3 (run 2).

Another reason for the improvement in net income is due to a higher allowed fair rate of return which leads to a higher effective Rate per kW-hr allowed by the PUC. This increase occurs because of the improved operations of the plant. Similar in effect to distinct performance based incentives, the PUC traditionally rewards the utility for better operations with more favorable rate cases. In this case, the utility not only makes more money for achieving a higher capacity but also can charge its customers more.(Boston Edison Interview, 1994)

7.3 Investing in Capital Equipment

This model run examines the practice of investing internally instead of paying a portion of dividends to the stockholder. Several variables are presented and compared with the base run to see if the plant can improve its performance, stock price, and net income from this management strategy. As in the last scenario, periodic outages and forced outages have been removed for clarity.

In this case, at week 200, the utility owner decides to reduce stockholder dividends from 75% of profits (net income after taxes) to 35%. Although this reduction can have severe effects on stock price, if the utility carefully invests the income, the long run net income will be higher and the long run stock price might actually be higher because of growth, better performance and even a more amicable Public Utility Commission.

The results of several different variables are shown in Figures 7.3-1 through 7.3-7. With an increase in investment in new plant parts and capital equipment from $20,000 to $100,000 per week and smaller increases in maintenance budgeting, several results are evident. First, capacity is only slightly improved. Since the plant is running well already, a comparably large increase in internal investment does not improve weekly operations considerably.

There are larger positive differences in Net Income and Rate per kWh allowed by the PUC. There is also a large (about 10%) decrease in stock price during the reduction in dividend payments, which was expected. However, when normal dividend payments are resumed, the resulting stock price is actually higher that the original stock price by a small margin. The overall result that can be gained from this run is that plant reinvestment, while difficult to do because of the temporary negative impact on stock price it generates, can be beneficial in the long run due to higher net income and, once the dividends are restored, a slightly positive effect on stock price.

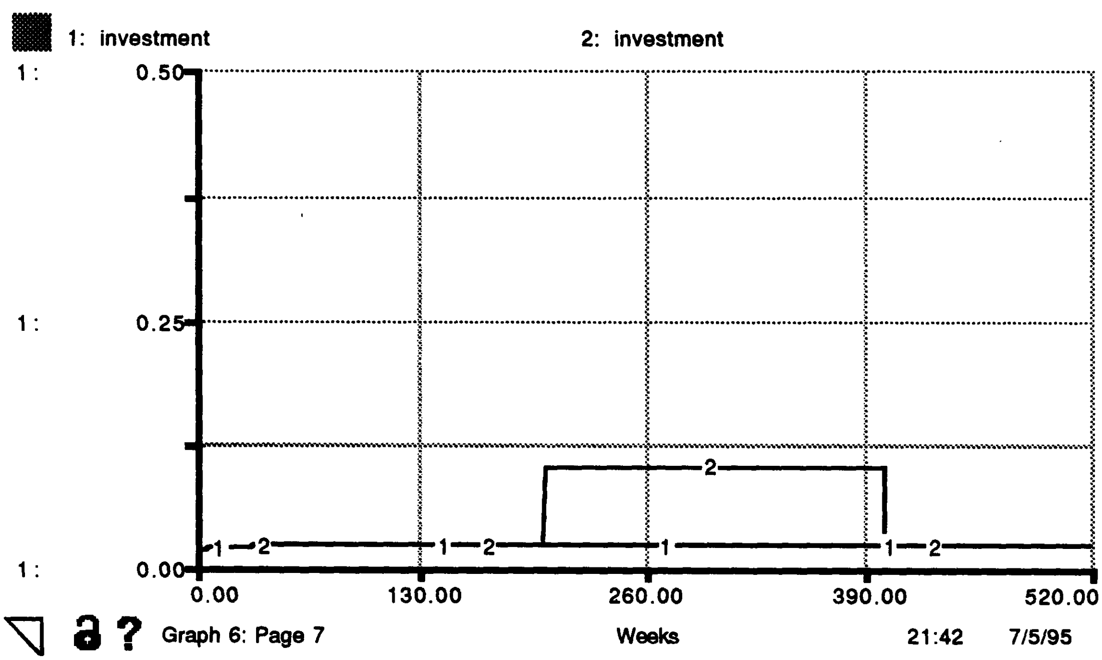

Figure 7.3-1 Comparison of reinvestment strategies: Case 1-baseline, Case 2- Dividends cut by 50% and reinvested.

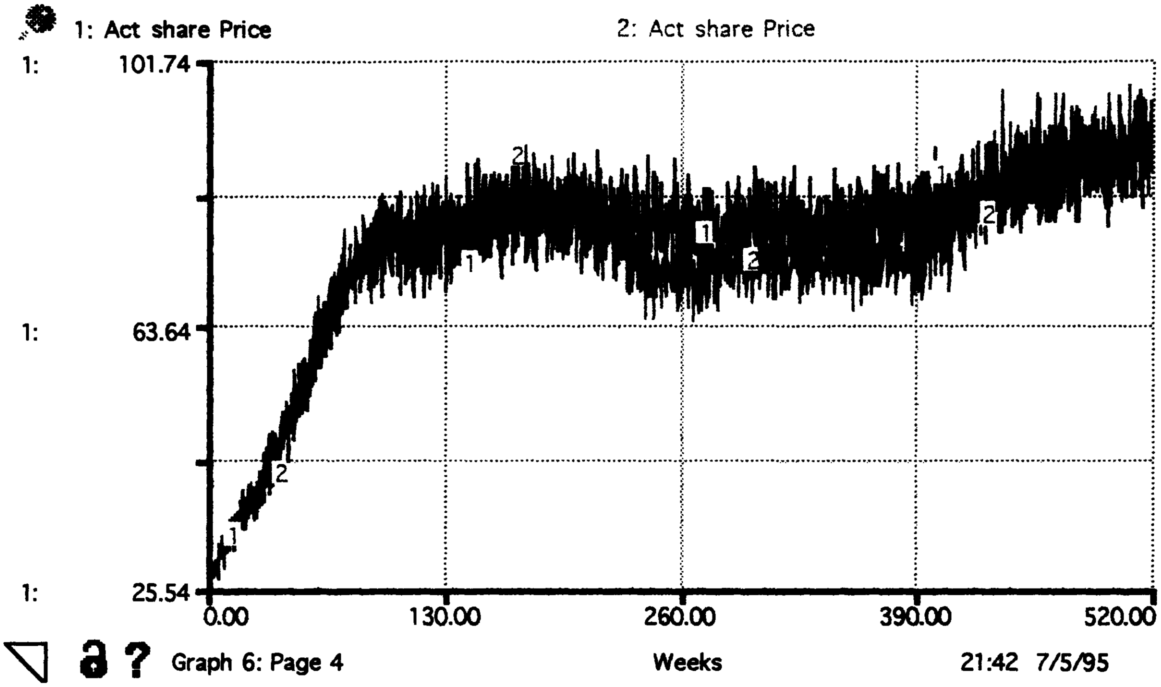

Figure 7.3-2 Share Price for comparison of reinvestment strategies: Case 1-baseline, Case 2- Dividends cut by 50% and reinvested.

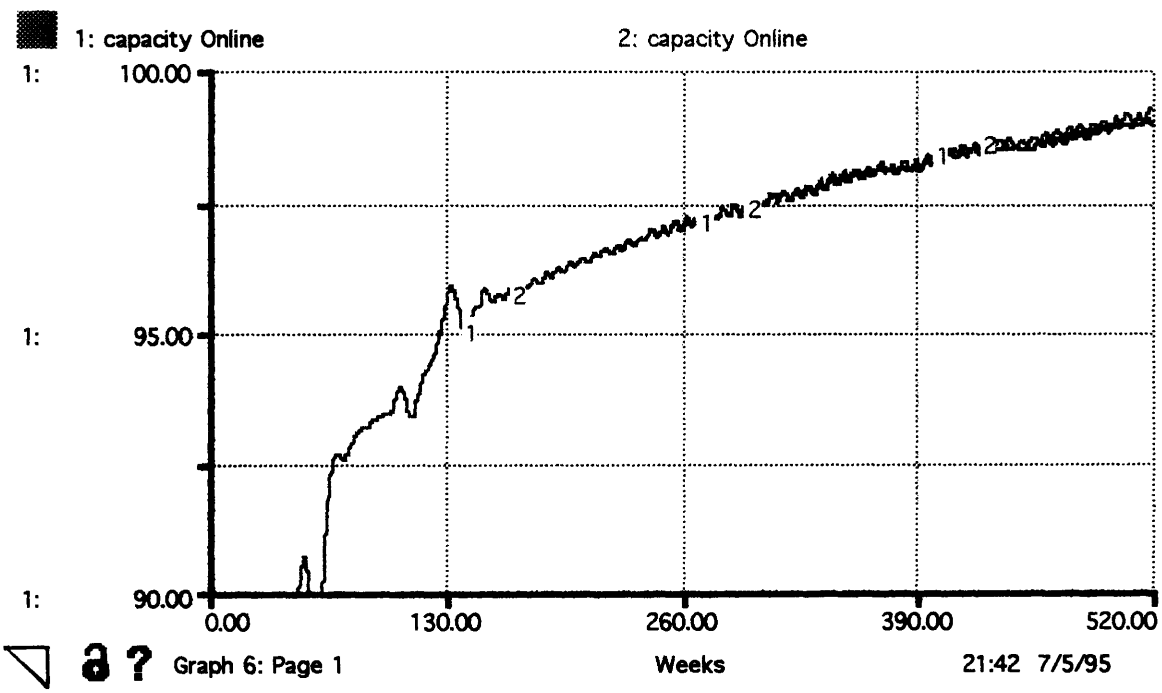

Figure 7.3-3 Capacity for comparison of reinvestment strategies: Case 1-baseline, Case 2- Dividends cut by 50% and reinvested.

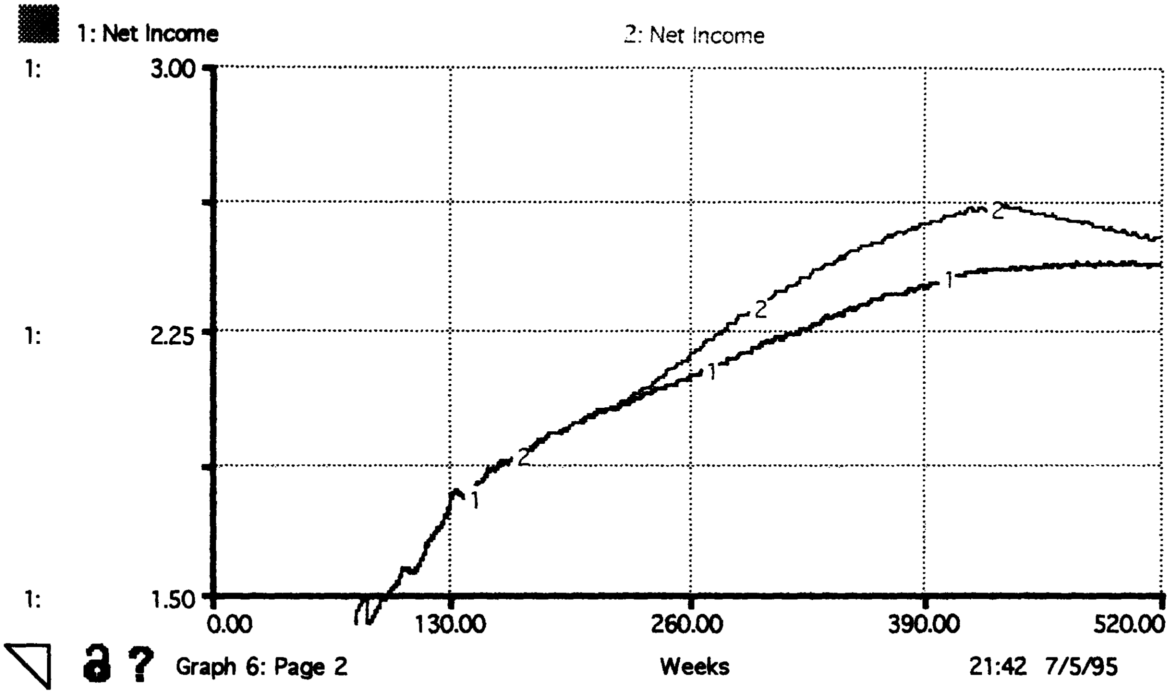

Figure 7.3-4 Net Income after Taxes for comparison of reinvestment strategies: Case 1-baseline, Case 2- Dividends cut by 50% and reinvested.

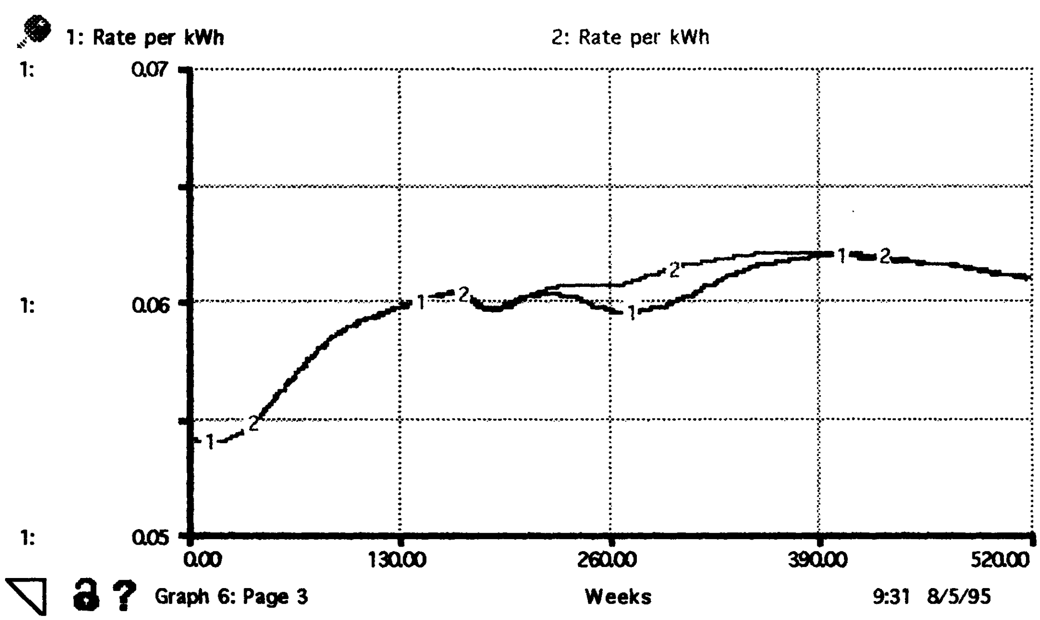

Figure 7.3-5 Effective Rate per kWh for comparison of reinvestment strategies: Case 1-baseline, Case 2- Dividends cut by 50% and reinvested.

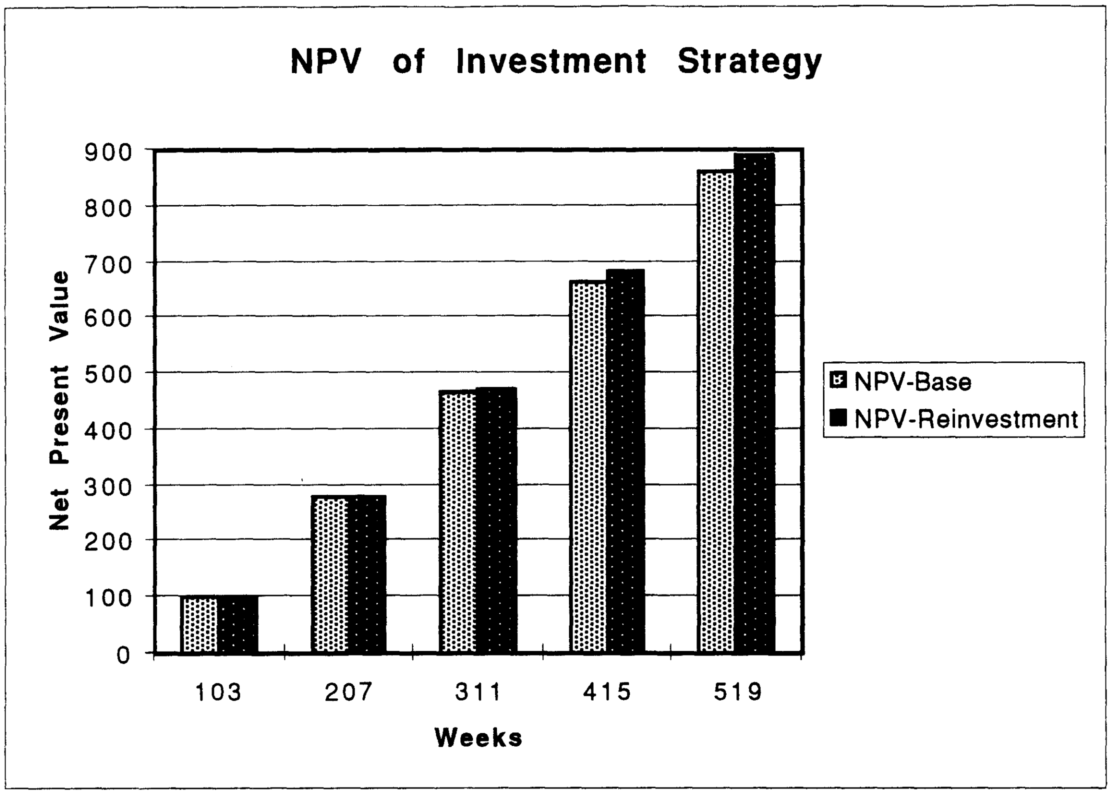

Figure 7.3-6 NPV of Reinvestment in plant for Base Case and Reinvesting 50% of dividends.

Case	End of Run NPV Income
Base Case	859.81
Reinvestment of Dividends	889.10

The results of this run show that the Present Value of Net Income for the reinvestment of dividends is greater than for the base case. It is important to note that the reduction in stock price is reflected in net income over the long run because the reduction in stock price increases the cost of capital to the utility. Since the cost of capital can represent about 75% of the utility's costs, the cost of capital significantly affects these costs, thus driving down net income.

Considering that the reduction in stock price is at least partially reflected in the net income, the manager can review the present value results to compare the reinvestment strategy in this case. Of course, reduction in stock price carries some additional negative connotations. First of all, very few executives are rewarded for lowering the stock price for 4 years. Second, if the bond rating institutions, or PUC are not convinced that the utility is correctly reinvesting its money, then their downgrading on bond ratings and perceived prudence might severely affect the utility.

For any case when a manager is using the model, he must consider all tools including experience, other financial models and the extensive literature written about nuclear utility policy.

8. Policy Implications

Utility owners and regulators can use the utility model to aid in strategic decision making, as a learning tool, or as a tool to explore the consequences of external events. As demonstrated above, the model provides a long term quantitative comparison between several alternative policies. Experiments require only a ten minute run time per scenario.

However, considering the limitations of the model is as important as considering the utility of the model in planning by utility managers or regulators. A user of the model must study the structure and boundaries of the model prior to testing policy decisions.

The limitations, demonstrated in the results section, include the exactness of the answers the user of the model is seeking. Whenever one models soft variables (Public Concern, Stock Analyst's Perceived Risk, etc.) and their interactions on hard variables (Net Income, Broken Equipment, etc.) some consideration for error must be included. In this model, the most important results are trends. However, since all policies are operating in a consistent environment, the relative values still provide considerable insight into the results of policy decisions.

Another limitation is the boundary of the model. This model is only a imitation of the environment in which nuclear plants operate. It cannot model outside changes, such as the Russian disposition of plutonium or the nuclear waste issue, without adding complexity to the model. If the model does not reflect reality, the model might still be valid. The model, a simplified view of nuclear utility operations, can still be used by policy makers to value strategic decisions and outside influences which are included in the model.

8.1 Utility

Once all of the limitations are accounted for, a utility can incorporate the model into its strategic planning arsenal to incorporate additional factors which are not currently considered in utility planning models. For instance, the plant manager can use the model to optimize preventative maintenance planning in light of regulatory pressures to maximize income while maintaining the same safety level.

The model illustrates critical variables to the nuclear plant manager such as net income, core melt frequency, capacity on-line, and labor costs. These variables are all shown on every run so the utility manager can easily compare safety costs and long-term net income results.

8.2 Regulators

Regulators need a tool to help them understand the implications to the utility of their decisions over the long run. Once the regulators can agree on the underlying assumptions of the model, both parties in the rate case determination or regulation case can better work to negotiate a settlement knowing the long term implications of their point of view.

8.2.1 Public Utility Commission

The PUC's purpose is to guarantee service to all electric customers while maintaining reasonable electric rates. At the same time it is charged with guaranteeing a "fair rate of return" to the utility owners for providing their pledge of service. Recently, activist groups and changing political policies have made the PUCs assume a more active role in utility decision making.

In their effort to reduce the fat at the utilities and reduce electric bills, PUCs have taken some draconian measures which have caused long-term electric bills to be higher than they otherwise would have been. PUCs have been disallowing rate base adjustments recently creating difficult situations for the utilities as they try to recoup their investments in new plants. If PUCs were able to see the long-term effects of their actions, which can involve the utility incurring more debt and making its capital costs increase, then they might be willing to investigate other methods to reduce the electric bills for the consumer.

Another method used, particularly in Massachusetts, has been performance based incentives. These incentives allow the utility to charge the rate-payer more if their safety and performance measures exceed certain levels. There are two problems with this policy which can be evaluated using the model. The first is that rewarding the utility for higher capacity factors effectively doubles its incentive for obtaining higher capacity factors. Doubling the incentive might make the utility forego long-term planning to maximize short-term capacity. The second is that effectively the rate-payer is punished if the utility enhances its performance since the PUC is rewarding the utility with higher rates. Perhaps the PUC could use the model to test several alternative policies to see which ones maximize long-term safety while sufficiently compensating the utility and not hurting the rate-payer.

8.2.2 Nuclear Regulatory Commission

The NRC's purpose is to ensure the safe operation of Nuclear Power Plants for the public. The NRC is constantly investigating ways to improve the safety of nuclear power plants without bankrupting the utilities. Many improvements have been made since TMI in the NRC's method of regulating nuclear plants. However, much of the NRC's actions at nuclear plants divert valuable recourses from plant operations and can indeed hurt the plant performance and even safety.

Since the NRC is interested in enhancing plant performance, a tool such as this model can be used to improve regulatory strategies to optimize plant performance and safety. If a plant is running well in terms of risk assessment, capacity factors, and personnel training, then the NRC could evaluate potential methods for correctly rewarding the utility. If it relaxes monitoring too much, the utility might slip in areas which are not being monitored under the relaxed standard. However, reducing monitoring to the minimal amount possible is a worthwhile goal since the model demonstrates that exaggerated requirements can lead directly to reduced safety at the plant.

8.3 Bond and Stock Rating Institutions

Stock and Bond analysts appear to be overly concerned in the next dividend or debt payment and less interested in safety than other parties. However, since a core melt will prevent most investors from retrieving their investment, many analysts watch the utility's SALP scores and INPO reports to see if a particular reactor is at heightened risk. They then adjust their ratings accordingly.

To understand utility actions with regard to long-term investments, preventative maintenance programs, and PUC decisions, bond and stock analysts can use this model as a tool to decide on the prudence of utility management decisions. The long-term analysis aspects of the model are especially appealing for the bond analyst who must establish risk of default over the entire lifetime of the bond.

8.4 Best Course of Action under Competition

This model can also be used as a tool to see the effects of various budget cutting methods a utility owner might use to make nuclear plants competitive with Independent Power Producers (IPPs). By using the model to investigate various strategies, one quickly realizes that safety and economic performance go hand in hand. After running the model to achieve the best performance, the question as to why the best running plants have also been the cheapest to operate and also among the safest becomes much easier to answer.

9. Summary and Conclusions

This thesis demonstrated, through the use of system dynamics, a tool that can be used to study how the limitation of resources because of social, political, informational, plant, or financial dynamics affect the long-term performance and safety of nuclear power plants. The thesis also shows how resources are limited by social/political processes. Understanding these processes is crucial for utility managers and policy makers. In addition to advancing learning organizations, lean management, technical solutions, and other methods which have worked so far to improve performance of nuclear plants, plant managers and regulators must evaluate other outside factors which affect the operation of nuclear power plants.(Hansen et. al., 1989)

This thesis demonstrated the monetary effects of a nuclear accident, various preventative maintenance strategies, and internal reinvestment of dividends on the economic and safety performance of a nuclear utility. In this case, system dynamics provided a useful tool to uncover strategies for dealing with outside and internal factors in light of many different competing stakeholders.

Even if the nuclear industry were to survive another Three Mile Island type of accident, the costs to utilities and the public would be large. Putting a dollar value on the post accident costs can help the utility manager and regulators make the best spending decisions. Over a ten year period, the cost of a nuclear accident to an independent nuclear plant would be around $130 million according to our model. Since a plant manager can estimate the probability of having a nuclear accident at the other plants in the country, he can decide how much spending is worthwhile. In the case of other plants, through INPO and information sharing, the utility owner can just multiply the probability of another nuclear accident by $130 million to get a rough estimate of how much should be spent on other plants' safety.

The model quantitatively analyzed the value of varying preventative maintenance programs. It showed that spending 10% of the labor budget on preventative maintenance can be worth about $86 million more than eliminating preventative maintenance not required by the NRC. On the other hand, it showed that spending 20% of the labor budget on preventative maintenance can be detrimental. The present value of net income for this case is $10 million less than spending only 10% of the labor budget.

In dealing with an accident at another nuclear plant, the utility can actively reduce its own total cost by developing strategies in advance to deal with the onslaught of investigations, regulations, financial perturbations, and public interest group lawsuits. One method presented was to reduce preventative maintenance shortly after the accident. This approach was chosen for two reasons: it would free up some necessary personnel to respond to NRC inquiries, especially engineers and since the utility is required to perform so many mandatory inspections after the accident, preventative maintenance is redundant.

Reducing preventative maintenance resulted in a higher capacity factor shortly after the accident which led directly to increased net income. Additionally, since the capacity is higher compared to the base case, the PUC is more likely to approve rate increases allowing the utility to recoup even more cost. A third factor is the social feedback because the utility's performance factors are higher. Public interest groups, the media and the local public end up protesting the utility less creating a better environment for rate cases. The improvement in rate cases, improved performance at the plant, and reduced local public outcry improved the utility's perceived financial risk. This reduction in risk then led to reduced capital cost through better bond ratings and even a higher stock price.

Finally, this model demonstrated a slight improvement in long-term economic performance of the utility if it invests in capital improvement and maintenance while foregoing some dividend payments.

Further work will be required including refinement of personnel allocation and improvement of the safety sector to include more detailed Probabilistic Risk Analysis if a better representation of safety is required. The model must then be fit to an operating utility and tested to perform the experimental validation of the model. Once the model has been tested on an operating utility, it can be used by utility managers as powerful strategic planning tool.

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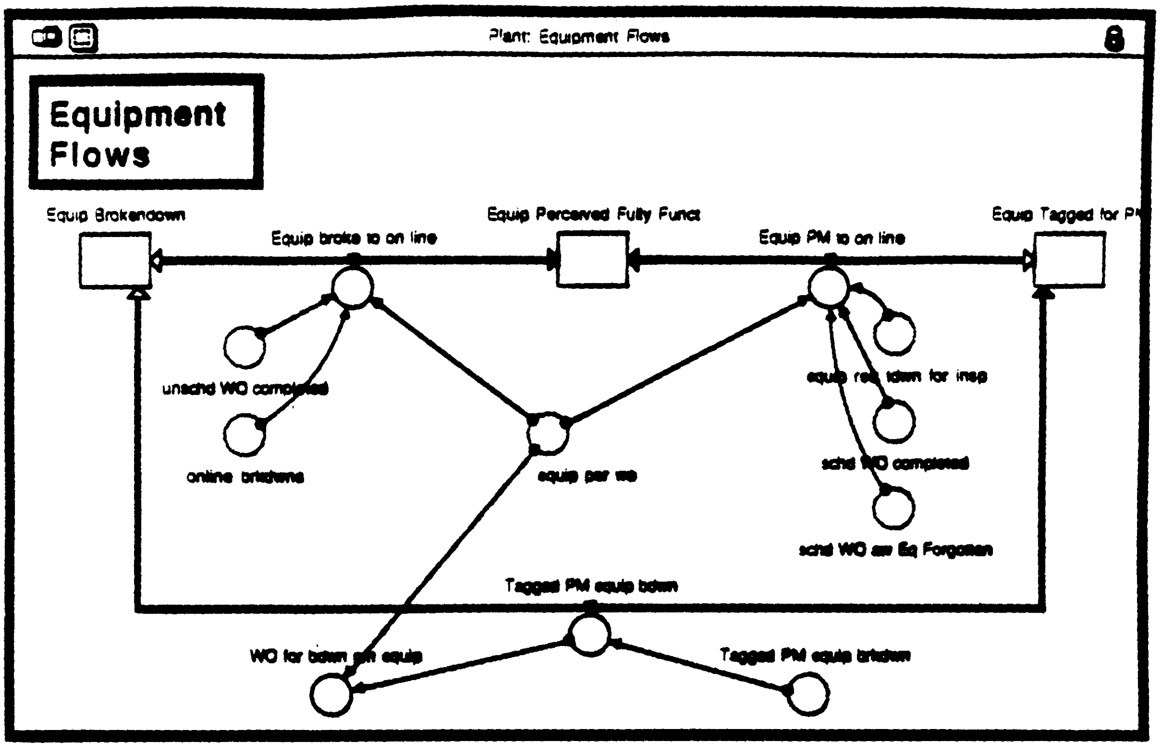
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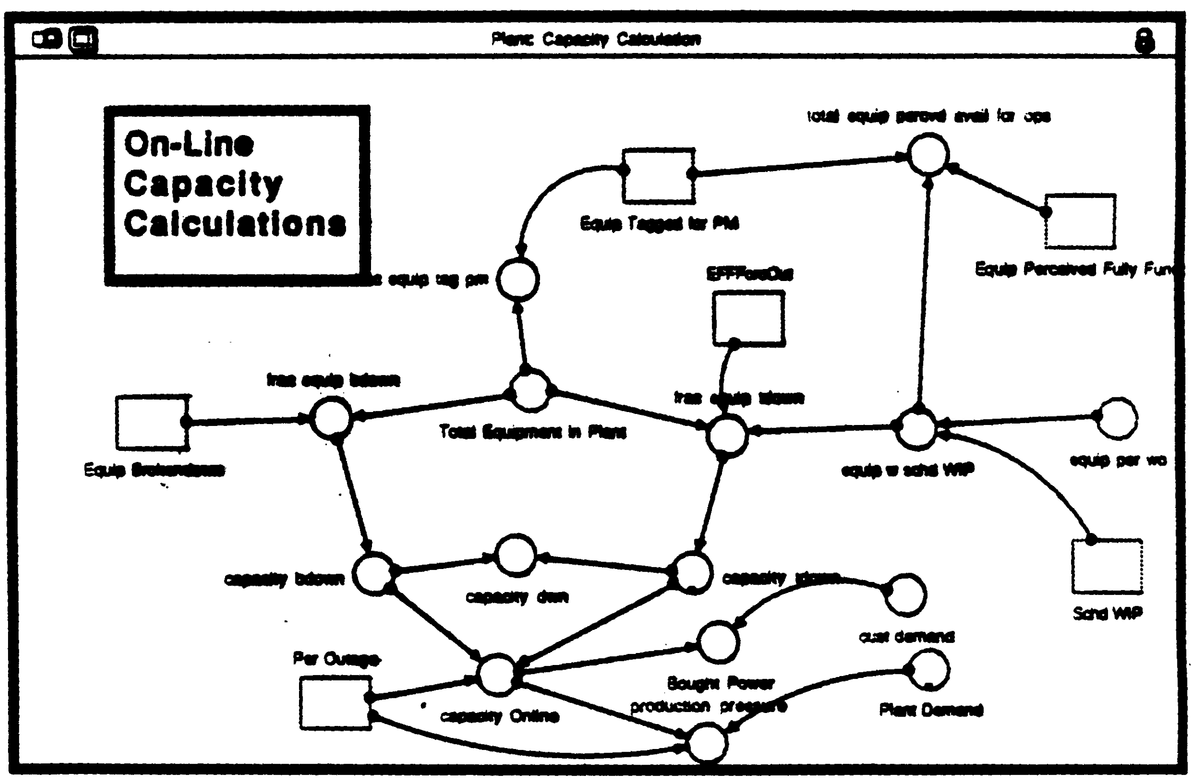
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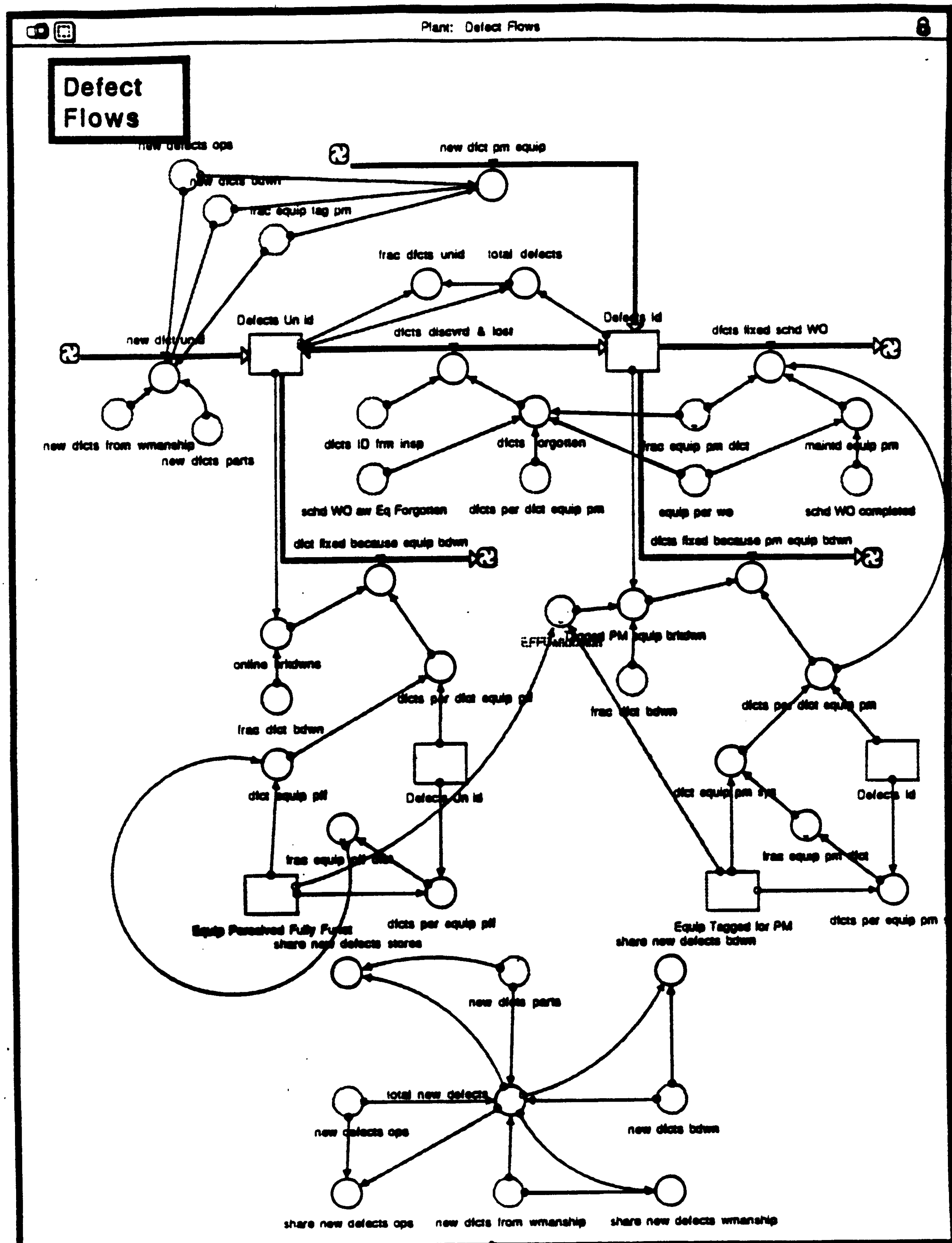
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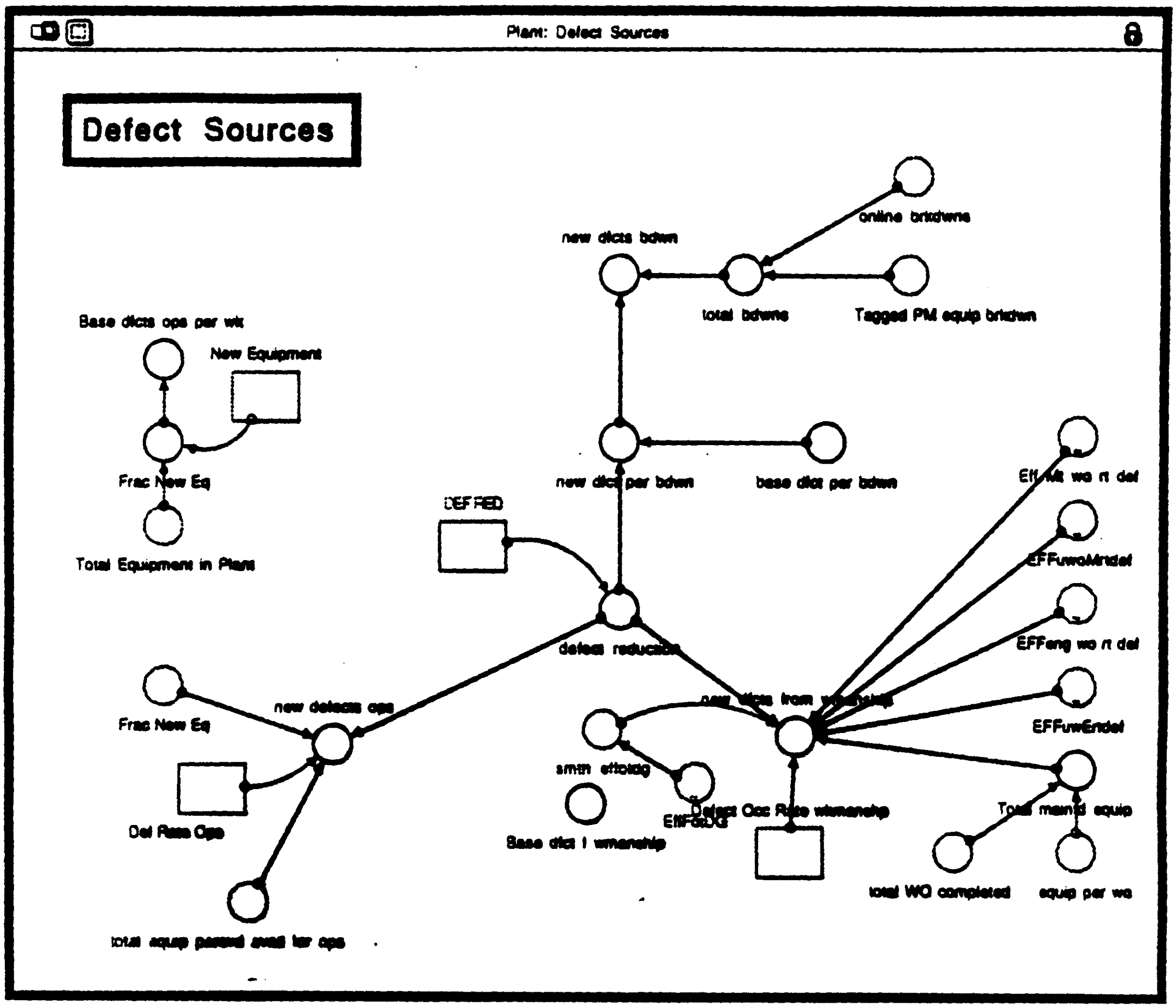

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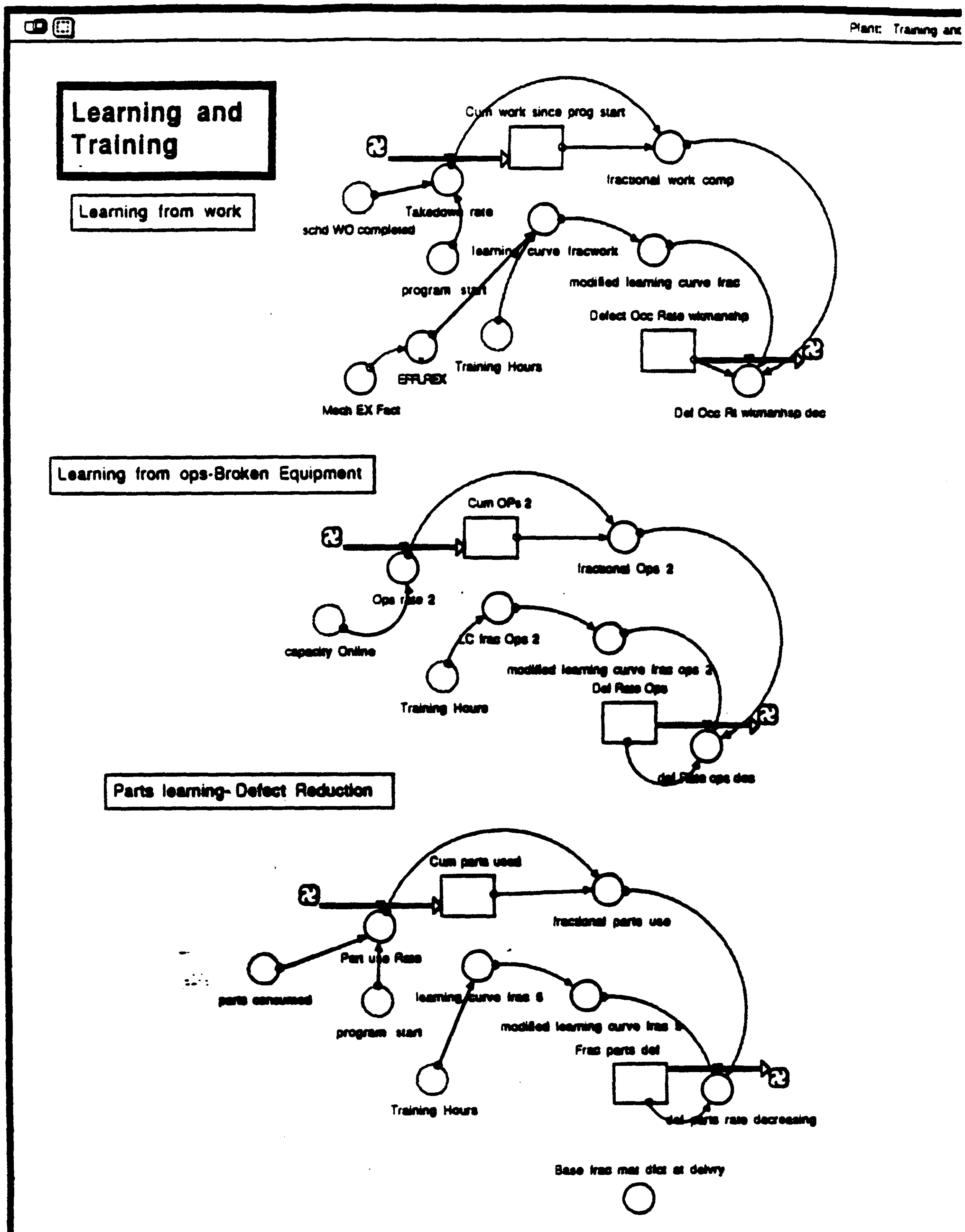
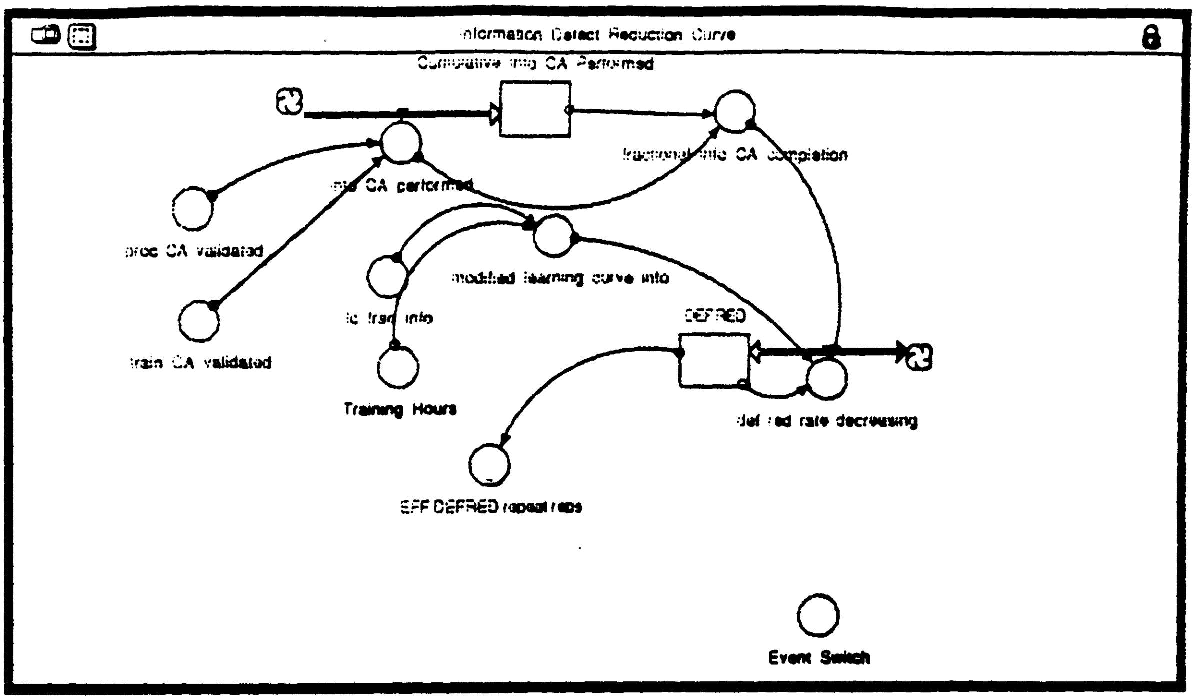
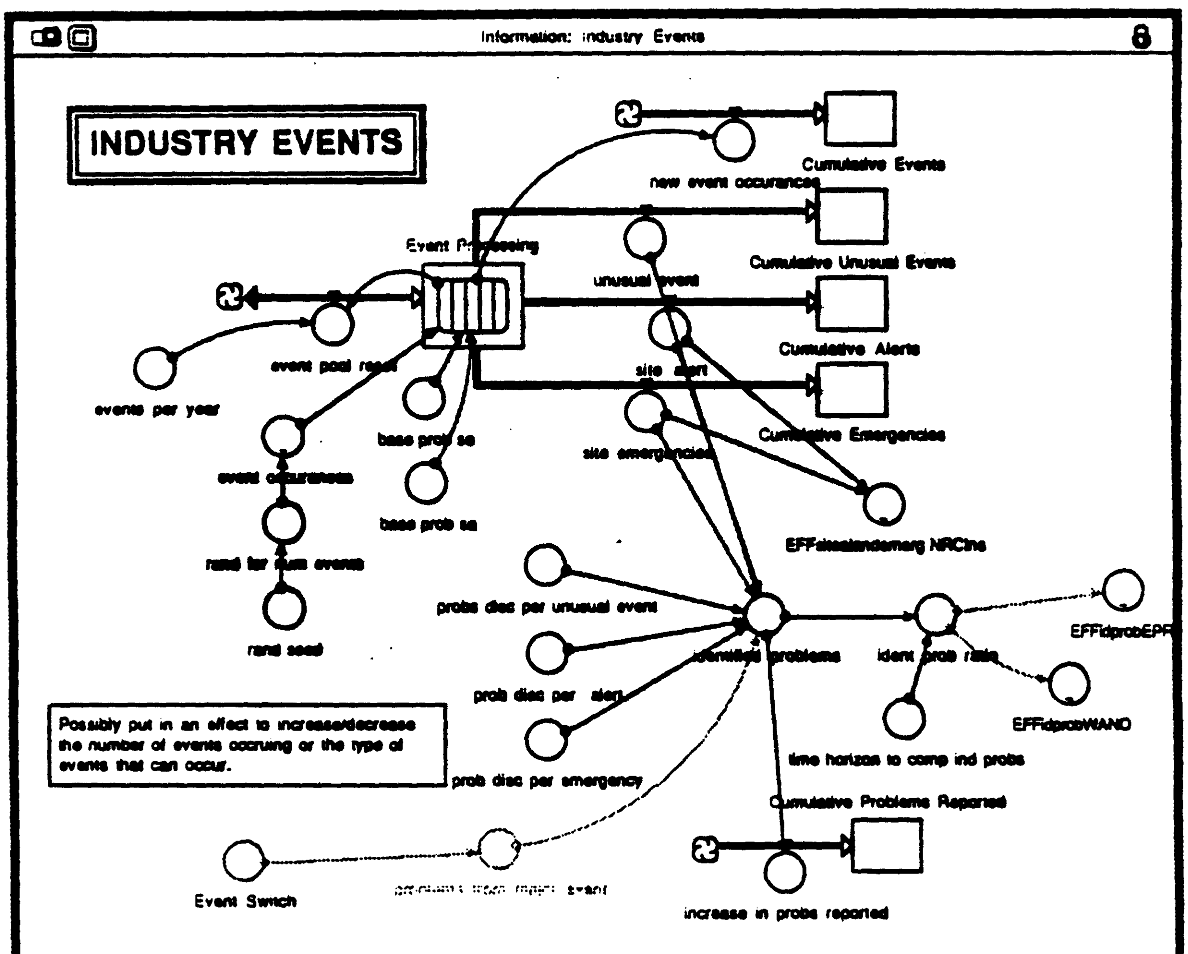
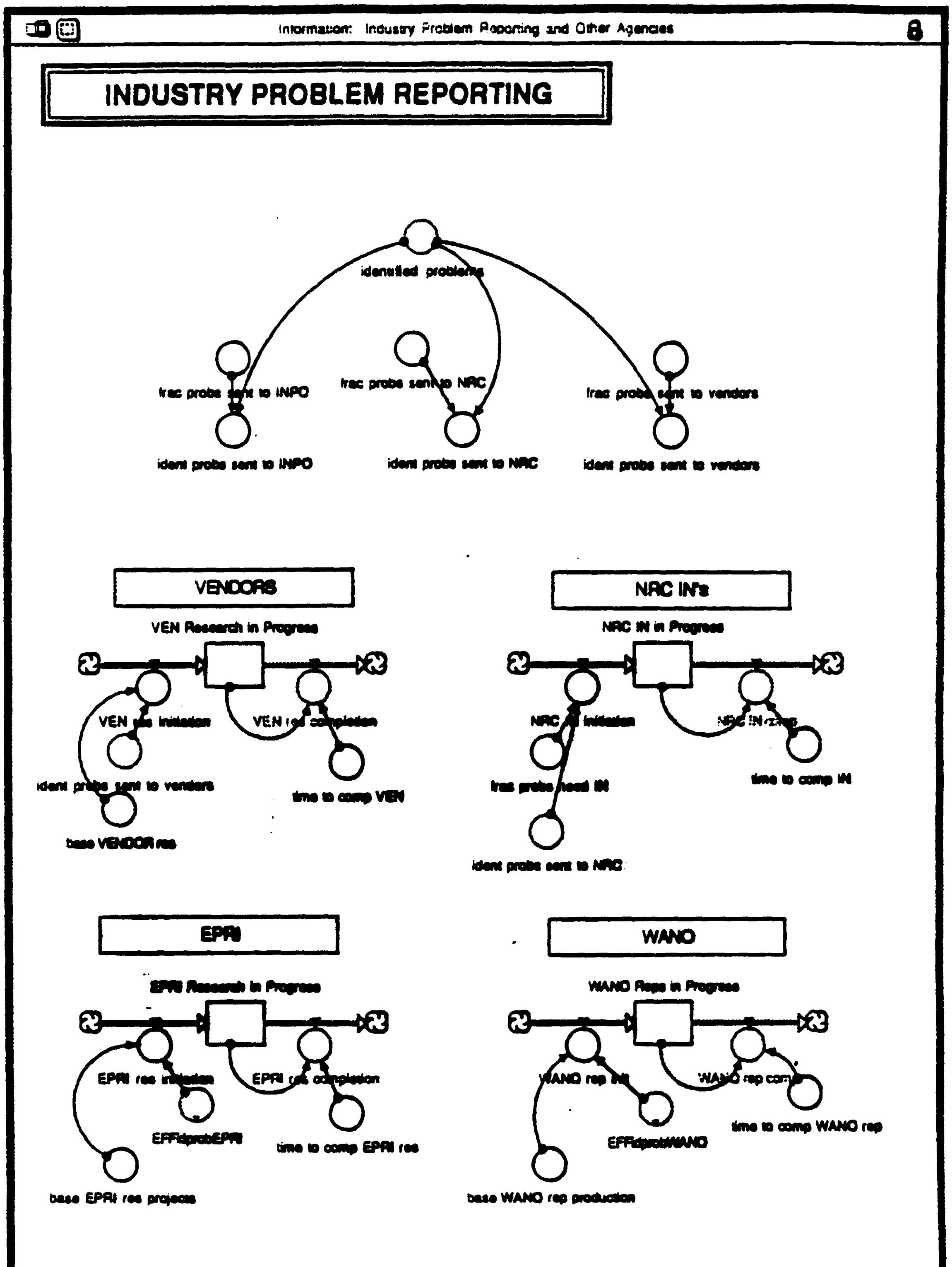
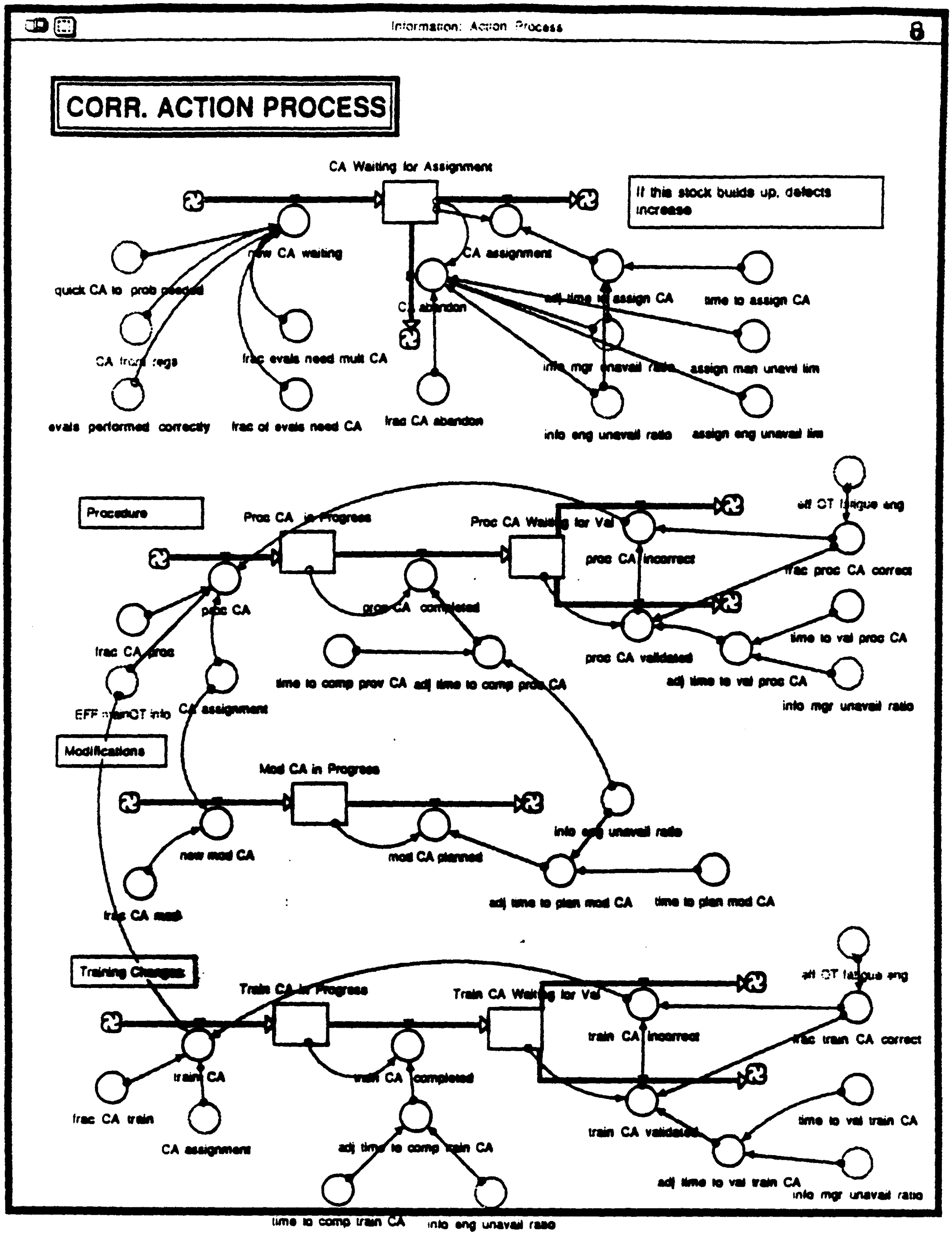
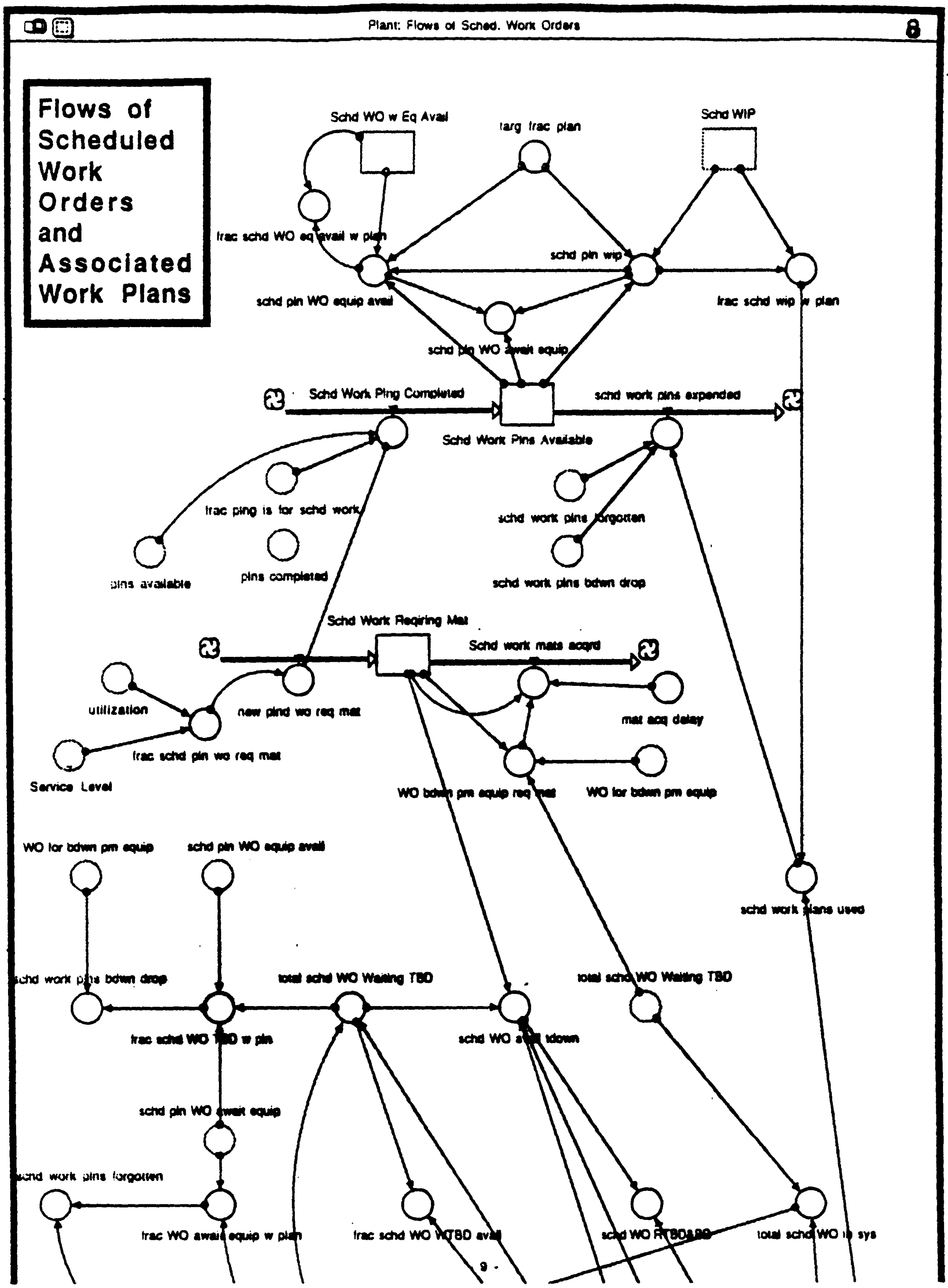

Plant: Training and
Learning and Training
Learning from work
Cum work since prog start
fractional work comp
Takedown rate
schd WO completed
learning curve fracwork
program start
modified learning curve frac
Defect Occ Rate wkmanshp
Training Hours
EFFLREX
Mech EX Fact
Def Occ Rt wkmanshp dec
Learning from ops-Broken Equipment
Cum OPs 2
fractional Ops 2
Ops rate 2
capacity Online
LC frac Ops 2
modified learning curve frac ops 2
Def Rate Ops
Training Hours
def Rate ops dec
Parts learning- Defect Reduction
Cum parts used
fractional parts use
Part use Rate
parts consumed
program start
learning curve frac 6
modified learning curve frac 6
Frac parts def
Training Hours
def parts rate decreasing
Base frac mat dfct at delvry


Information Defect Reduction Curve
Cumulative Info CA Performed
fractional info CA completion
info CA performed
proc CA validated
modified learning curve info
DEFRED
train CA validated
Training Hours
defred rate decreasing
EFF DEFRED repeat reps
Event Switch

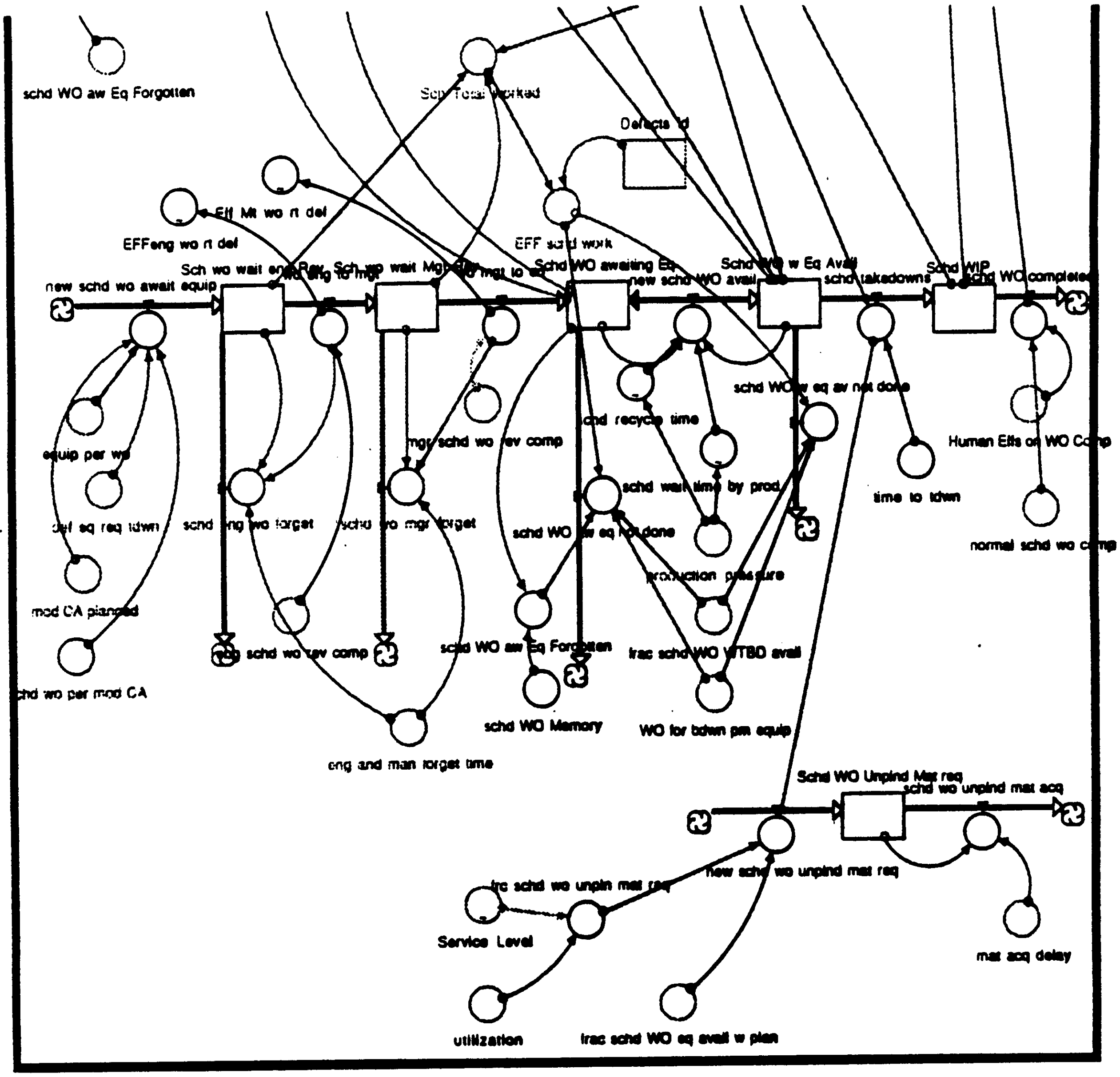

Information: Industry Events
INDUSTRY EVENTS
Cumulative Events
new event occurance
Cumulative Unusual Events
Event Processing
unusual event
Cumulative Alerts
events per year
site alert
Cumulative Emergencies
base prob se
site emergencies
event occurances
base prob sa
EFFalertsandemerg NRCins
rand for num events
rand seed
probs disc per unusual event
identified problems
ident prob rate
EFFidprobEPR
prob disc per alert
EFFidprobWANO
time horizon to comp ind probs
Possibly put in an effect to increase/decrease the number of events occuring or the type of events that can occur.
prob disc per emergency
Cumulative Problems Reported
Event Switch
increase in probs reported

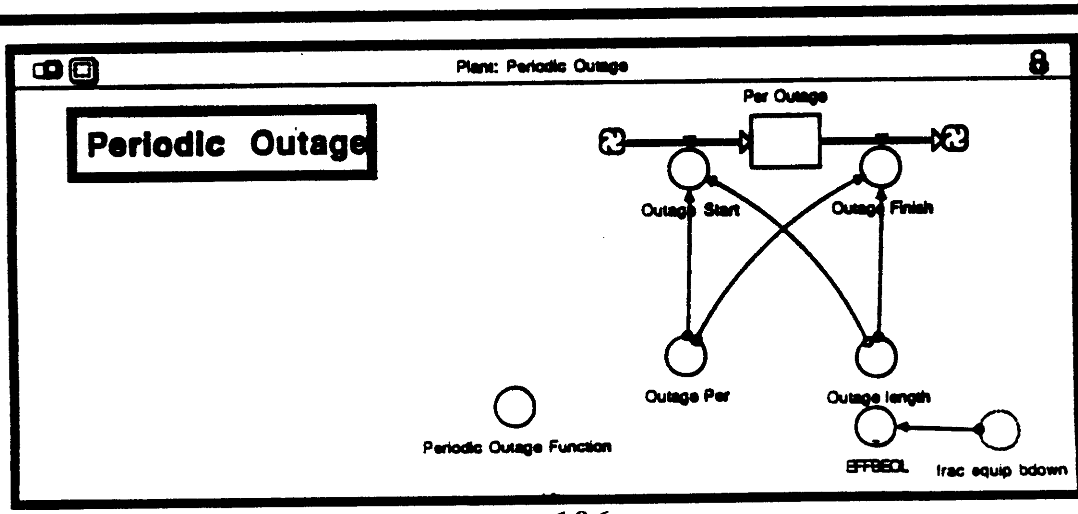

Information: Industry Problem Reporting and Other Agencies
INDUSTRY PROBLEM REPORTING
identified problems
frac probs sent to INPO
frac probs sent to NRC
frac probs sent to vendors
ident probs sent to INPO
ident probs sent to NRC
ident probs sent to vendors
VENDORS
VEN Research in Progress
VEN res initiation
VEN res completion
ident probs sent to vendors
time to comp VEN
base VENDOR res
NRC IN's
NRC IN in Progress
NRC IN initiation
frac probs need IN
time to comp IN
ident probs sent to NRC
EPRI
EPRI Research in Progress
EPRI res initiation
EPRI res completion
EFFidprobEPRI
time to comp EPRI res
base EPRI res projects
WANO
WANO Reps in Progress
WANO rep init
EFFidprobWANO
time to comp WANO rep
base WANO rep production

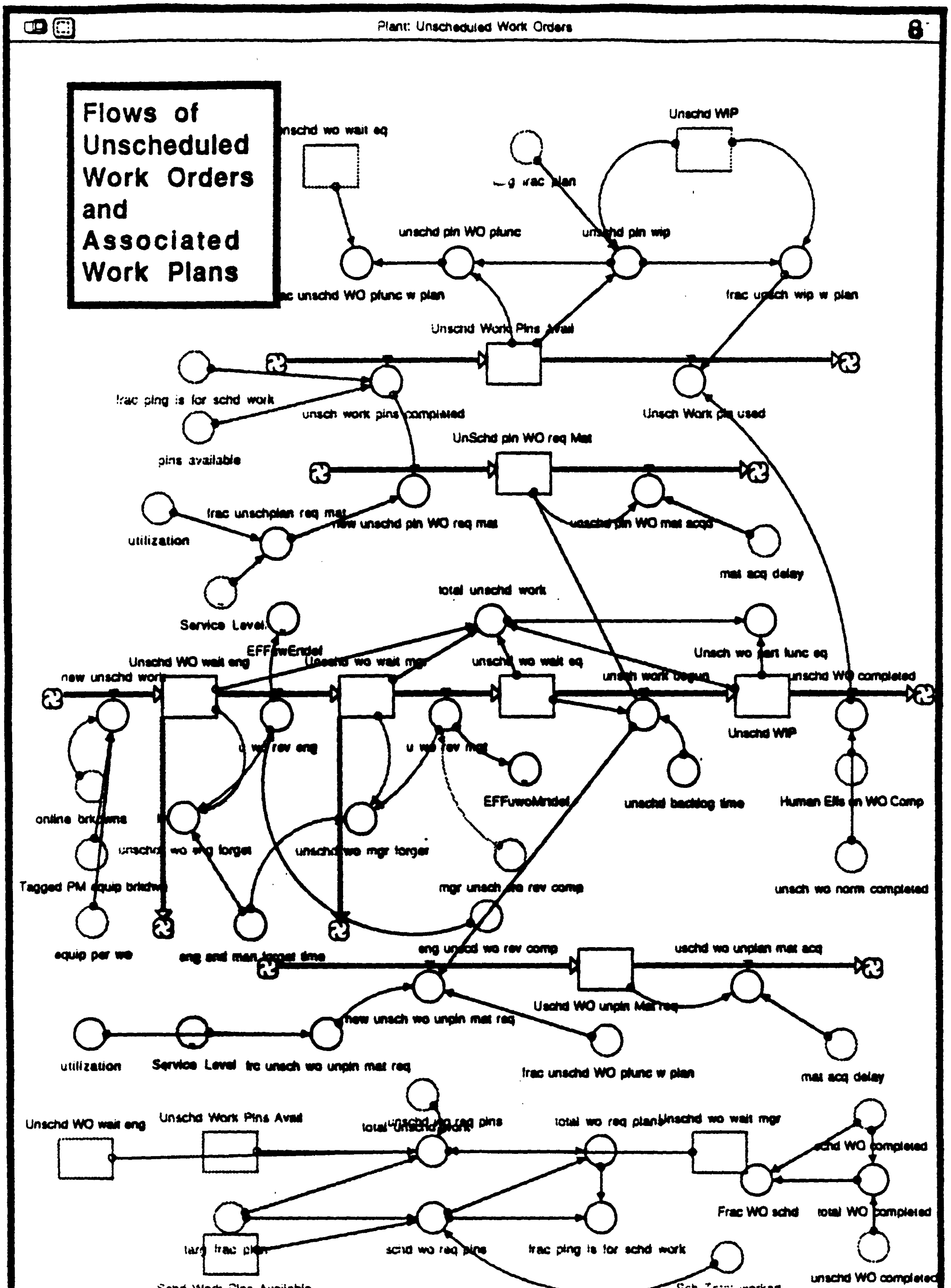

Information: Action Process
CORR. ACTION PROCESS
CA Waiting for Assignment
If this stock builds up, defects increase
new CA waiting
CA assignment
CA abandon
adj time to assign CA
time to assign CA
quick CA to prob needed
CA from regs
frac evals need mult CA
info mgr unavail ratio
assign man unavl lim
evals performed correctly
frac of evals need CA
frac CA abandon
info eng unavail ratio
assign eng unavail lim
Procedure
Proc CA in Progress
Proc CA Waiting for Val
eff OT fatigue eng
proc CA incorrect
frac proc CA correct
proc CA
proc CA completed
proc CA validated
time to val proc CA
frac CA proc
time to comp prov CA
adj time to comp proc CA
adj time to val proc CA
info mgr unavail ratio
CA assignment
Modifications
Mod CA in Progress
info eng unavail ratio
new mod CA
mod CA planned
frac CA mod
adj time to plan mod CA
time to plan mod CA
Training Changes
Train CA in Progress
Train CA Waiting for Val
train CA incorrect
frac train CA correct
train CA
train CA completed
train CA validated
time to val train CA
frac CA train
CA assignment
adj time to comp train CA
adj time to val train CA
info mgr unavail ratio
time to comp train CA
info eng unavail ratio

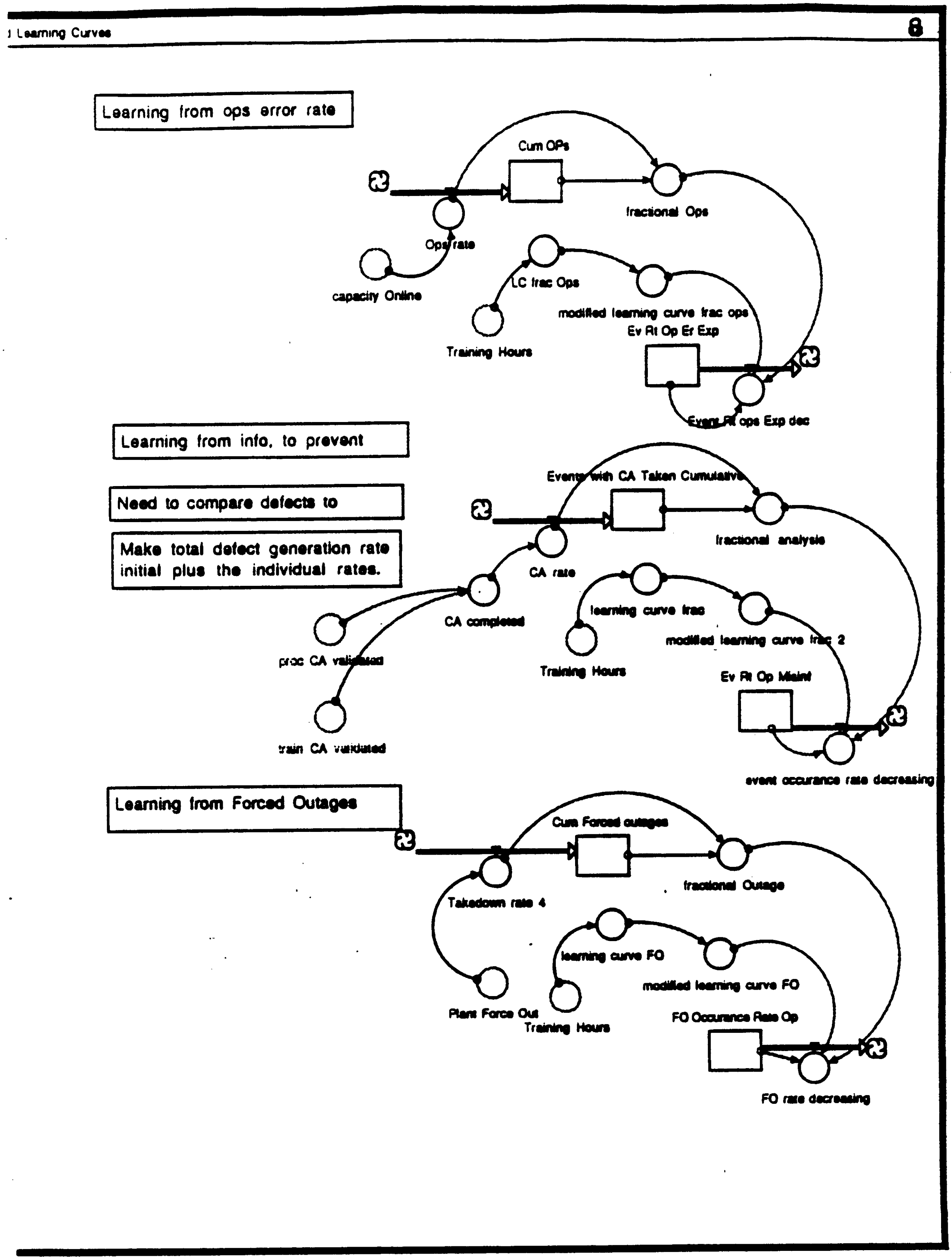


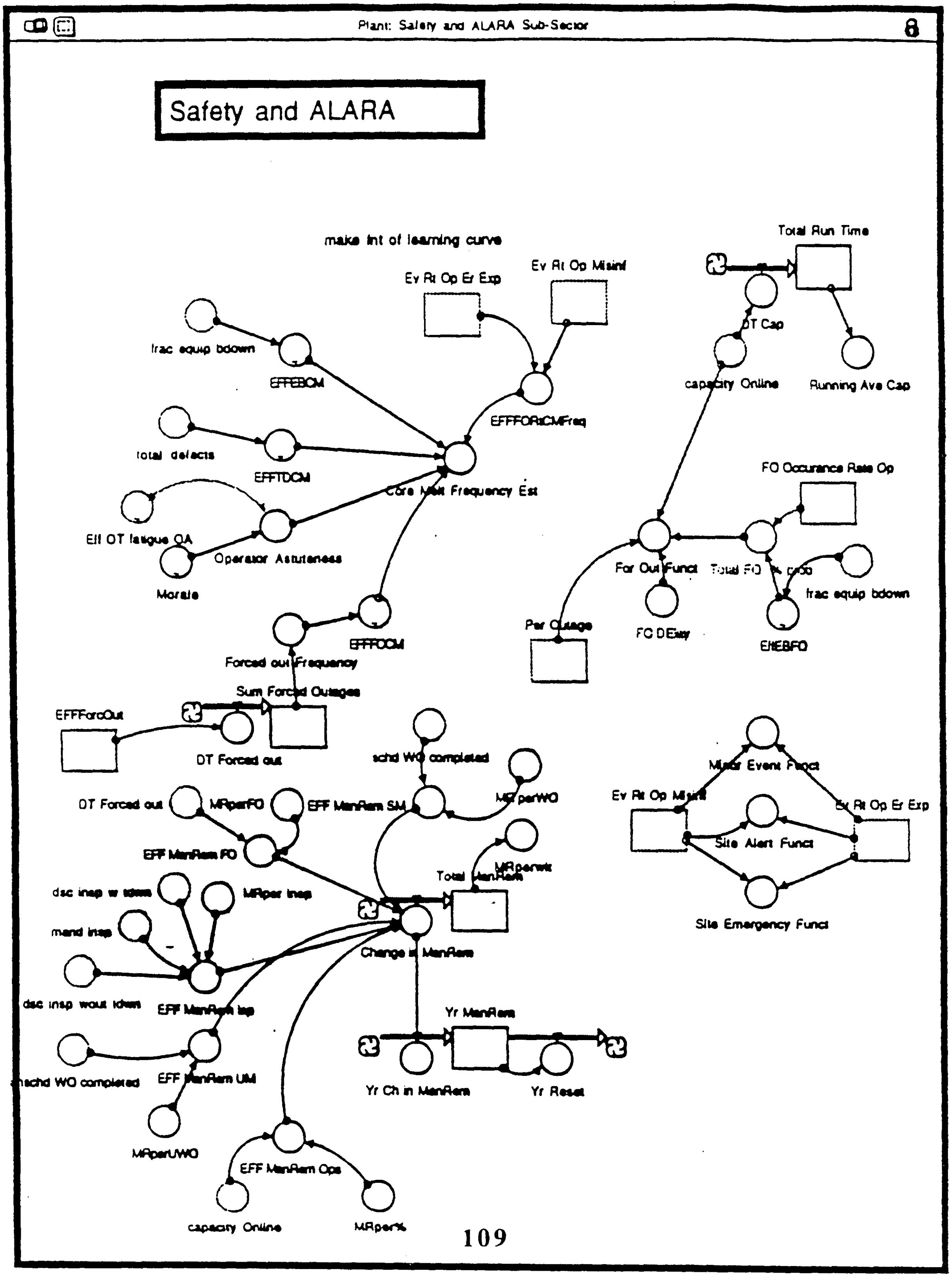
Plant: Flows of Sched. Work Orders
Flows of Scheduled Work Orders and Associated Work Plans
Schd WO w Eq Avail
targ frac plan
Schd WIP
frac schd WO eq avail w plan
schd pln wip
schd pln WO equip avail
frac schd wip w plan
schd pln WO await equip
Schd Work Plng Completed
schd work plns expended
Schd Work Plns Available
frac plng is for schd work
schd work plns forgotten
plns available
plns completed
schd work plns bdwn drop
Schd Work Reqiring Mat
Schd work mats acqrd
utilization
new plnd wo req mat
mat acq delay
frac schd pln wo req mat
Service Level
WO bdwn pm equip req mat
WO for bdwn pm equip
WO for bdwn pm equip
schd pln WO equip avail
schd work plans used
schd work plns bdwn drop
total schd WO Waiting TBD
total schd WO Waiting TBD
frac schd WO TBD w pln
schd WO await tdown
schd pln WO await equip
schd work plns forgotten
frac WO await equip w plan
frac schd WO WTBD avail
schd WO RTBD&BD
total schd WO in sys

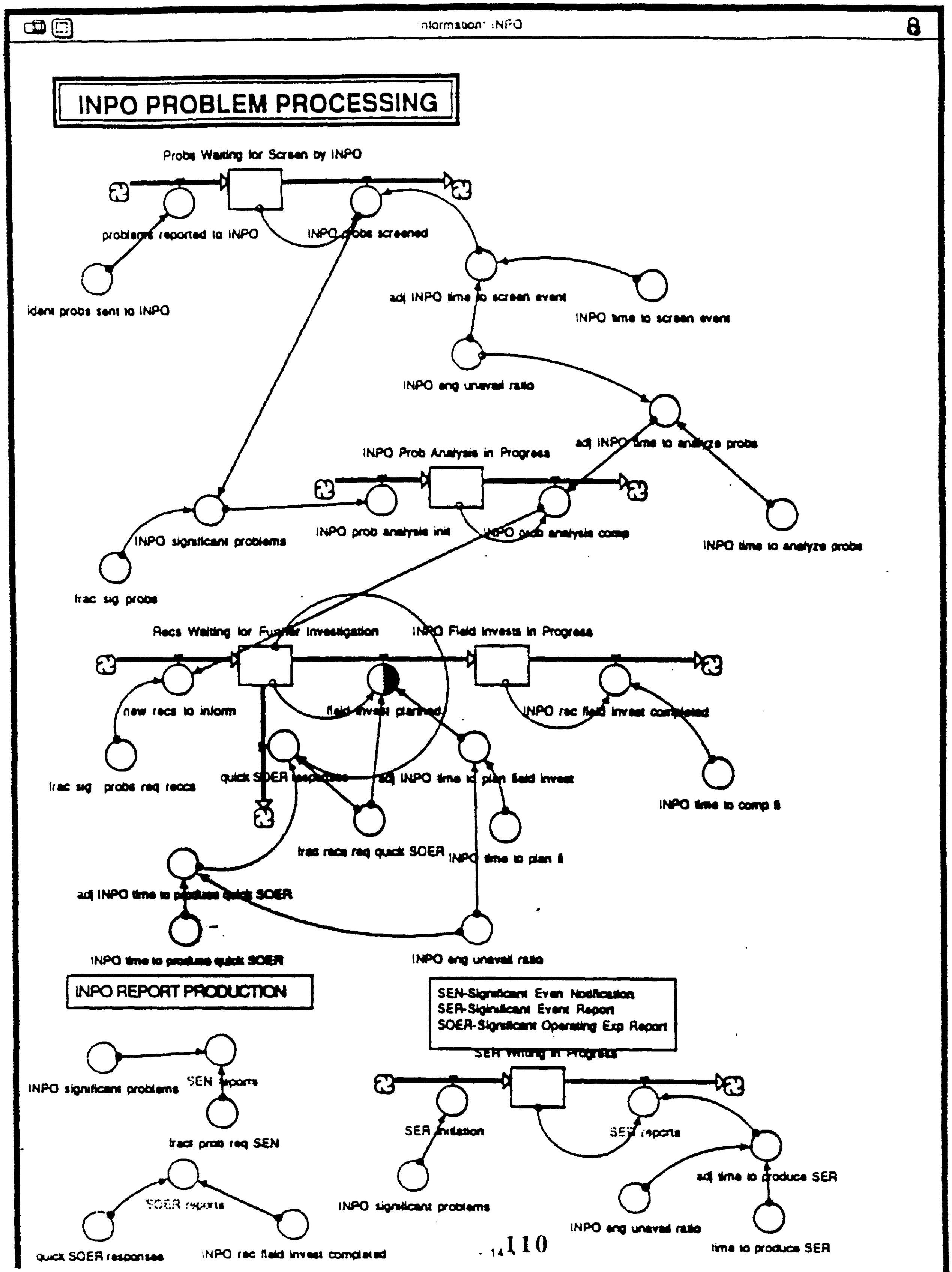

schd WO aw Eq Forgotten
Defects Id
Eff Mt wo rt del
EFFeng wo rt del
EFF schd work
new schd wo await equip
Sch wo wait eng Rev
Schd WO awaiting Eq
Schd WO w Eq Avail
schd takedowns
Schd WIP
Schd WO completed
schd WO w eq av not done
schd recycle time
Human Effs on WO Comp
equip per wo
mgr schd wo rev comp
schd wait time by prod
time to tdwn
normal schd wo comp
schd WO aw eq not done
production pressure
mod CA planned
schd WO aw Eq Forgotten
frac schd WO WTBD avail
chd wo per mod CA
schd WO Memory
WO for bdwn pm equip
eng and man forget time
Schd WO Unplnd Mat req
schd wo unplnd mat acq
new schd wo unplnd mat req
frc schd wo unpln mat req
Service Level
mat acq delay
utilization
frac schd WO eq avail w plan

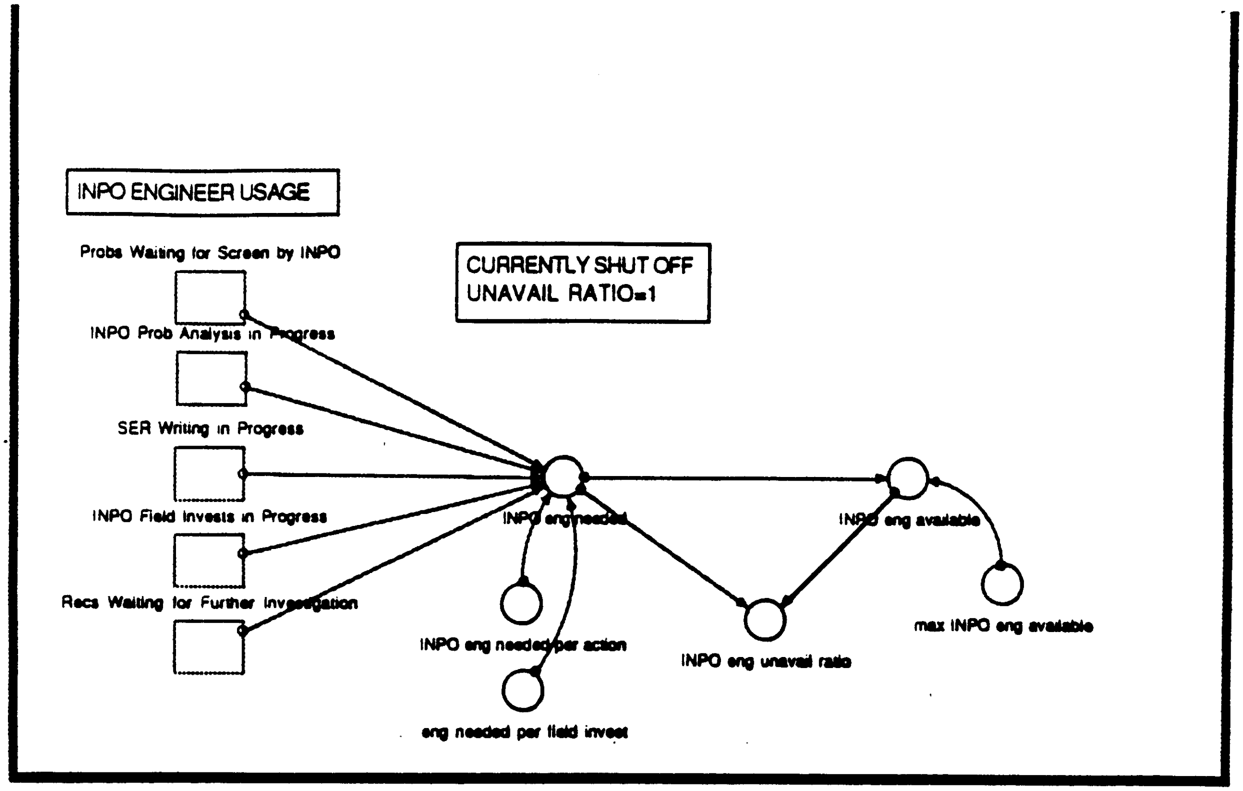

Plant: Periodic Outage
Periodic Outage
Per Outage
Outage Start
Outage Finish
Outage Per
Outage length
Periodic Outage Function
EFFBEOL
frac equip bdown

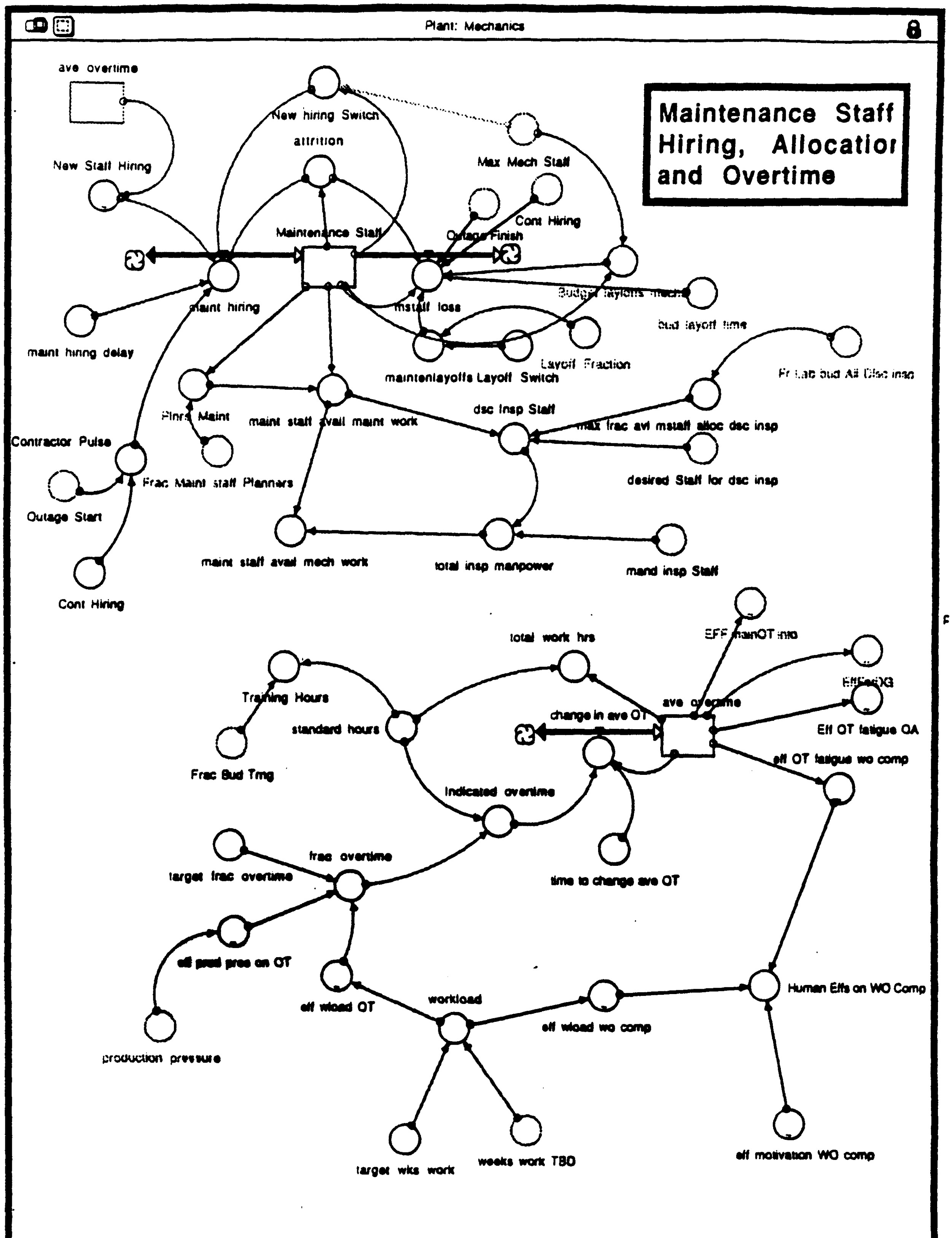

Plant: Unscheduled Work Orders
Flows of Unscheduled Work Orders and Associated Work Plans
Unschd WIP
unschd pln WO plunc
unschd pln wip
frac unsch wip w plan
Unschd Work Plns Avail
frac plng is for schd work
unsch work plns completed
Unsch Work pln used
plns available
UnSchd pln WO req Mat
frac unschplan req mat
new unschd pln WO req mat
unschd pln WO mat acq
utilization
mat acq delay
total unschd work
Service Level
Unschd WO wait eng
Unschd wo wait mgr
unschd wo wait eq
unsch work begun
Unsch wo start func eq
unschd WO completed
new unschd work
online brkdowns
unschd wo eng forget
unschd wo mgr forget
EFFuwoMrdel
unschd backlog time
Human Effs on WO Comp
Tagged PM equip brkdwn
mgr unsch wo rev comp
unsch wo norm completed
equip per wo
eng and man forget time
eng unscd wo rev comp
uschd wo unplan mat acq
Uschd WO unpln Mat req
new unsch wo unpln mat req
frac unschd WO plunc w plan
Service Level
frc unsch wo unpln mat req
Unschd Work Plns Avail
total wo req plans
Frac WO schd
total WO completed
schd wo req plns
frac plng is for schd work
unschd WO completed

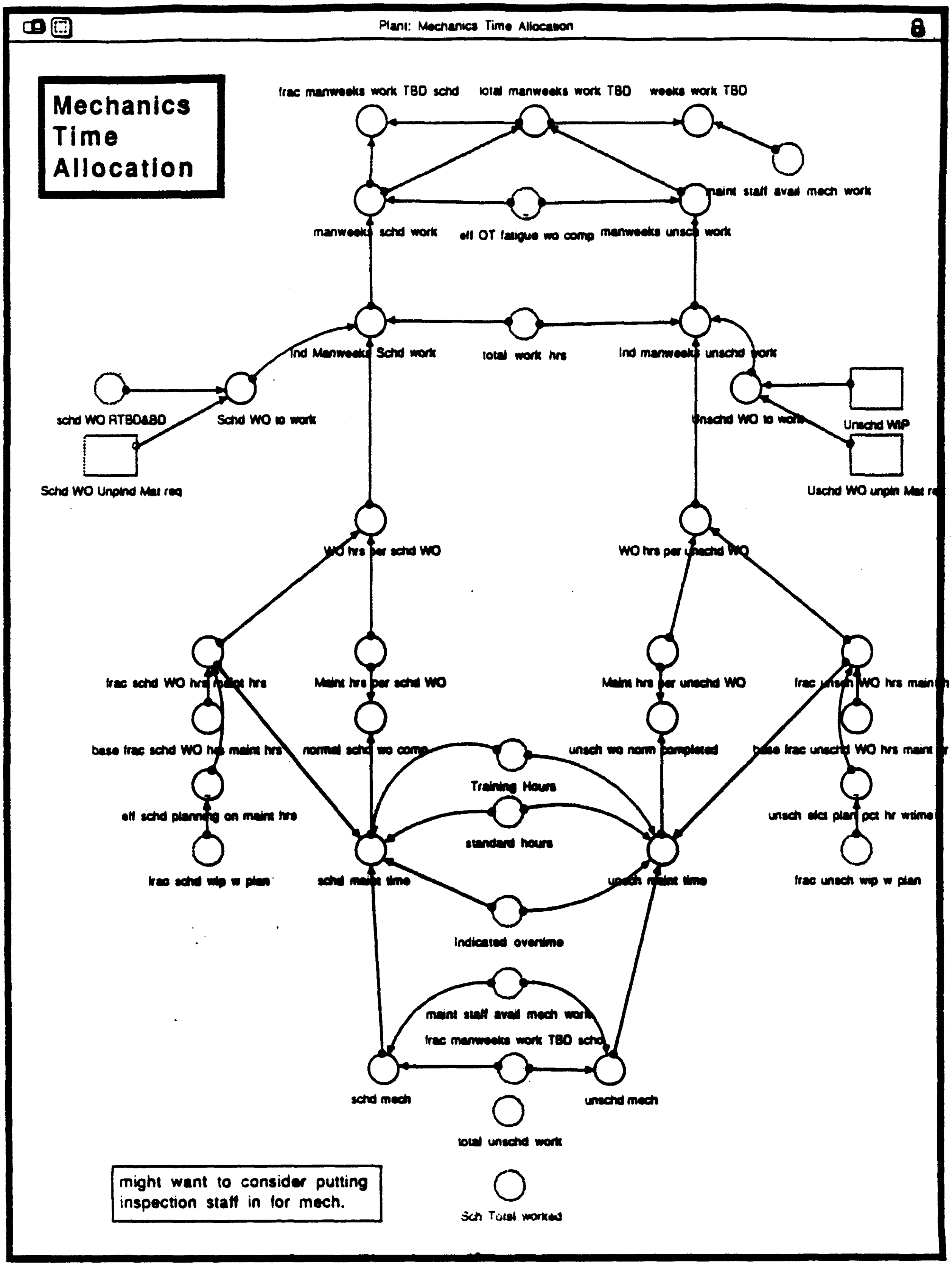

Learning Curves
8
Learning from ops error rate
Cum OPs
fractional Ops
Ops rate
capacity Online
LC frac Ops
modified learning curve frac ops
Training Hours
Ev Rt Op Er Exp
Event Rt ops Exp dec
Learning from info, to prevent
Need to compare defects to
Make total defect generation rate initial plus the individual rates.
Events with CA Taken Cumulative
fractional analysis
CA rate
CA completed
learning curve frac
modified learning curve frac 2
Training Hours
Ev Rt Op Maint
event occurance rate decreasing
Learning from Forced Outages
Cum Forced outages
fractional Outage
Takedown rate 4
learning curve FO
modified learning curve FO
Plant Force Out
Training Hours
FO Occurance Rate Op
FO rate decreasing


Plant: Safety and ALARA Sub-Sector
Safety and ALARA
make fnt of learning curve
Ev Rt Op Er Exp
Ev Rt Op Misinf
Total Run Time
DT Cap
capacity Online
Running Ave Cap
frac equip bdown
EFFEBCM
EFFFORtCMFreq
total defects
EFFTDCM
Core Melt Frequency Est
FO Occurance Rate Op
Eff OT fatigue OA
Operator Astuteness
Morale
For Out Funct
FO DExp
EffEBFO
Per Outage
EFFFOCM
Forced out Frequency
Sum Forced Outages
EFFForcOut
DT Forced out
schd WO completed
MRperWO
Minor Event Funct
Ev Rt Op Misinf
Ev Rt Op Er Exp
Site Alert Funct
Site Emergency Funct
DT Forced out
MRperFO
EFF ManRem SM
EFF ManRem FO
MRperwk
Total ManRem
dsc insp w tdwn
MRper insp
mand insp
Change in ManRem
dsc insp wout tdwn
EFF ManRem Isp
Yr ManRem
schd WO completed
EFF ManRem UM
Yr Ch in ManRem
Yr Reset
MRperUWO
EFF ManRem Ops
capacity Online
MRper%

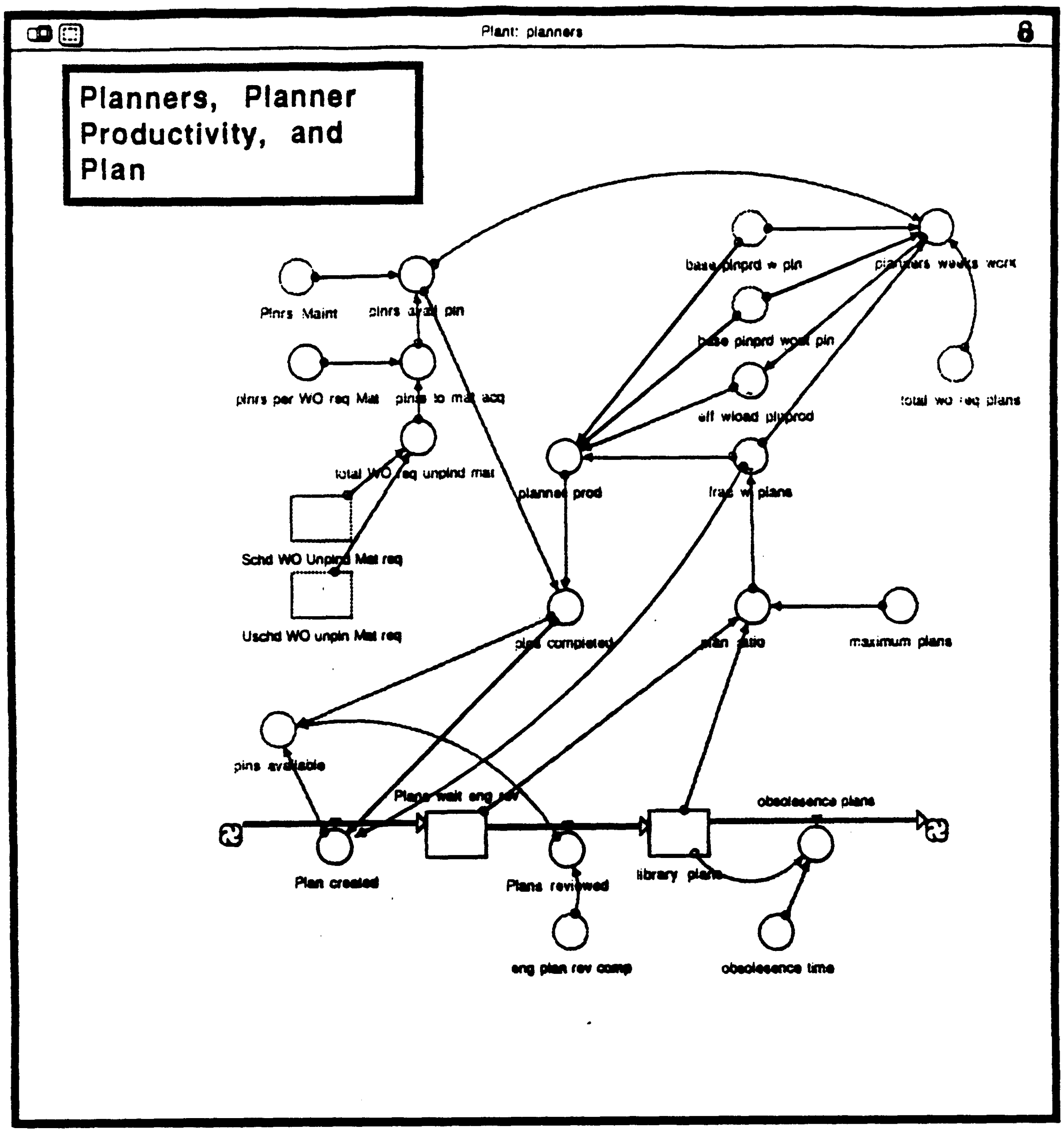

Information: INPO
INPO PROBLEM PROCESSING
Probs Waiting for Screen by INPO
problems reported to INPO
INPO probs screened
ident probs sent to INPO
adj INPO time to screen event
INPO time to screen event
INPO eng unavail ratio
adj INPO time to analyze probs
INPO Prob Analysis in Progress
INPO significant problems
INPO prob analysis init
INPO prob analysis comp
INPO time to analyze probs
frac sig probs
Recs Waiting for Further Investigation
INPO Field Invests in Progress
new recs to inform
field invest planned
INPO rec field invest completed
frac sig probs req reccs
quick SOER responses
adj INPO time to plan field invest
INPO time to comp fi
frac recs req quick SOER
INPO time to plan fi
adj INPO time to produce quick SOER
INPO time to produce quick SOER
INPO eng unavail ratio
INPO REPORT PRODUCTION
SEN-Significant Even Notification
SER-Significant Event Report
SOER-Significant Operating Exp Report
SER Writing in Progress
INPO significant problems
SEN reports
fract prob req SEN
SER initiation
SER reports
adj time to produce SER
INPO significant problems
INPO eng unavail ratio
SOER reports
quick SOER responses
INPO rec field invest completed
time to produce SER

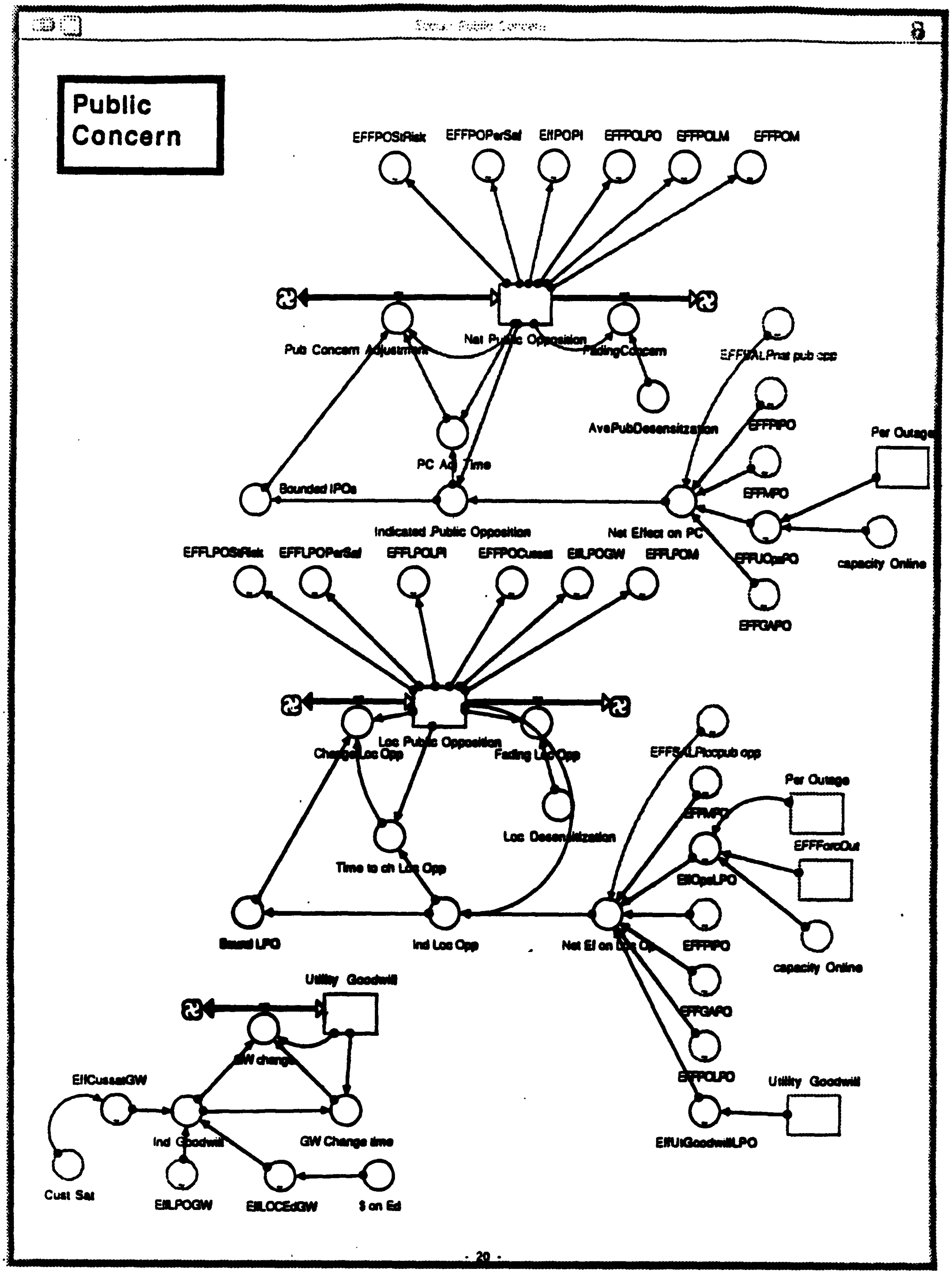

INPO ENGINEER USAGE
CURRENTLY SHUT OFF
UNAVAIL RATIO=1
Probs Waiting for Screen by INPO
INPO Prob Analysis in Progress
SER Writing in Progress
INPO Field Invests in Progress
Recs Waiting for Further Investigation
INPO eng needed
INPO eng available
INPO eng needed per action
eng needed per field invest
INPO eng unavail ratio
max INPO eng available

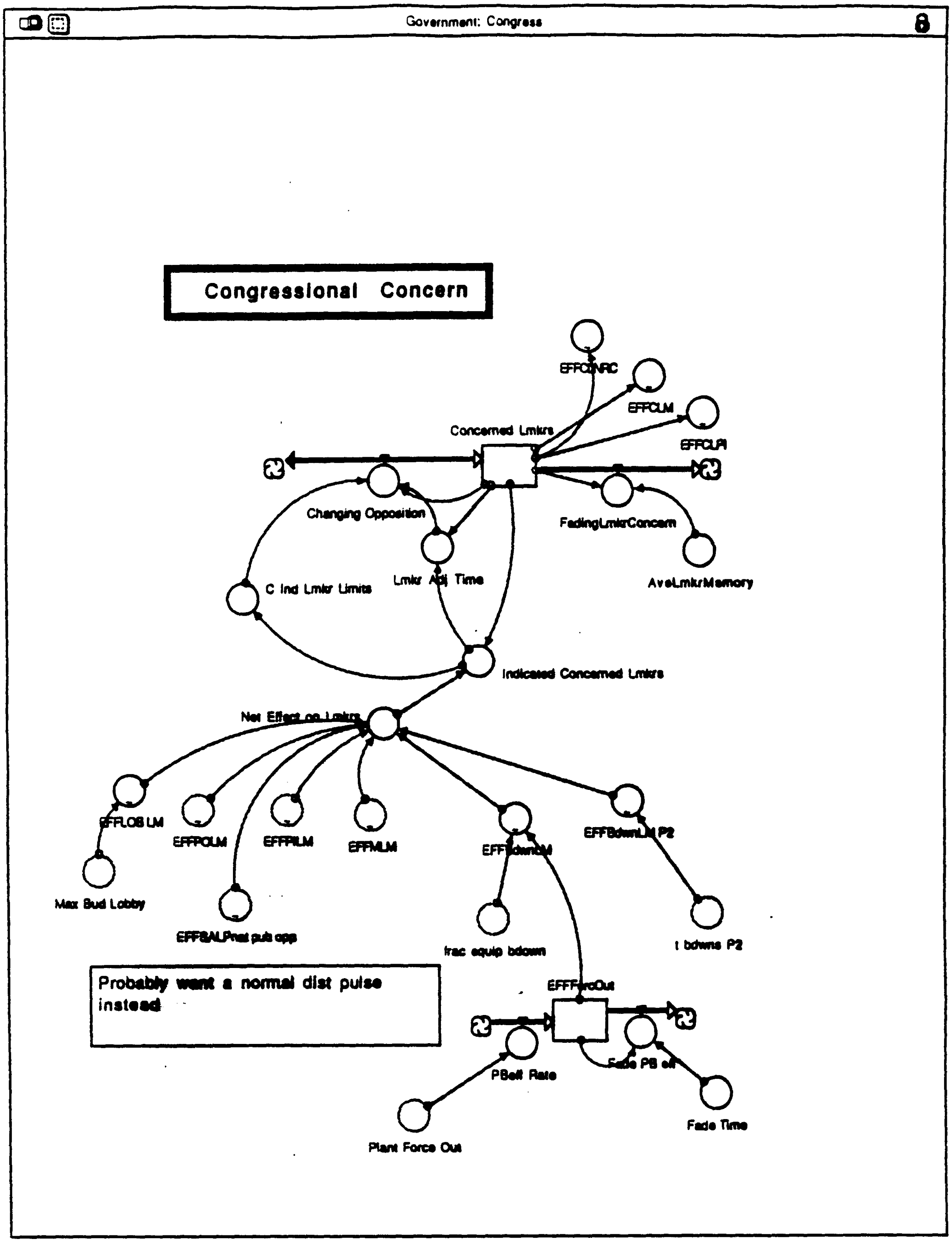

Plant: Mechanics
Maintenance Staff Hiring, Allocation and Overtime
ave overtime
New hiring Switch
attrition
New Staff Hiring
Max Mech Staff
Cont Hiring
Maintenance Staff
Outage Finish
maint hiring
mstaff loss
maint hiring delay
bud layoff time
Layoff Fraction
maintenlayoffs Layoff Switch
Plnrs Maint
maint staff avail maint work
dsc Insp Staff
max frac avl mstaff alloc dsc insp
Contractor Pulse
Frac Maint staff Planners
desired Staff for dsc insp
Outage Start
maint staff avail mech work
total insp manpower
mand insp Staff
Cont Hiring
total work hrs
Training Hours
ave overtime
change in ave OT
standard hours
Eff OT fatigue QA
eff OT fatigue wo comp
Frac Bud Trng
Indicated overtime
frac overtime
target frac overtime
time to change ave OT
eff wload OT
workload
Human Effs on WO Comp
eff wload wo comp
production pressure
target wks work
weeks work TBO
eff motivation WO comp



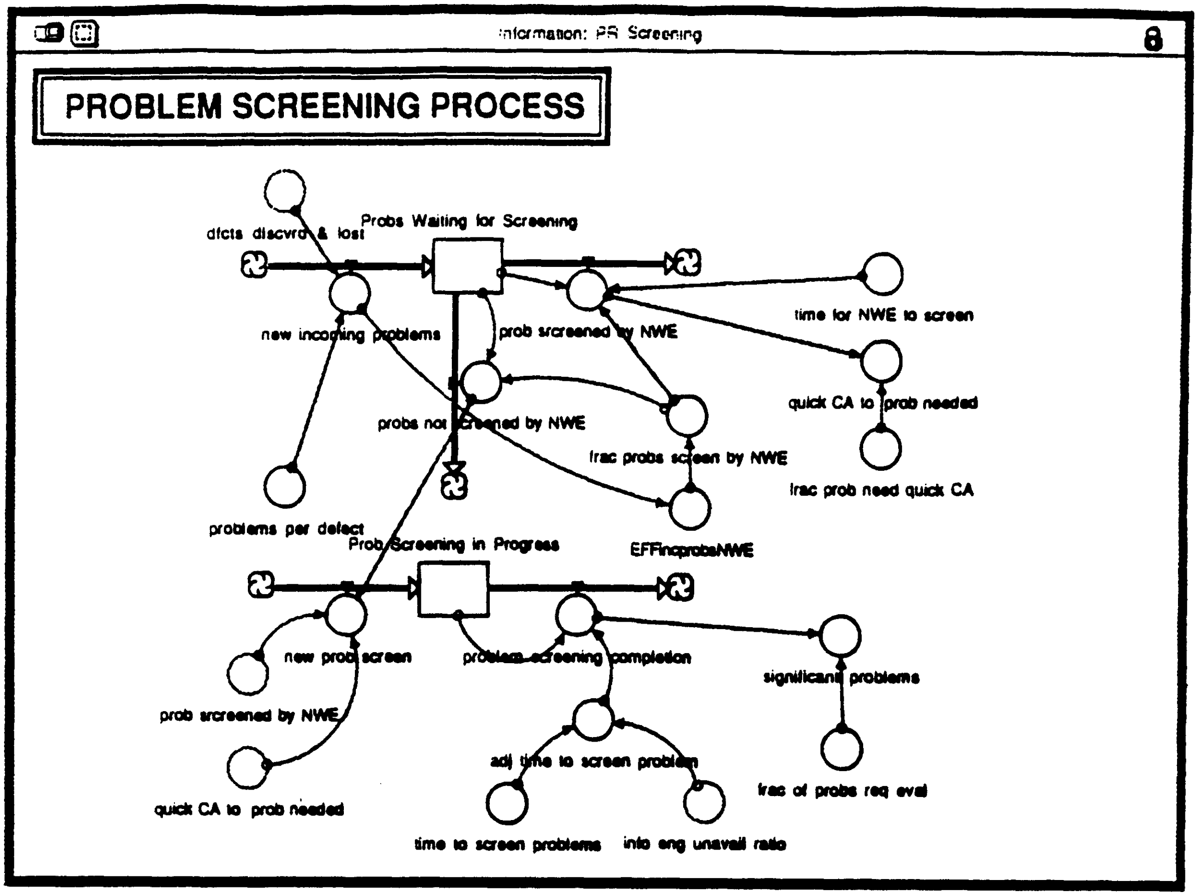
Plant: Mechanics Time Allocation
Mechanics Time Allocation
frac manweeks work TBD schd
total manweeks work TBD
weeks work TBD
maint staff avail mech work
manweeks schd work
eff OT fatigue wo comp
manweeks unsch work
Ind Manweeks Schd work
total work hrs
Ind manweeks unschd work
schd WO RTBD&BD
Schd WO to work
Unschd WO to work
Unschd WIP
Schd WO Unplnd Mat req
Uschd WO unpln Mat re
WO hrs per schd WO
WO hrs per unschd WO
frac schd WO hrs maint hrs
Maint hrs per schd WO
Maint hrs per unschd WO
base frac schd WO hrs maint hrs
normal schd wo comp
unsch wo norm completed
base frac unschd WO hrs maint
Training Hours
eff schd planning on maint hrs
standard hours
unsch elct plan pct hr wtime
frac schd wip w plan
schd maint time
unsch maint time
frac unsch wip w plan
Indicated overtime
maint staff avail mech work
frac manweeks work TBD schd
schd mech
unschd mech
total unschd work
might want to consider putting inspection staff in for mech.
Sch Total worked

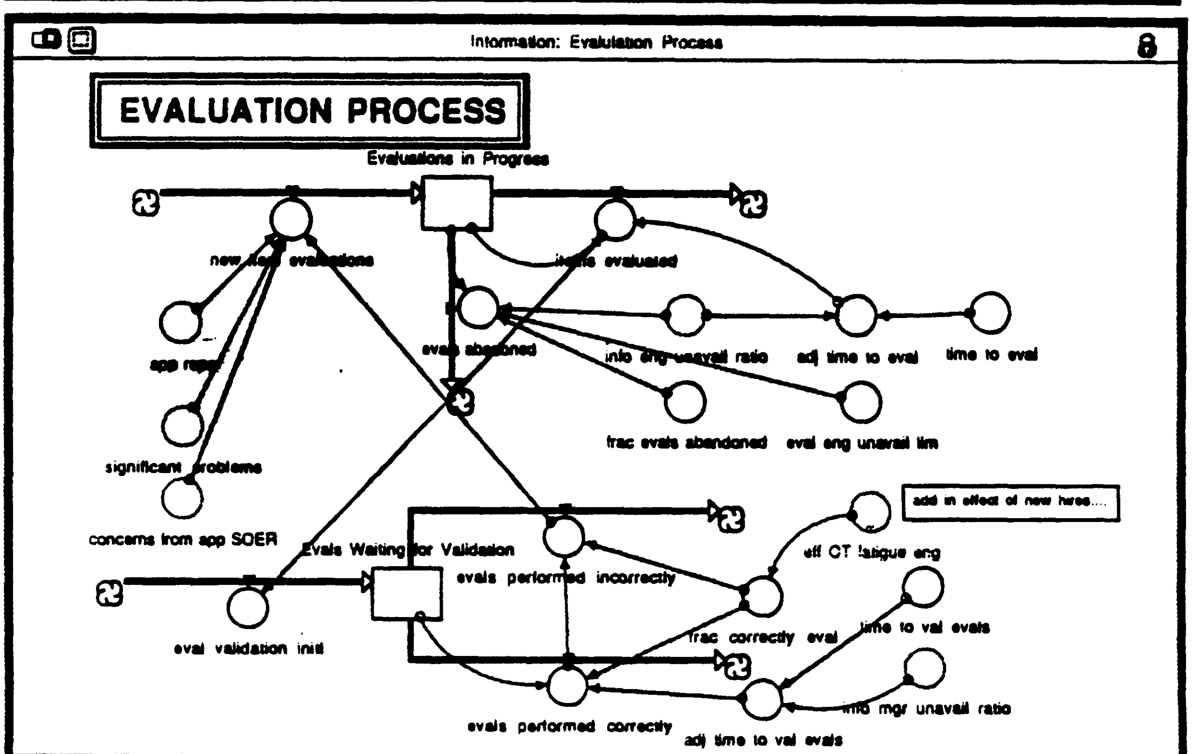

Plant: planners
Planners, Planner Productivity, and Plan
Plnrs Maint
plnrs per WO req Mat
total wo req plans
planner prod
maximum plans
Schd WO Unplnd Mat req
Uschd WO unpln Mat req
obsolesence plans
Plan created
library plans
eng plan rev comp
obsolesence time

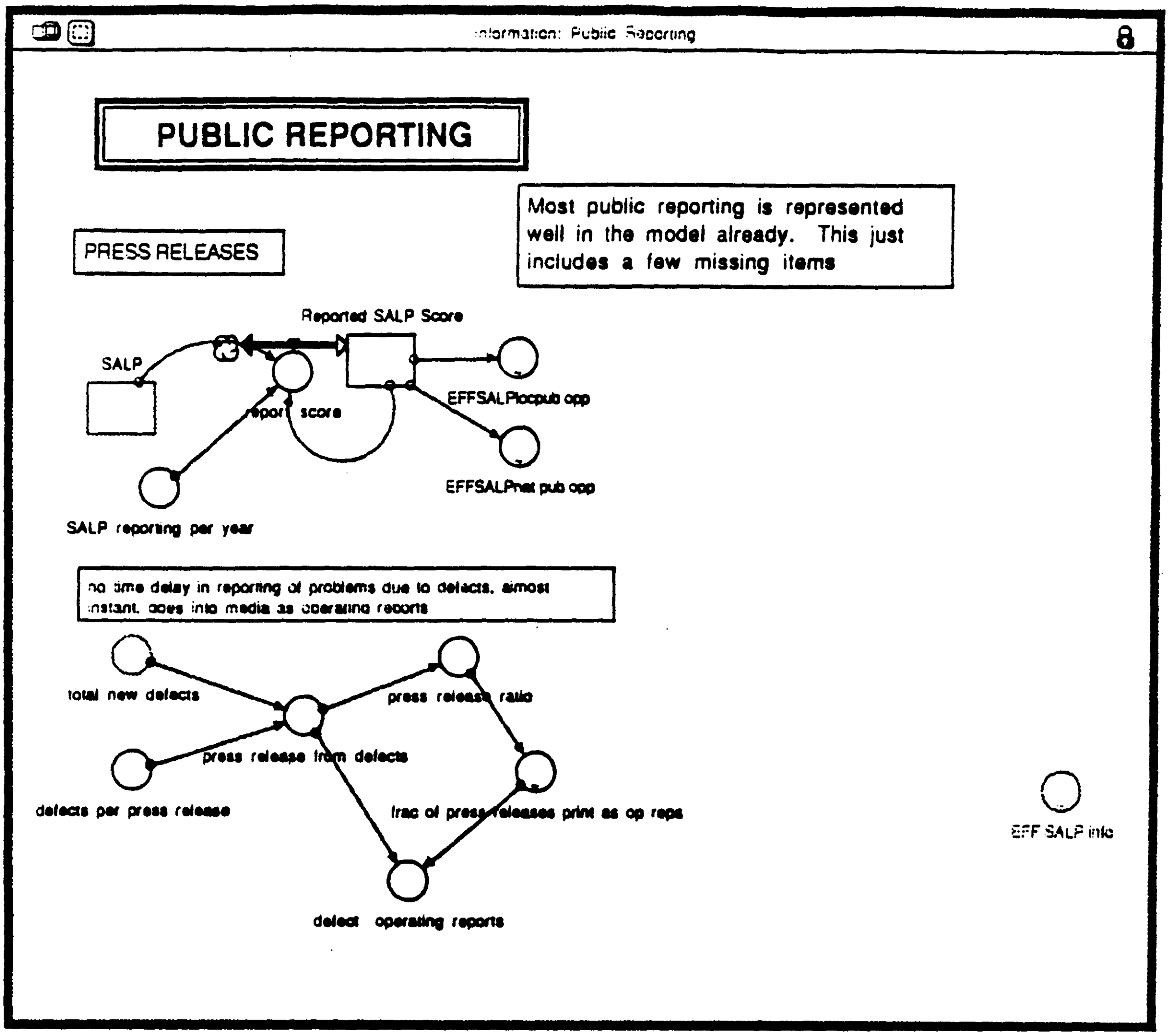

Public Concern
EFFPOStRisk
EFFPOPerSaf
EffPOPI
EFFPOLPO
EFFPOLM
EFFPOM
Net Public Opposition
Pub Concern Adjustment
FadingConcern
AvePubDesensitization
PC Adj Time
Bounded IPOs
Indicated Public Opposition
Net Effect on PC
EFFFIPO
EFFMPO
EFFUOpsPO
EFFGAPO
Per Outage
capacity Online
EFFLPOStRisk
EFFLPOPerSaf
EFFLPOLPI
EFFPOCussat
EffLPOGW
EFFLPOM
Loc Public Opposition
Change Loc Opp
Fading Loc Opp
Loc Desensitization
Time to ch Loc Opp
Bound LPO
Ind Loc Opp
Net Ef on Loc Op
EFFMPO
EFFForcOut
EffOpsLPO
EFFFIPO
EFFGAPO
EFFPOLPO
EffUtGoodwillLPO
Utility Goodwill
GW change
GW Change time
Ind Goodwill
EffCussatGW
Cust Sat
EffLPOGW
EffLOCEdGW
$ on Ed
- 20 -



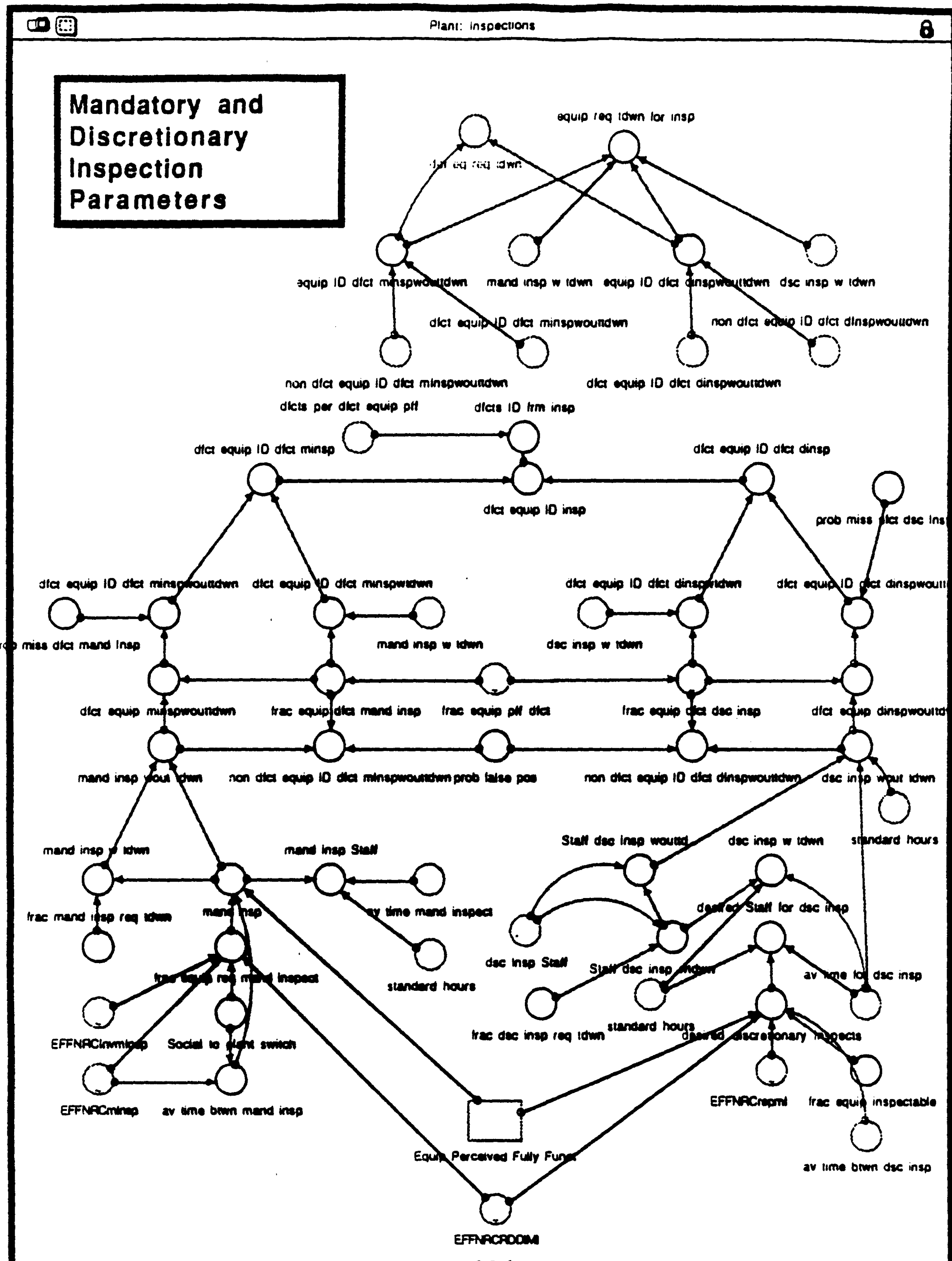
Government: Congress
Congressional Concern
Concerned Lmkrs
EFFCLM
EFFCLPI
Changing Opposition
FadingLmkrConcern
Lmkr Adj Time
AveLmkrMemory
C Ind Lmkr Limits
Indicated Concerned Lmkrs
EFFPOLM
EFFPILM
EFFMLM
Max Bud Lobby
EFFBALPnat pub opp
frac equip bdown
t bdwns P2
Probably want a normal dist pulse instead
PBelf Rate
Fade Time
Plant Force Out

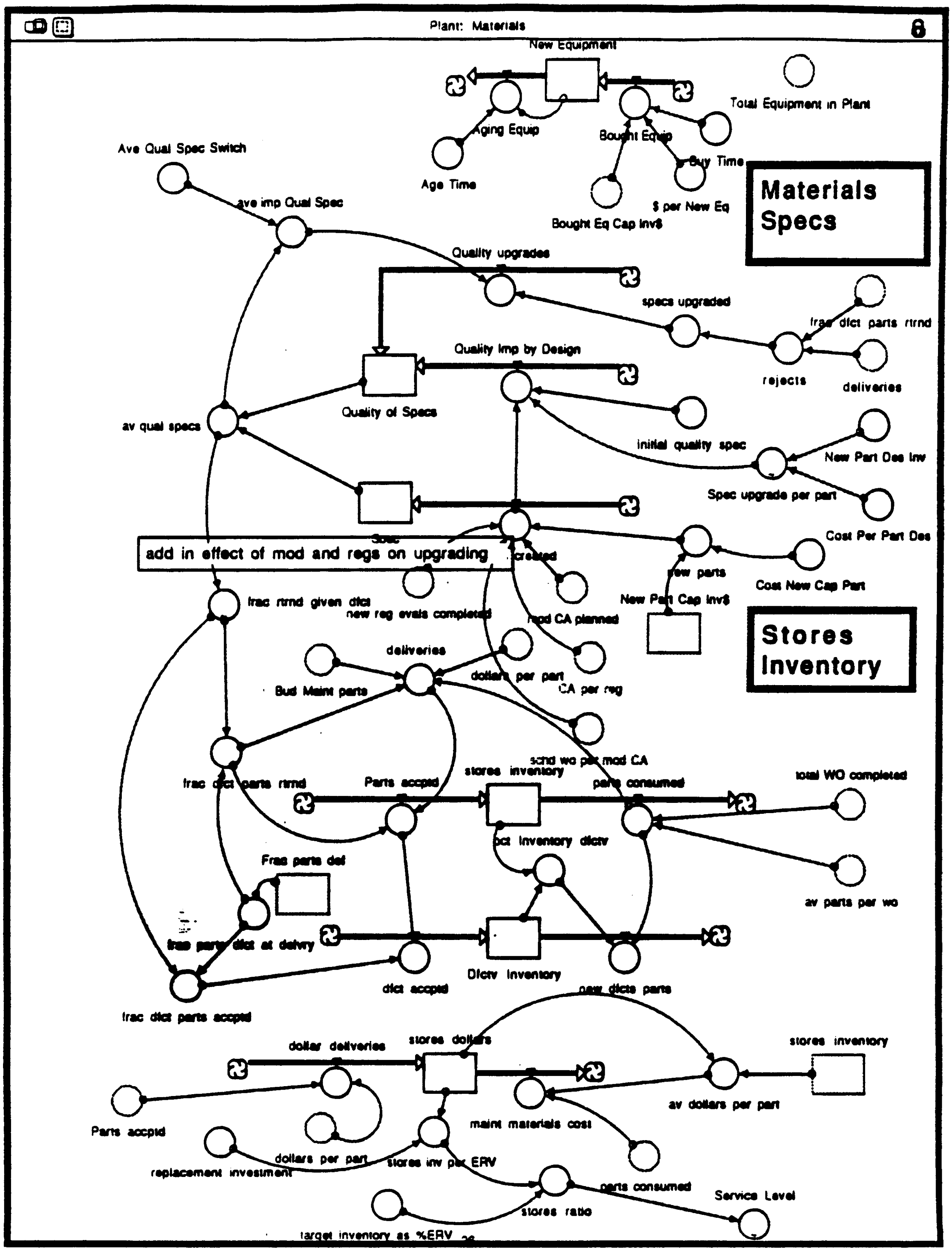

Information: PR Screening
PROBLEM SCREENING PROCESS
Probs Waiting for Screening
dfcts discvrd & lost
new incoming problems
prob srcreened by NWE
time for NWE to screen
quick CA to prob needed
probs not screened by NWE
frac probs screen by NWE
frac prob need quick CA
problems per defect
EFFincprobsNWE
Prob Screening in Progress
new prob screen
problem screening completion
significant problems
prob srcreened by NWE
adj time to screen problem
quick CA to prob needed
frac of probs req eval
time to screen problems
info eng unavail ratio

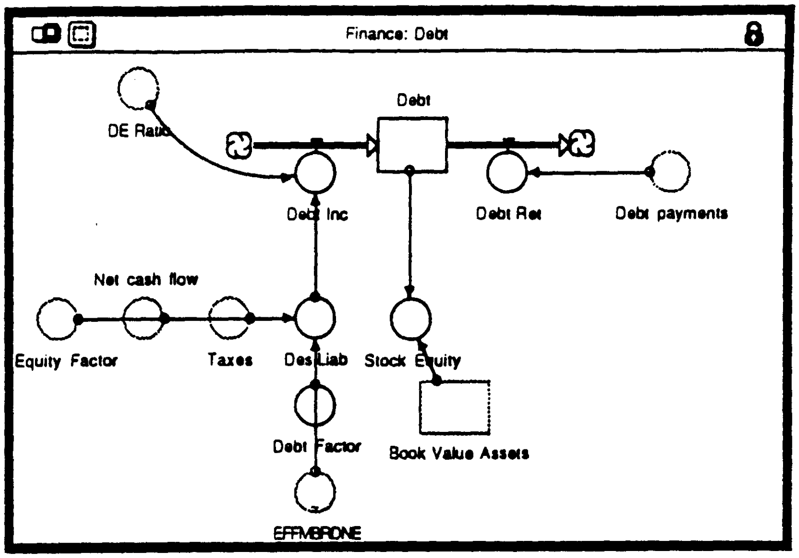

Information: Evaluation Process
EVALUATION PROCESS
Evaluations in Progress
new item evaluations
items evaluated
evals abandoned
info eng unavail ratio
adj time to eval
time to eval
frac evals abandoned
eval eng unavail lim
significant problems
concerns from app SOER
add in effect of new hires....
eff CT fatigue eng
Evals Waiting for Validation
evals performed incorrectly
eval validation init
frac correctly eval
time to val evals
evals performed correctly
info mgr unavail ratio
adj time to val evals

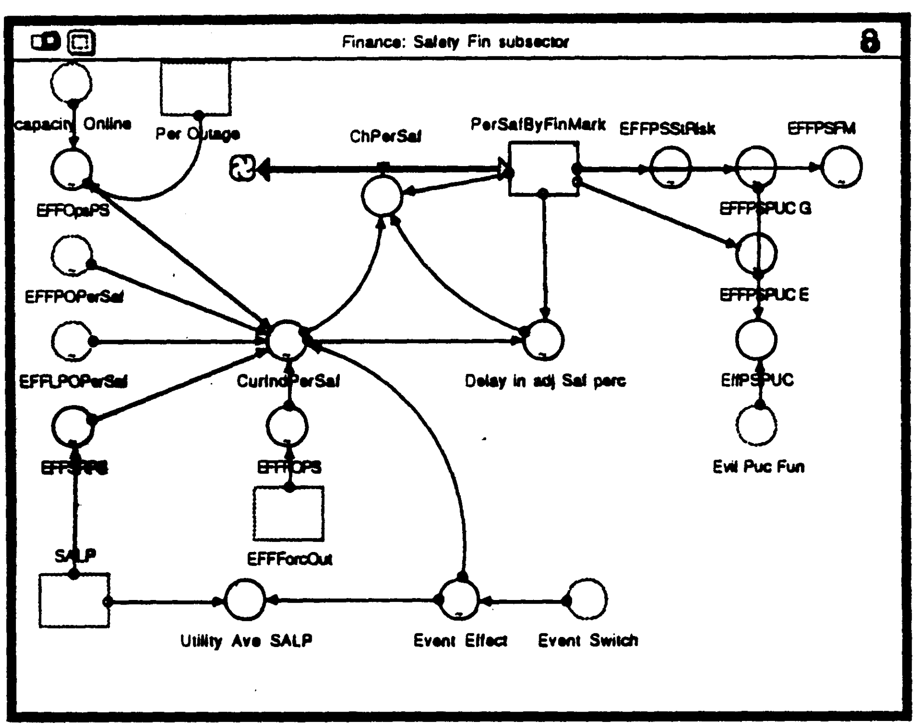


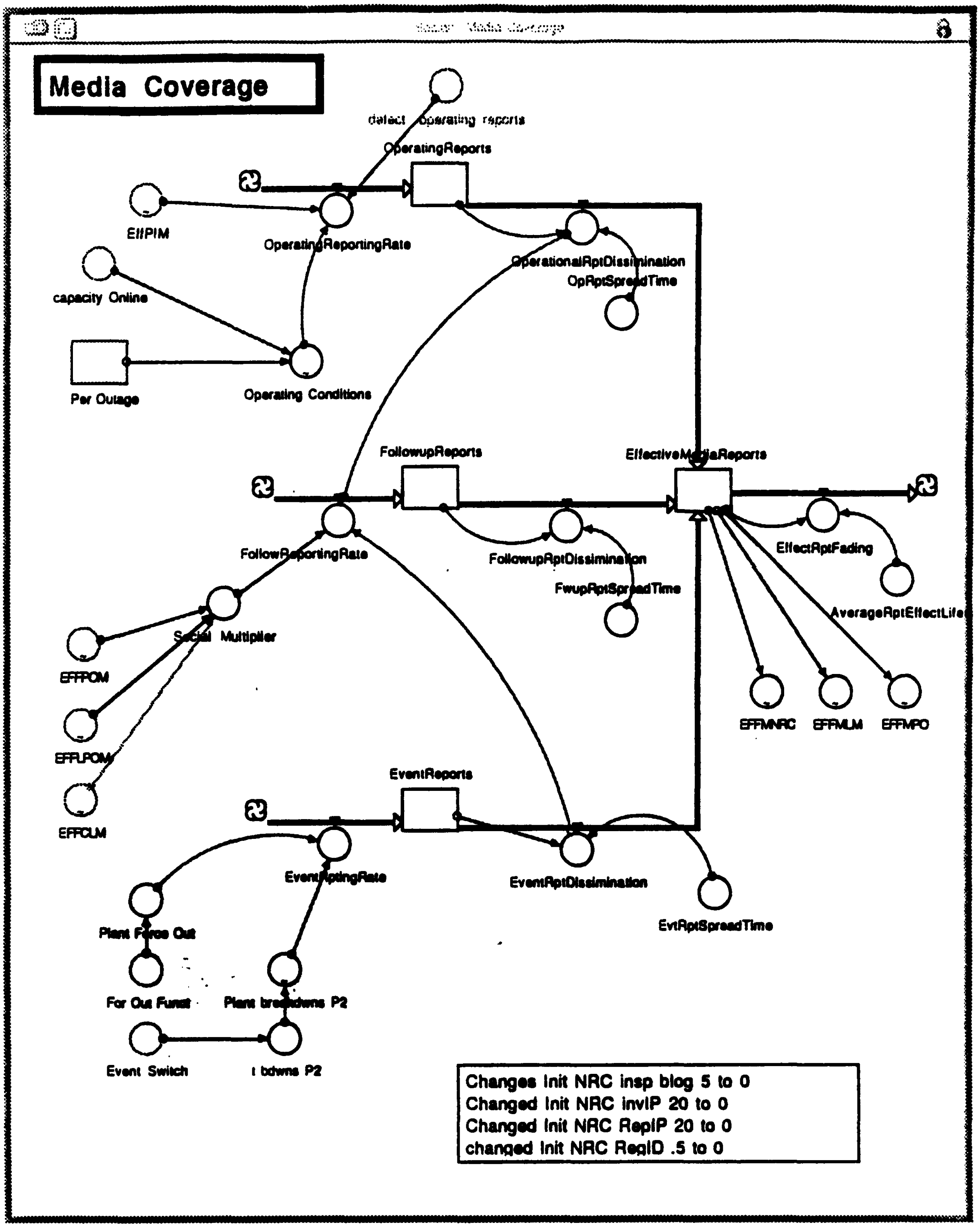
information: Public Reporting
PUBLIC REPORTING
Most public reporting is represented well in the model already. This just includes a few missing items
PRESS RELEASES
Reported SALP Score
SALP
report score
EFFSALPlocpub opp
EFFSALPnat pub opp
SALP reporting per year
no time delay in reporting of problems due to defects, almost instant, goes into media as operating reports
total new defects
press release ratio
press release from defects
defects per press release
frac of press releases print as op reps
defect operating reports
EFF SALP info


Plant: Inspections
Mandatory and Discretionary Inspection Parameters
equip req tdwn for insp
equip ID dfct minspwouttdwn
mand insp w tdwn
equip ID dfct dinspwouttdwn
dsc insp w tdwn
dfct equip ID dfct minspwouttdwn
non dfct equip ID dfct dinspwouttdwn
non dfct equip ID dfct minspwouttdwn
dfct equip ID dfct dinspwouttdwn
dfcts per dfct equip pff
dfcts ID frm insp
dfct equip ID dfct minsp
dfct equip ID dfct dinsp
dfct equip ID insp
prob miss dfct dsc insp
dfct equip ID dfct minspwtdwn
dfct equip ID dfct dinspwtdwn
dfct equip minspwouttdwn
frac equip dfct mand insp
frac equip pff dfct
frac equip dfct dsc insp
dfct equip dinspwouttdwn
mand insp wout tdwn
non dfct equip ID dfct minspwouttdwn
prob false pos
non dfct equip ID dfct dinspwouttdwn
dsc insp wout tdwn
standard hours
mand insp w tdwn
mand insp Staff
Staff dsc insp wouttd
dsc insp w tdwn
frac mand insp req tdwn
mand insp
av time mand inspect
desired Staff for dsc insp
dsc insp Staff
Staff dsc insp wtdwn
av time for dsc insp
frac equip req mand inspect
standard hours
EFFNRCInwmisp
Social to plant switch
frac dsc insp req tdwn
standard hours
desired discretionary inspects
EFFNRCminsp
av time btwn mand insp
EFFNRCrepml
frac equip inspectable
Equip Perceived Fully Func
av time btwn dsc insp
EFFNRCRDDIMI

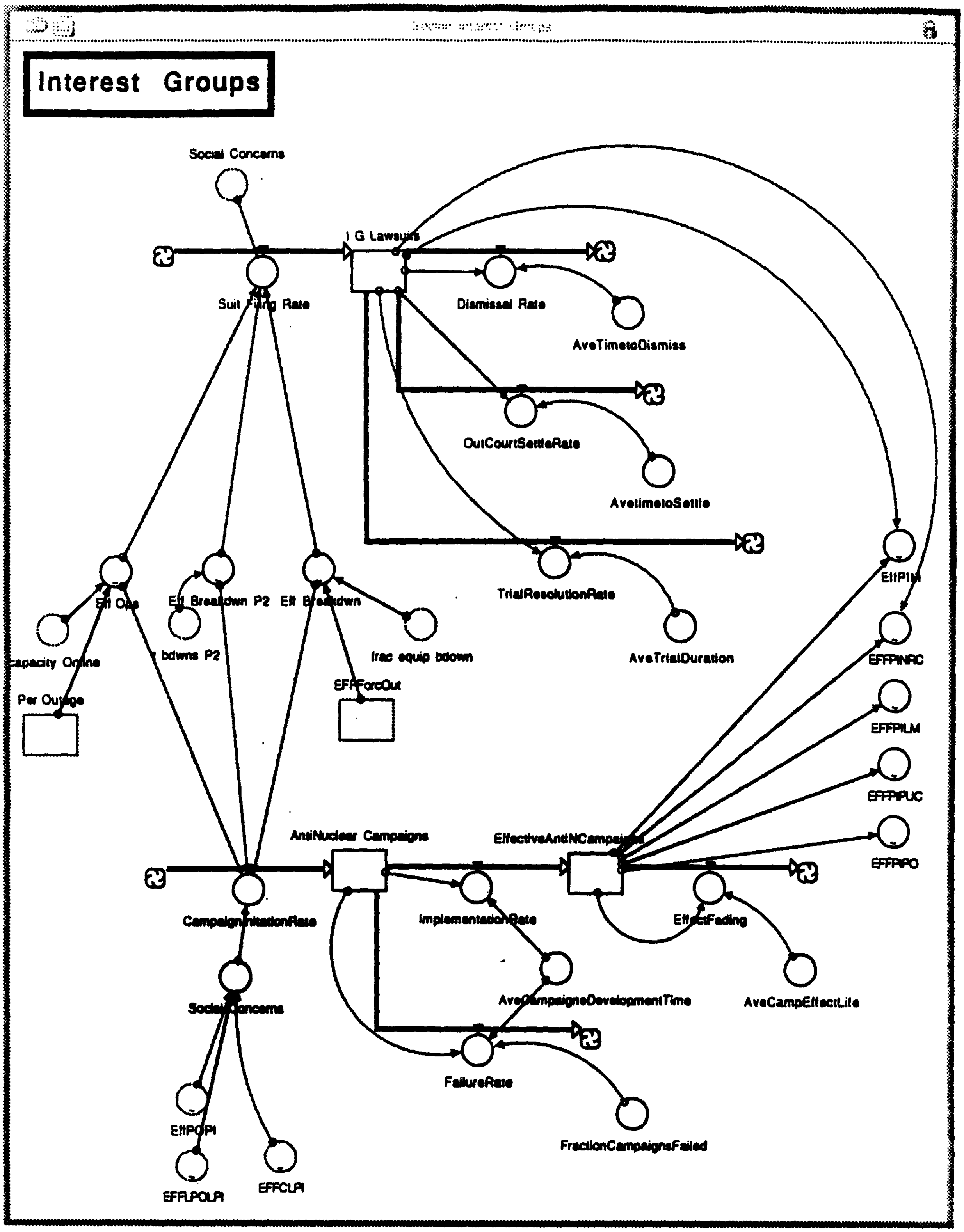

Plant: Materials
New Equipment
Aging Equip
Bought Equip
Total Equipment in Plant
Buy Time
Age Time
$ per New Eq
Bought Eq Cap Inv$
Ave Qual Spec Switch
ave imp Qual Spec
Materials Specs
Quality upgrades
specs upgraded
frac dict parts rtrnd
rejects
deliveries
Quality Imp by Design
Quality of Specs
av qual specs
initial quality spec
New Part Des Inv
Spec upgrade per part
Cost Per Part Des
add in effect of mod and regs on upgrading
Spec
created
new parts
Cost New Cap Part
New Part Cap Inv$
frac rtrnd given dict
new reg evals completed
mod CA planned
Stores Inventory
deliveries
Bud Maint parts
dollars per part
CA per reg
schd wo per mod CA
frac dict parts rtrnd
Parts accptd
stores inventory
parts consumed
total WO completed
pct Inventory dictv
Frac parts def
av parts per wo
frac parts dict at delvry
Dfctv Inventory
dict accptd
new dicts parts
frac dict parts accptd
dollar deliveries
stores dollars
stores inventory
av dollars per part
Parts accptd
maint materials cost
dollars per part
replacement investment
stores inv per ERV
parts consumed
Service Level
stores ratio
target inventory as %ERV


Finance: Debt
Debt
DE Ratio
Debt Inc
Debt Ret
Debt payments
Net cash flow
Equity Factor
Taxes
Des Liab
Stock Equity
Book Value Assets
Debt Factor
EFFMBRONE

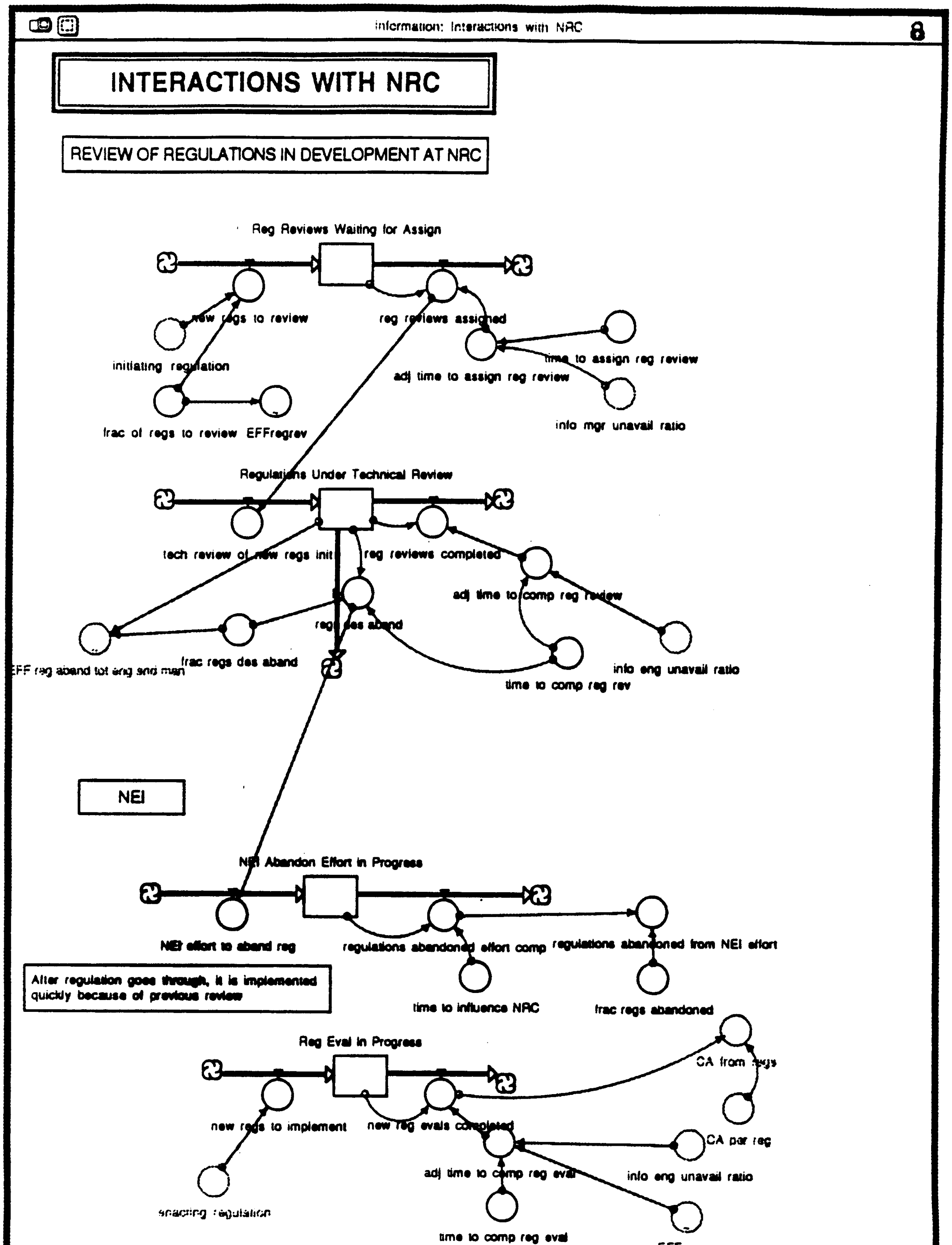

Finance: Safety Fin subsector
capacity Online
Per Outage
ChPerSaf
PerSafByFinMark
EFFPSStRisk
EFFPSFM
EFFOpsPS
EFFPSPUC G
EFFPOPerSaf
EFFPSPUC E
EFFLPOPerSaf
CurIndPerSaf
Delay in adj Saf perc
EffPSPUC
Evil Puc Fun
EFFForcOut
SALP
Utility Ave SALP
Event Effect
Event Switch

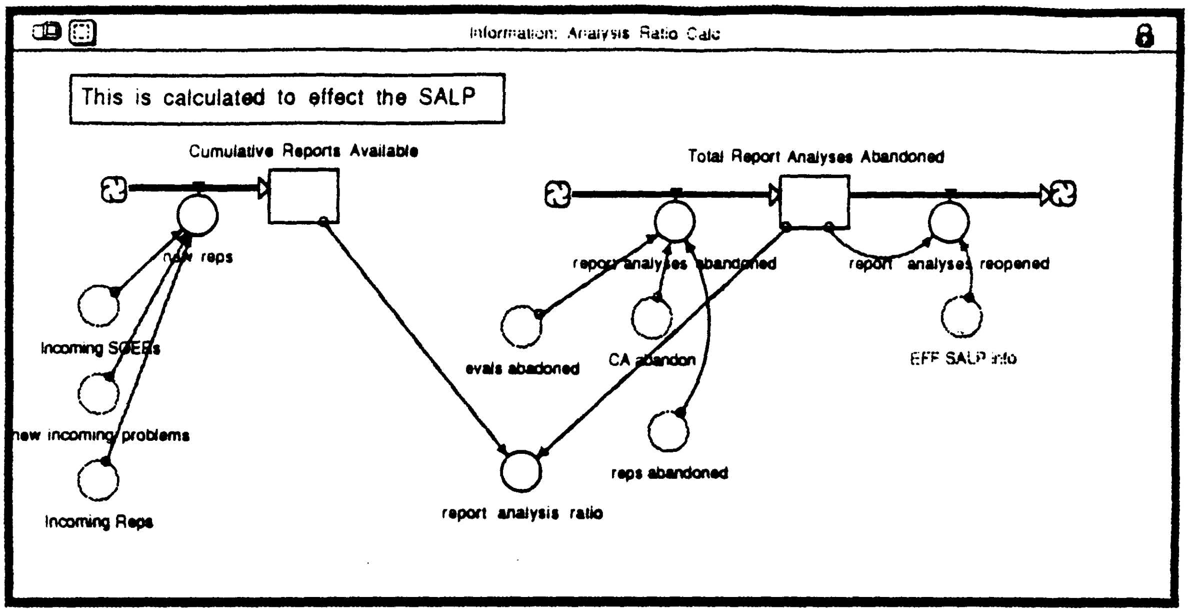


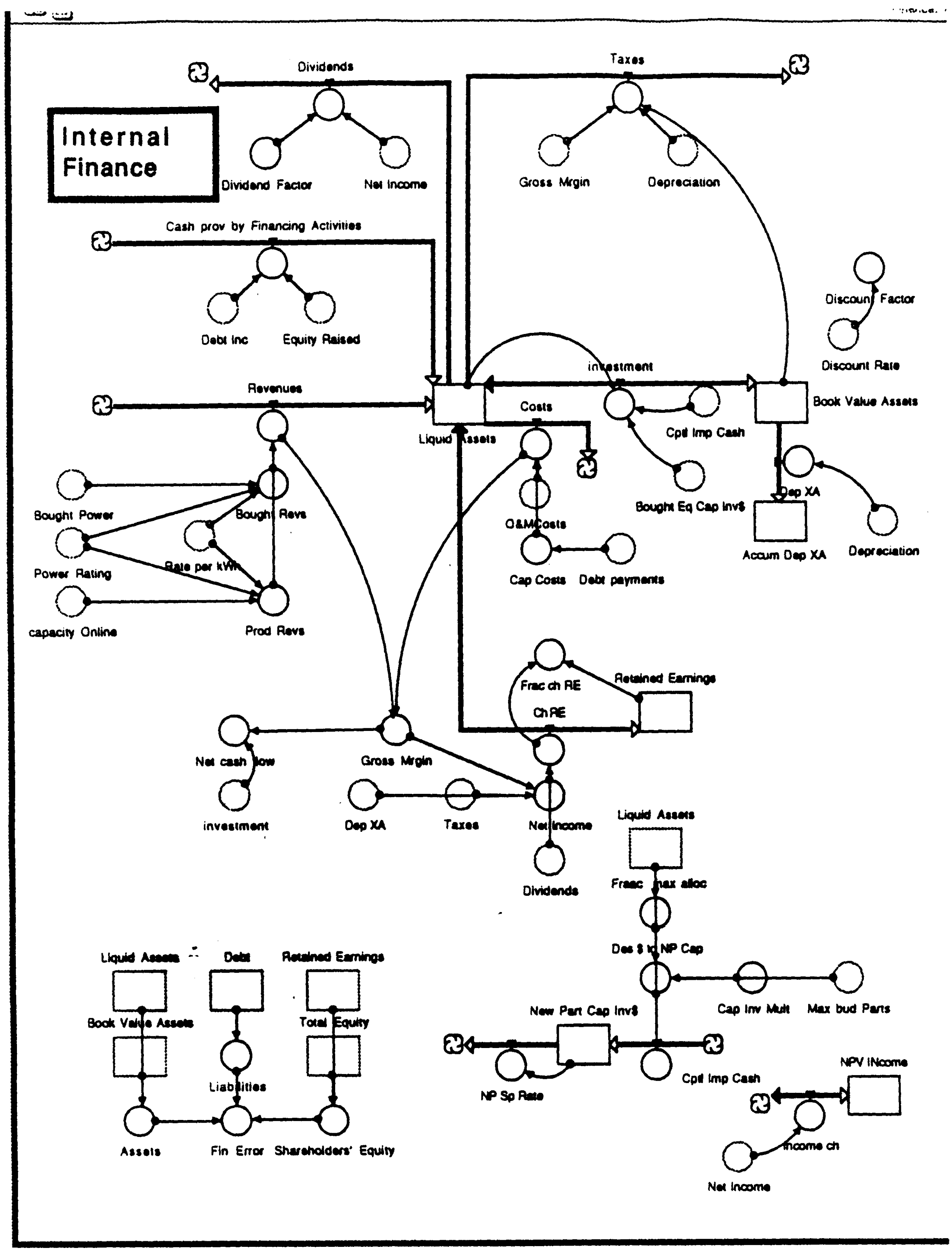
Media Coverage
detect operating reports
OperatingReports
EffPIM
OperatingReportingRate
OperationalRptDissimination
OpRptSpreadTime
capacity Online
Per Outage
Operating Conditions
FollowupReports
EffectiveMediaReports
FollowReportingRate
FollowupRptDissimination
FwupRptSpreadTime
EffectRptFading
AverageRptEffectLife
Social Multiplier
EFFPOM
EFFLPOM
EFFCLM
EFFMNRC
EFFMLM
EFFMPO
EventReports
EventRptingRate
EventRptDissimination
EvtRptSpreadTime
Plant Force Out
For Out Funct
Plant breakdwns P2
Event Switch
t bdwns P2
Changes Init NRC insp blog 5 to 0
Changed Init NRC invIP 20 to 0
Changed Init NRC RepIP 20 to 0
changed Init NRC RegID .5 to 0



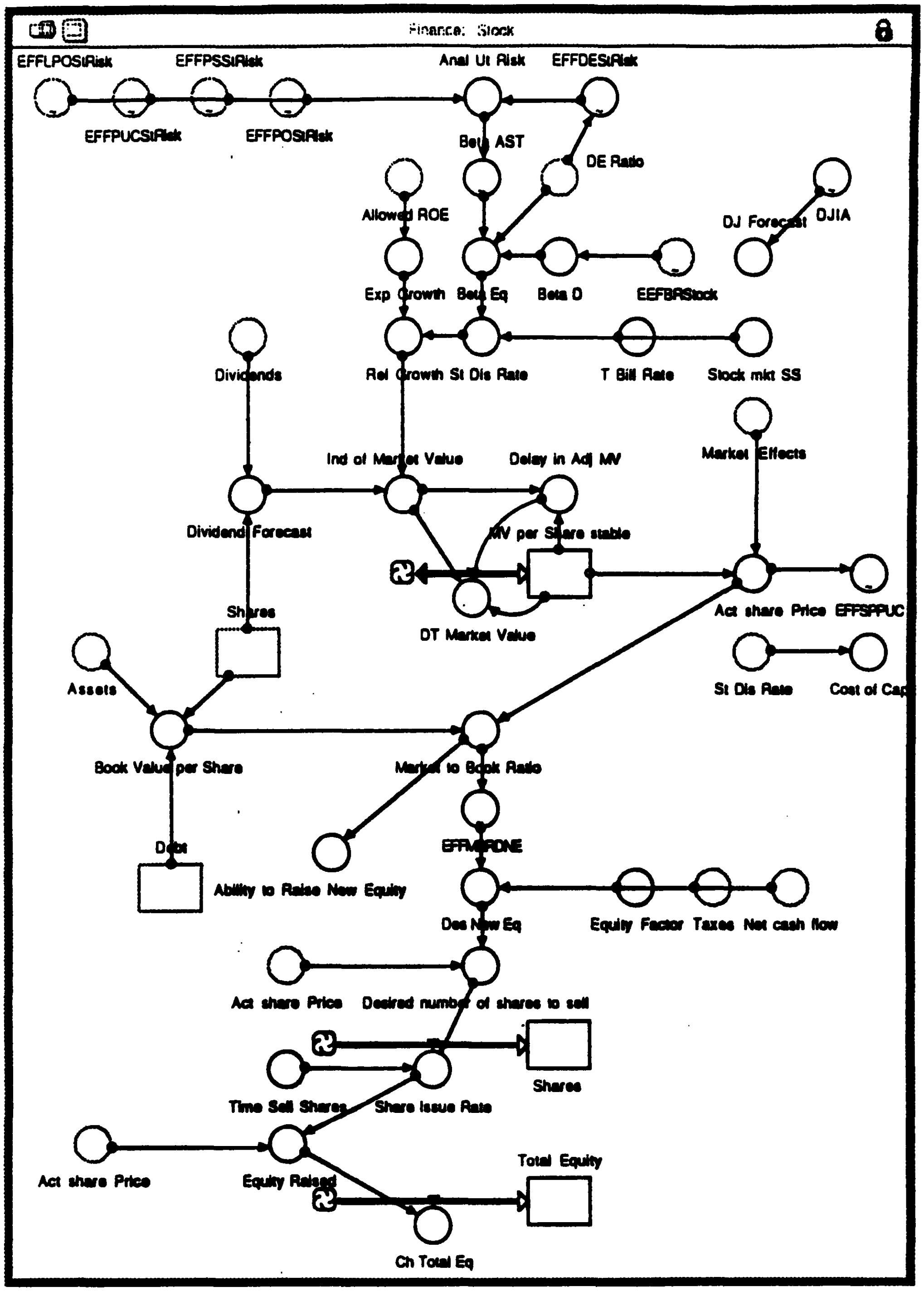
Interest Groups
Social Concerns
I G Lawsuits
Suit Filing Rate
Dismissal Rate
AveTimetoDismiss
OutCourtSettleRate
AvetimetoSettle
TrialResolutionRate
AveTrialDuration
Eff Ops
Eff Breakdown P2
Eff Breakdwn
capacity Online
bdwns P2
frac equip bdown
Per Outage
EFFForcOut
EffPIM
EFFPINRC
EFFPILM
EFFPIPUC
EFFPIPO
AntiNuclear Campaigns
EffectiveAntiNCampaigns
CampaignInitiationRate
ImplementationRate
EffectFading
AveCampEffectLife
AveCampaignsDevelopmentTime
Social Concerns
FailureRate
FractionCampaignsFailed
EffPOPI
EFFLPOLPI
EFFCLPI


information: Interactions with NRC
INTERACTIONS WITH NRC
REVIEW OF REGULATIONS IN DEVELOPMENT AT NRC
Reg Reviews Waiting for Assign
new regs to review
reg reviews assigned
initiating regulation
time to assign reg review
adj time to assign reg review
frac of regs to review
EFFregrev
info mgr unavail ratio
Regulations Under Technical Review
tech review of new regs init
reg reviews completed
adj time to comp reg review
regs des aband
EFF reg aband tot eng and man
frac regs des aband
info eng unavail ratio
time to comp reg rev
NEI
NEI Abandon Effort in Progress
NEI effort to aband reg
regulations abandoned effort comp
regulations abandoned from NEI effort
After regulation goes through, it is implemented quickly because of previous review
time to influence NRC
frac regs abandoned
Reg Eval in Progress
CA from regs
new regs to implement
new reg evals completed
CA per reg
adj time to comp reg eval
info eng unavail ratio
enacting regulation
time to comp reg eval
EFFregrev

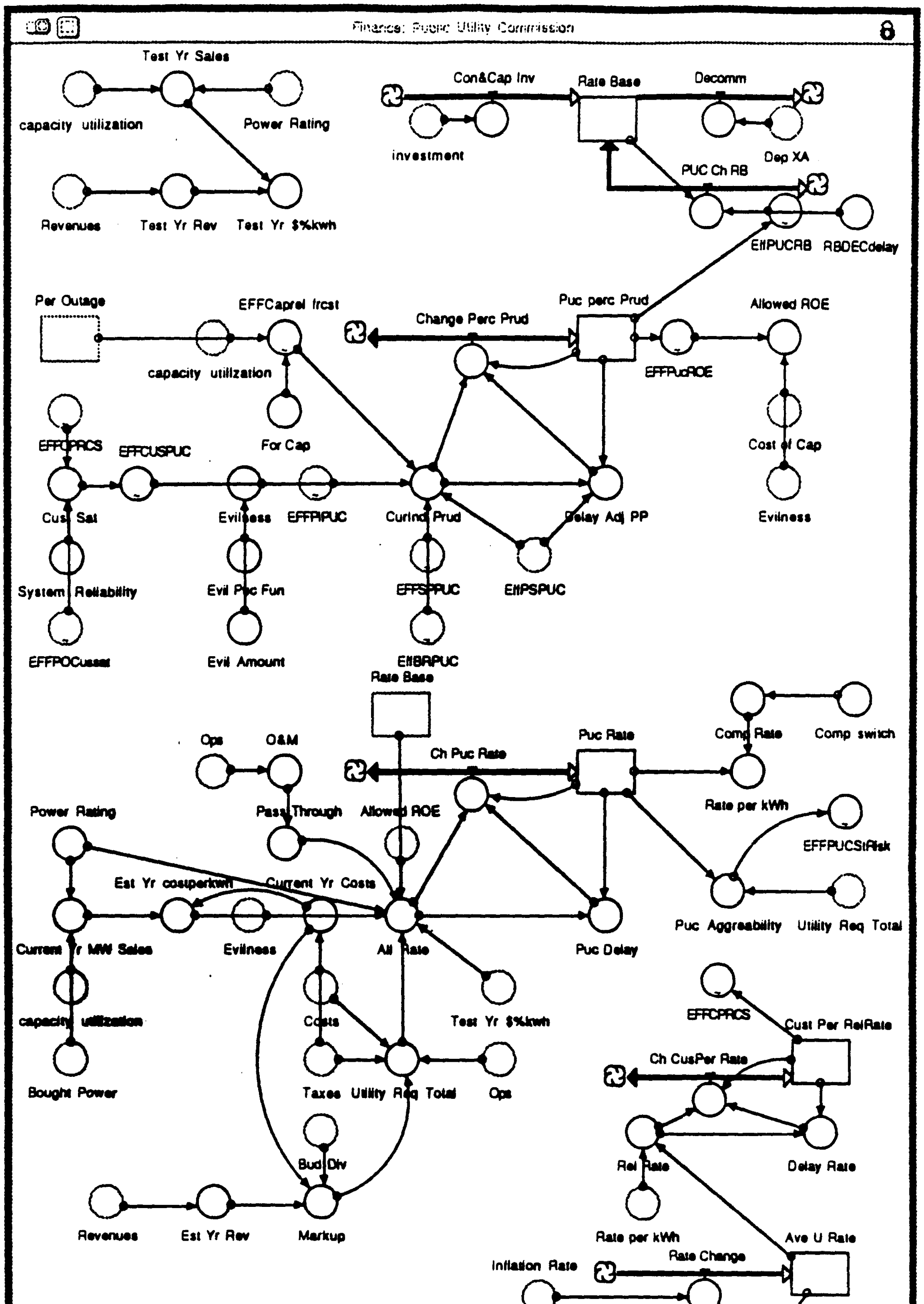

Information: Analysis Ratio Calc
This is calculated to effect the SALP
Cumulative Reports Available
Total Report Analyses Abandoned
new reps
report analyses abandoned
report analyses reopened
Incoming SOERs
evals abadoned
CA abandon
EFF SALP info
new incoming problems
reps abandoned
Incoming Reps
report analysis ratio

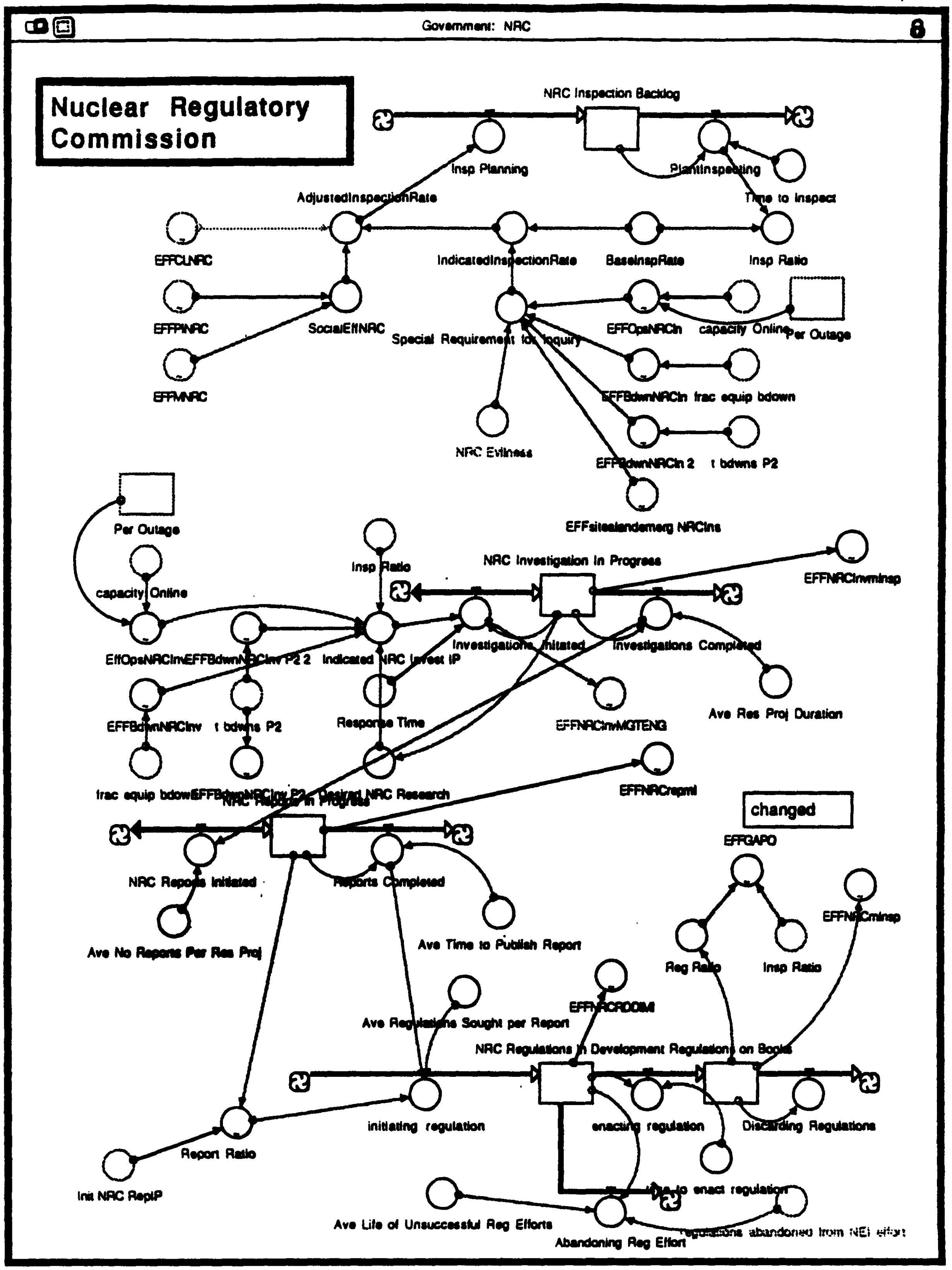


Internal Finance
Dividends
Dividend Factor
Net Income
Taxes
Gross Mrgin
Depreciation
Cash prov by Financing Activities
Debt Inc
Equity Raised
Discount Factor
Discount Rate
Revenues
investment
Liquid Assets
Costs
Cpd Imp Cash
Book Value Assets
Bought Eq Cap Inv$
Dep XA
Accum Dep XA
Depreciation
Bought Power
Bought Revs
Power Rating
Rate per kWh
capacity Online
Prod Revs
O&MCosts
Cap Costs
Debt payments
Frac ch RE
Retained Earnings
Ch RE
Net cash flow
Gross Mrgin
investment
Dep XA
Taxes
Net Income
Dividends
Liquid Assets
Frac max alloc
Des $ to NP Cap
Cap Inv Mult
Max bud Parts
New Part Cap Inv$
Cpd Imp Cash
NP Sp Rate
NPV INcome
Income ch
Net Income
Liquid Assets
Debt
Retained Earnings
Book Value Assets
Total Equity
Liabilities
Assets
Fin Error
Shareholders' Equity

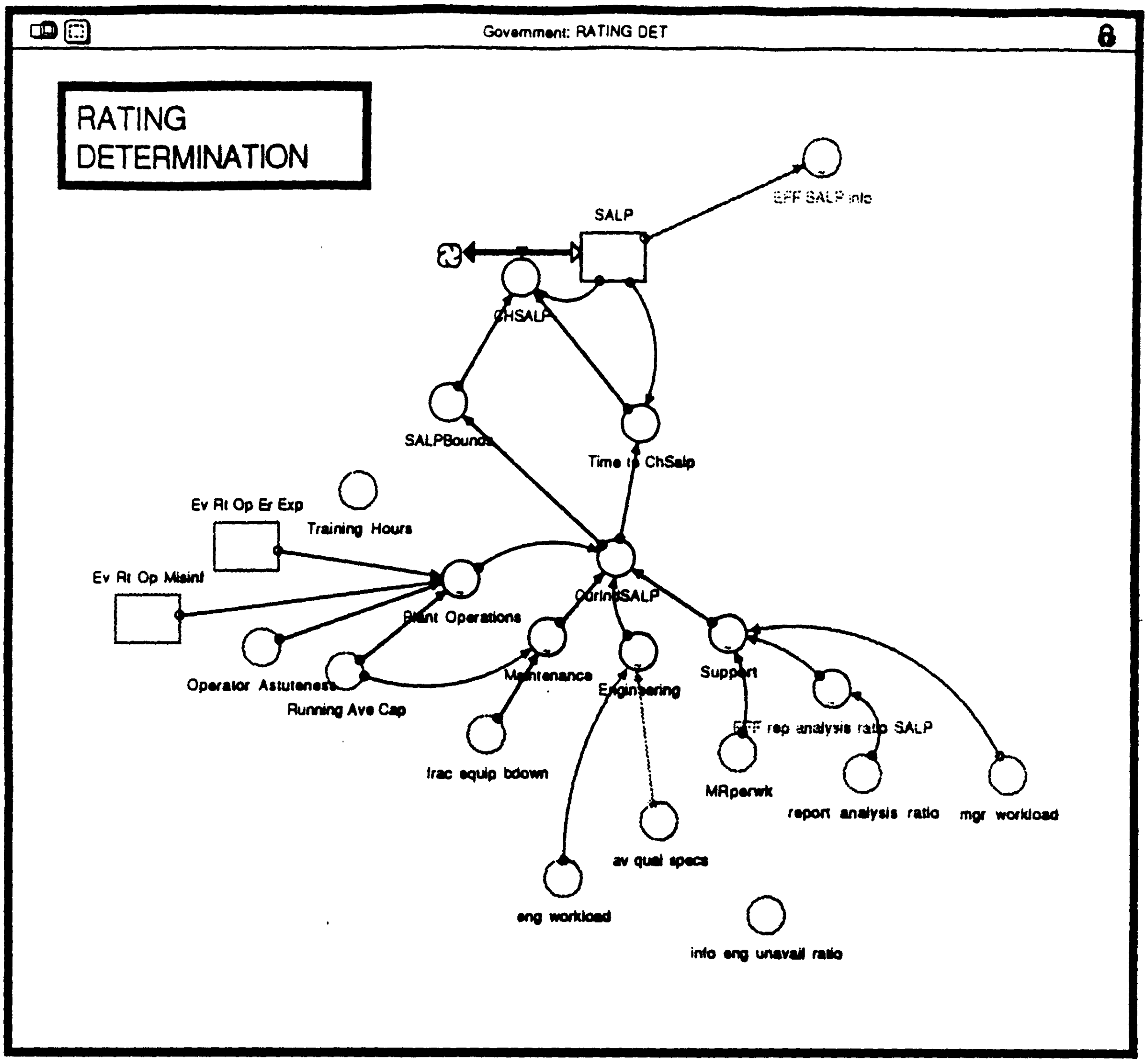


Finance: Stock
EFFLPOStRisk
EFFPSStRisk
Anal Ut Risk
EFFDEStRisk
EFFPUCStRisk
EFFPOStRisk
Beta AST
DE Ratio
Allowed ROE
DJ Forecast
DJIA
Exp Growth
Beta Eq
Beta D
EEFBRStock
Dividends
Rel Growth
St Dis Rate
T Bill Rate
Stock mkt SS
Market Effects
Ind of Market Value
Delay in Adj MV
Dividend Forecast
MV per Share stable
Shares
DT Market Value
Act share Price
EFFSPPUC
Assets
St Dis Rate
Cost of Cap
Book Value per Share
Market to Book Ratio
Debt
EFFMBRONE
Ability to Raise New Equity
Des New Eq
Equity Factor
Taxes
Net cash flow
Act share Price
Desired number of shares to sell
Shares
Time Sell Shares
Share Issue Rate
Total Equity
Act share Price
Equity Raised
Ch Total Eq

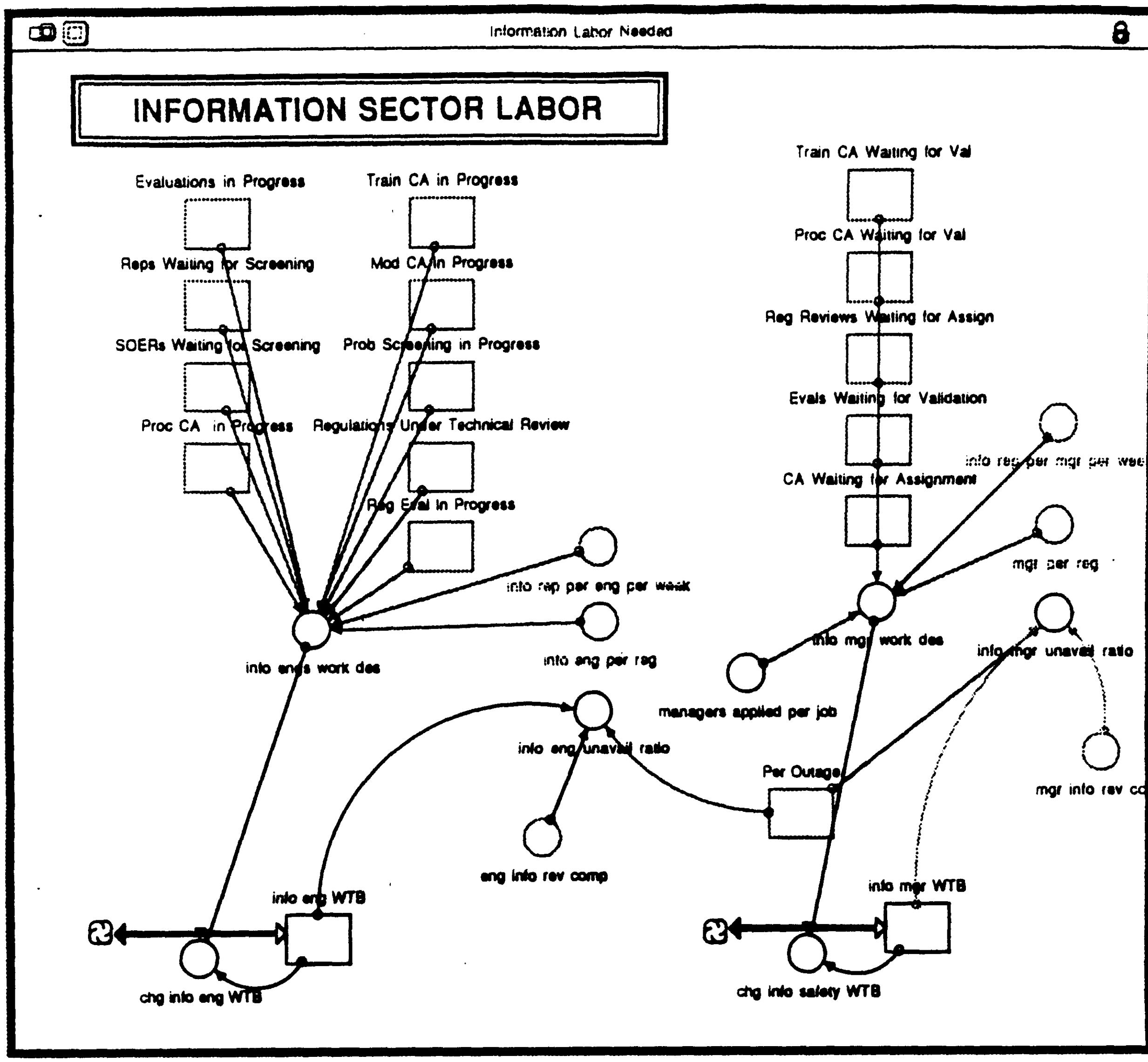

Finance: Public Utility Commission
Test Yr Sales
capacity utilization
Power Rating
Revenues
Test Yr Rev
Test Yr $%kwh
Con&Cap Inv
Rate Base
Decomm
investment
Dep XA
PUC Ch RB
EffPUCRB
RBDECdelay
Per Outage
EFFCaprel frcst
Change Perc Prud
Puc perc Prud
Allowed ROE
capacity utilization
EFFPucROE
EFFCPRCS
EFFCUSPUC
For Cap
Cost of Cap
Cust Sat
Evilness
EFFRIPUC
Curind Prud
Delay Adj PP
Evilness
System Reliability
Evil Puc Fun
EFFSPPUC
EffPSPUC
EFFPOCussat
Evil Amount
EffBRPUC
Rate Base
Puc Rate
Comp Rate
Comp switch
Ops
O&M
Ch Puc Rate
Rate per kWh
Power Rating
Pass Through
Allowed ROE
EFFPUCStRisk
Est Yr costperkwh
Current Yr Costs
Current Yr MW Sales
Evilness
All Rate
Puc Delay
Puc Aggreability
Utility Req Total
capacity utilization
Costs
Test Yr $%kwh
EFFCPRCS
Cust Per RelRate
Bought Power
Taxes
Utility Req Total
Ops
Ch CusPer Rate
Bud Div
Rel Rate
Delay Rate
Revenues
Est Yr Rev
Markup
Rate per kWh
Ave U Rate
Inflation Rate
Rate Change



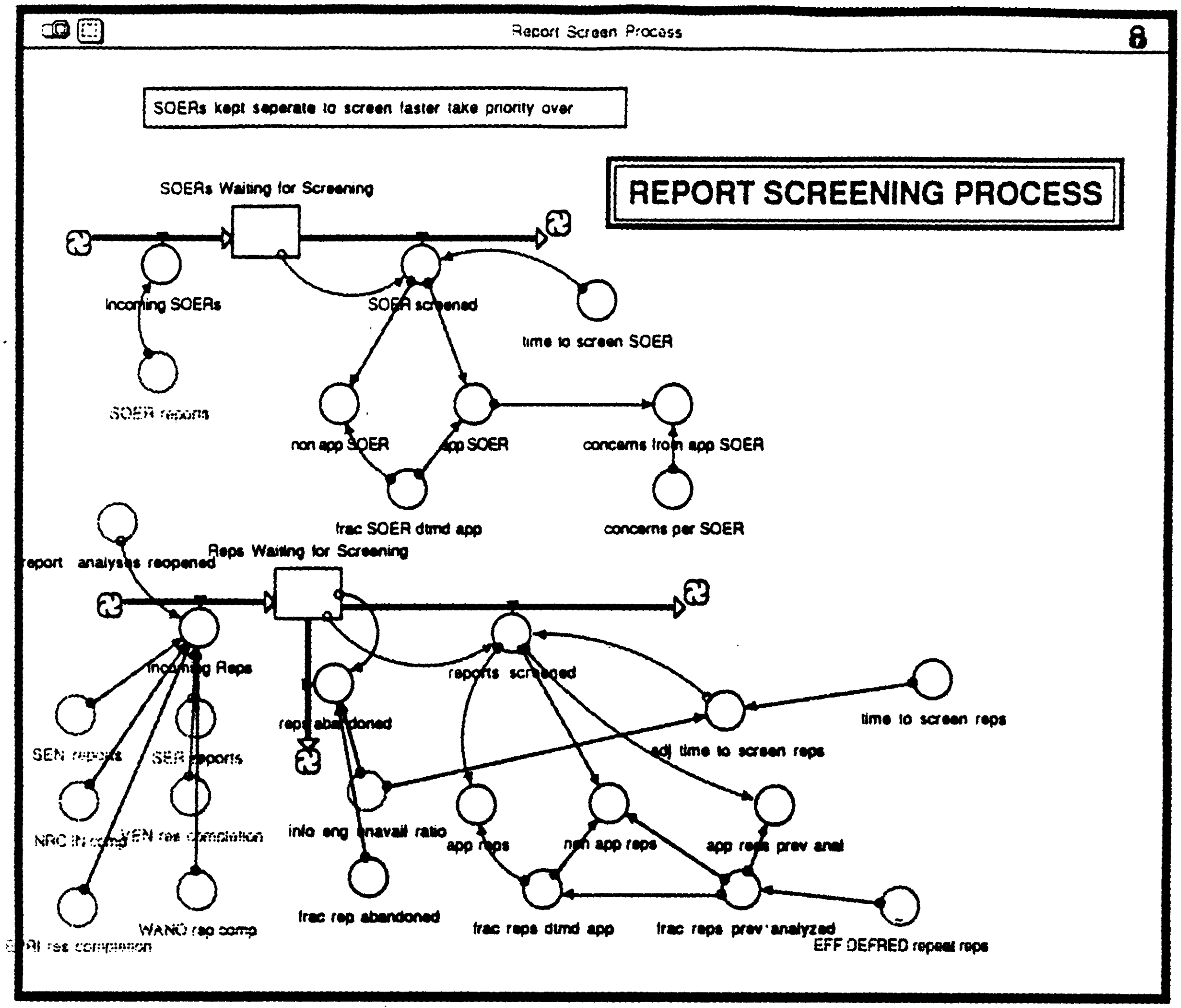
Government: NRC
Nuclear Regulatory Commission
NRC Inspection Backlog
Insp Planning
PlantInspecting
Time to Inspect
AdjustedInspectionRate
EFFCLNRC
IndicatedInspectionRate
BaseInspRate
Insp Ratio
EFFPINRC
SocialEffNRC
Special Requirement for Inquiry
EFFOpsNRCIn
capacity Online
Per Outage
EFFMNRC
EFFBdwnNRCIn
frac equip bdown
NRC Evilness
EFFBdwnNRCIn 2
t bdwns P2
EFFsitesandemerg NRCIns
Per Outage
capacity Online
Insp Ratio
NRC Investigation In Progress
EFFNRCInvmInsp
Investigations Initiated
Investigations Completed
Indicated NRC Invest IP
Response Time
EFFNRCInvMGTENG
Ave Res Proj Duration
EFFBdwnNRCInv
t bdwns P2
Desired NRC Research
EFFNRCrepml
NRC Reports In Progress
changed
EFFGAPO
NRC Reports Initiated
Reports Completed
Ave No Reports Per Res Proj
Ave Time to Publish Report
Reg Ratio
Insp Ratio
EFFNRCminsp
EFFNRCRODIM
Ave Regulations Sought per Report
NRC Regulations In Development
Regulations on Books
initiating regulation
enacting regulation
Discarding Regulations
Report Ratio
Init NRC RepIP
time to enact regulation
Ave Life of Unsuccessful Reg Efforts
Abandoning Reg Effort
regulations abandoned from NEI effort



Government: RATING DET
RATING DETERMINATION
EFF SALP info
SALP
CHSALP
SALPBounds
Time to ChSalp
Ev Rt Op Er Exp
Training Hours
Ev Rt Op Msinf
Plant Operations
CurIndSALP
Operator Astuteness
Running Ave Cap
Maintenance
Engineering
Support
EFF rep analysis ratio SALP
frac equip bdown
MRperwk
report analysis ratio
mgr workload
av qual specs
eng workload
info eng unavail ratio



Information Labor Needed
INFORMATION SECTOR LABOR
Evaluations in Progress
Train CA in Progress
Reps Waiting for Screening
Mod CA In Progress
SOERs Waiting for Screening
Prob Screening in Progress
Proc CA in Progress
Regulations Under Technical Review
Reg Eval In Progress
info rep per eng per week
info eng per reg
info engs work des
info eng unavail ratio
eng info rev comp
info eng WTB
chg info eng WTB
Train CA Waiting for Val
Proc CA Waiting for Val
Reg Reviews Waiting for Assign
Evals Waiting for Validation
CA Waiting for Assignment
info reg per mgr per wee
mgr per reg
info mgr work des
info mgr unavail ratio
managers applied per job
Per Outage
mgr info rev comp
info mgr WTB
chg info safety WTB



Report Screen Process
SOERs kept seperate to screen faster take priority over
REPORT SCREENING PROCESS
SOERs Waiting for Screening
Incoming SOERs
SOER screened
time to screen SOER
non app SOER
app SOER
concerns from app SOER
frac SOER dtmd app
concerns per SOER
report analyses reopened
Reps Waiting for Screening
Incoming Reps
reports screened
time to screen reps
reps abandoned
adj time to screen reps
SER reports
info eng unavail ratio
app reps
non app reps
app reps prev anal
WANO rep comp
frac rep abandoned
frac reps dtmd app
frac reps prev analyzed
EFF DEFRED repeat reps

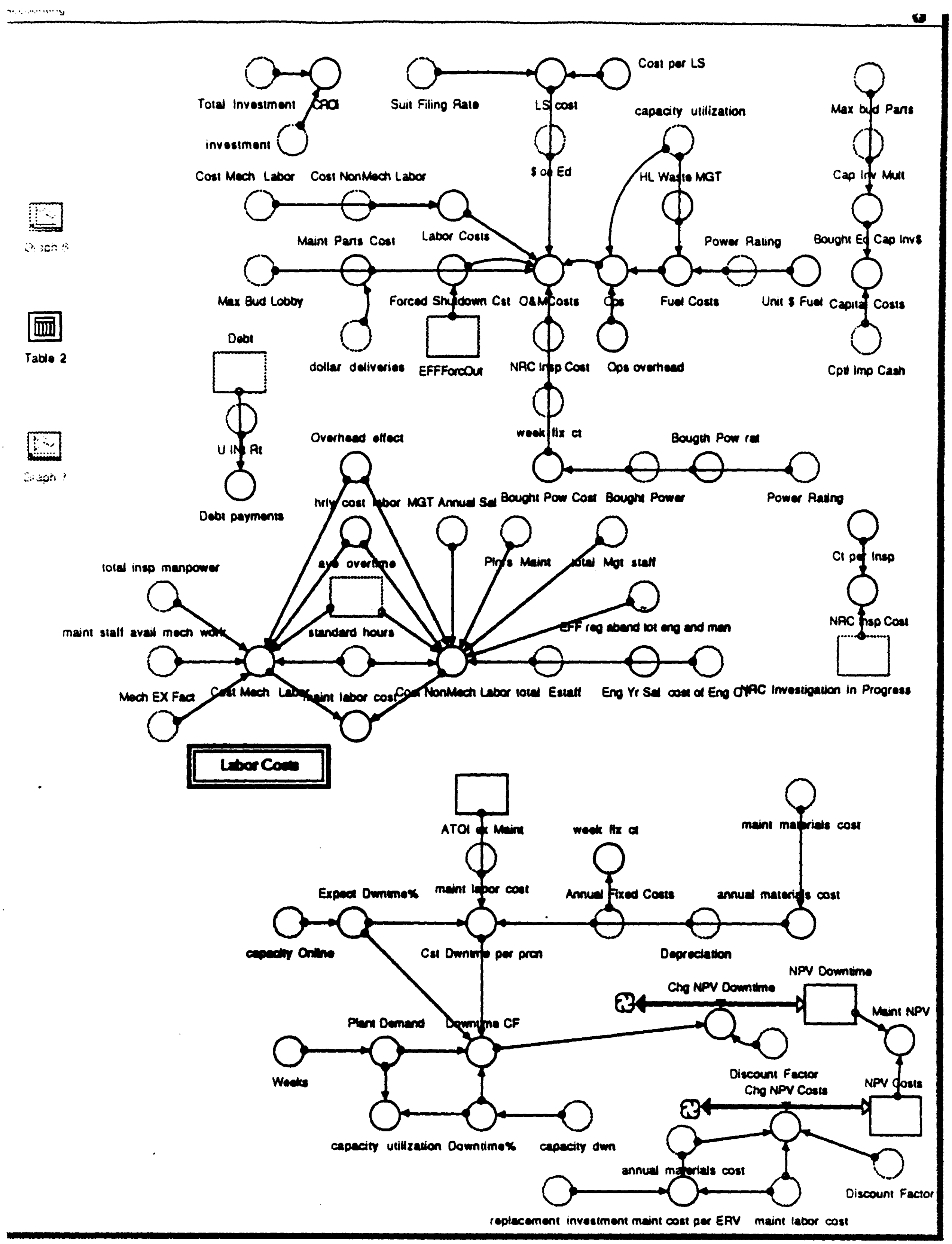
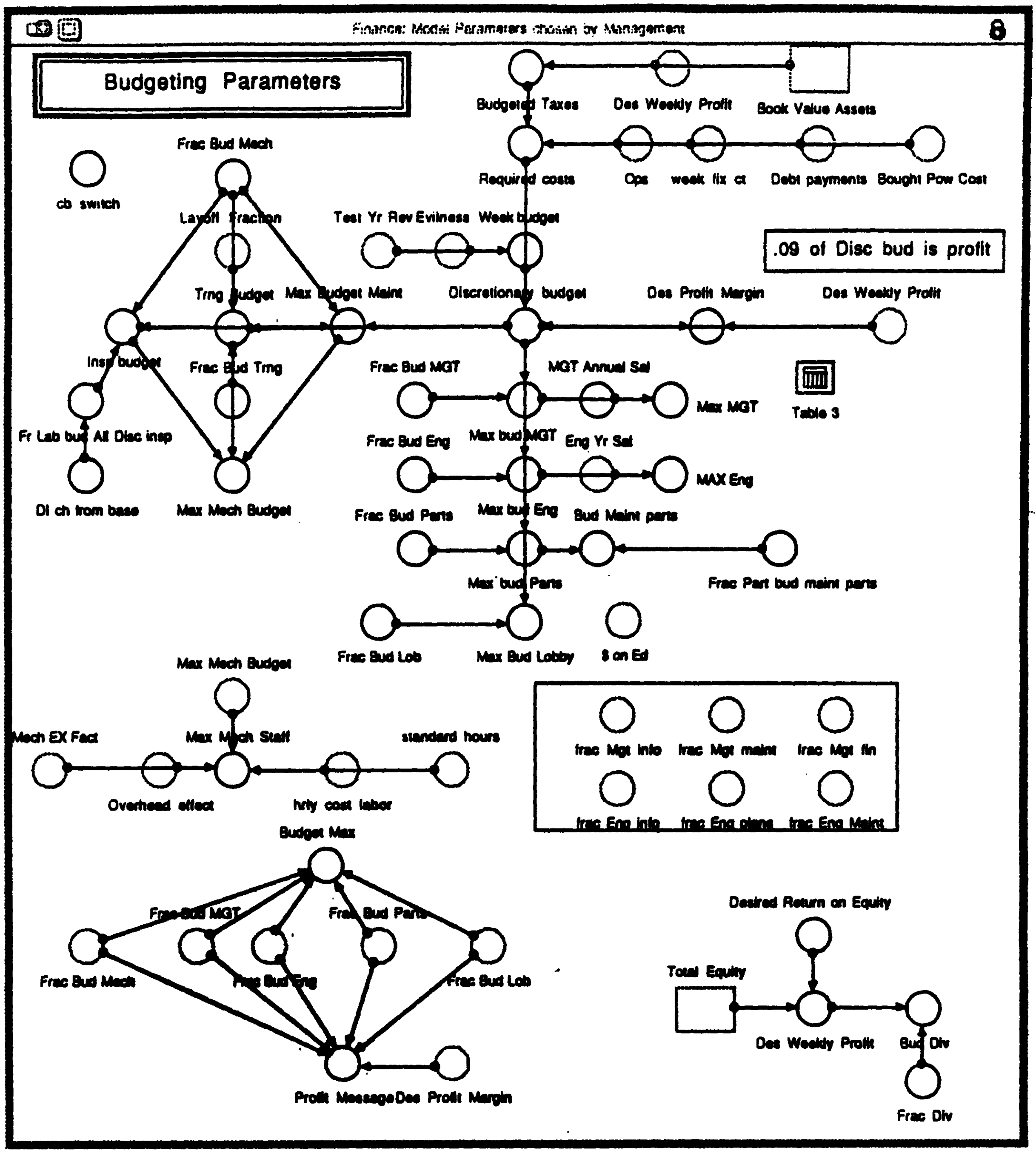
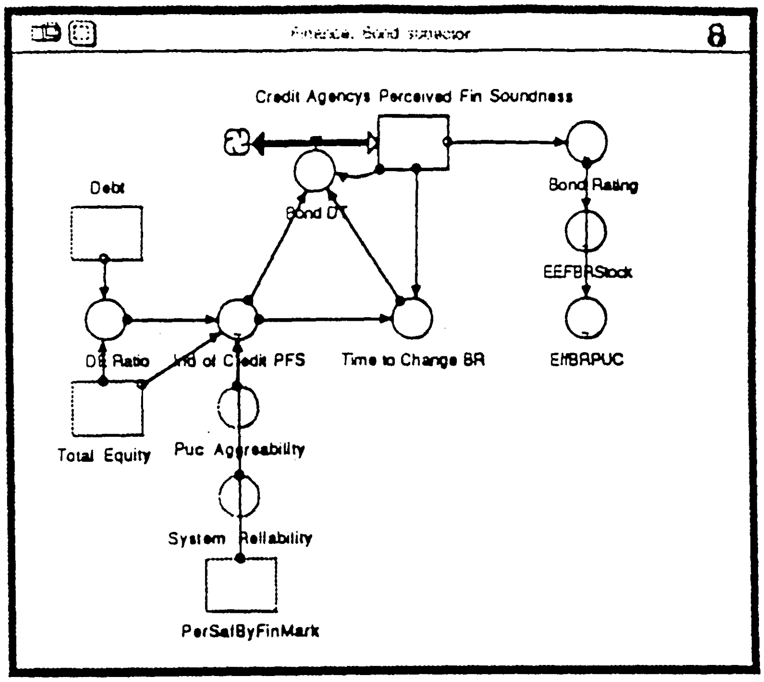
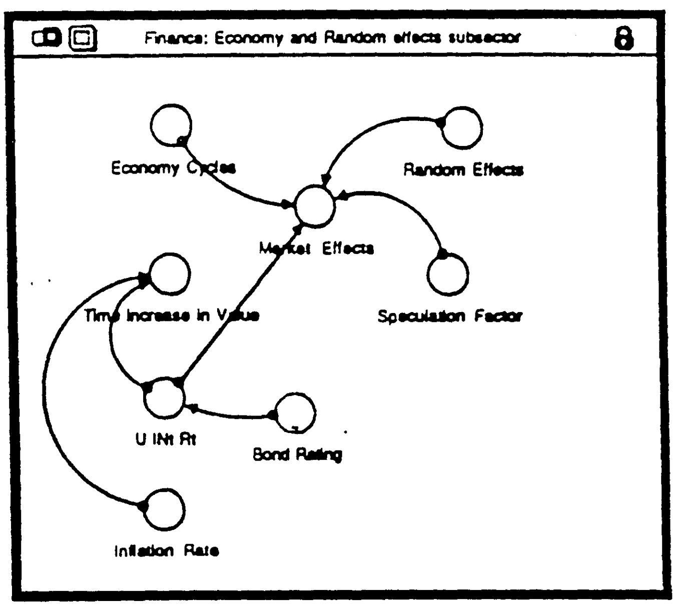


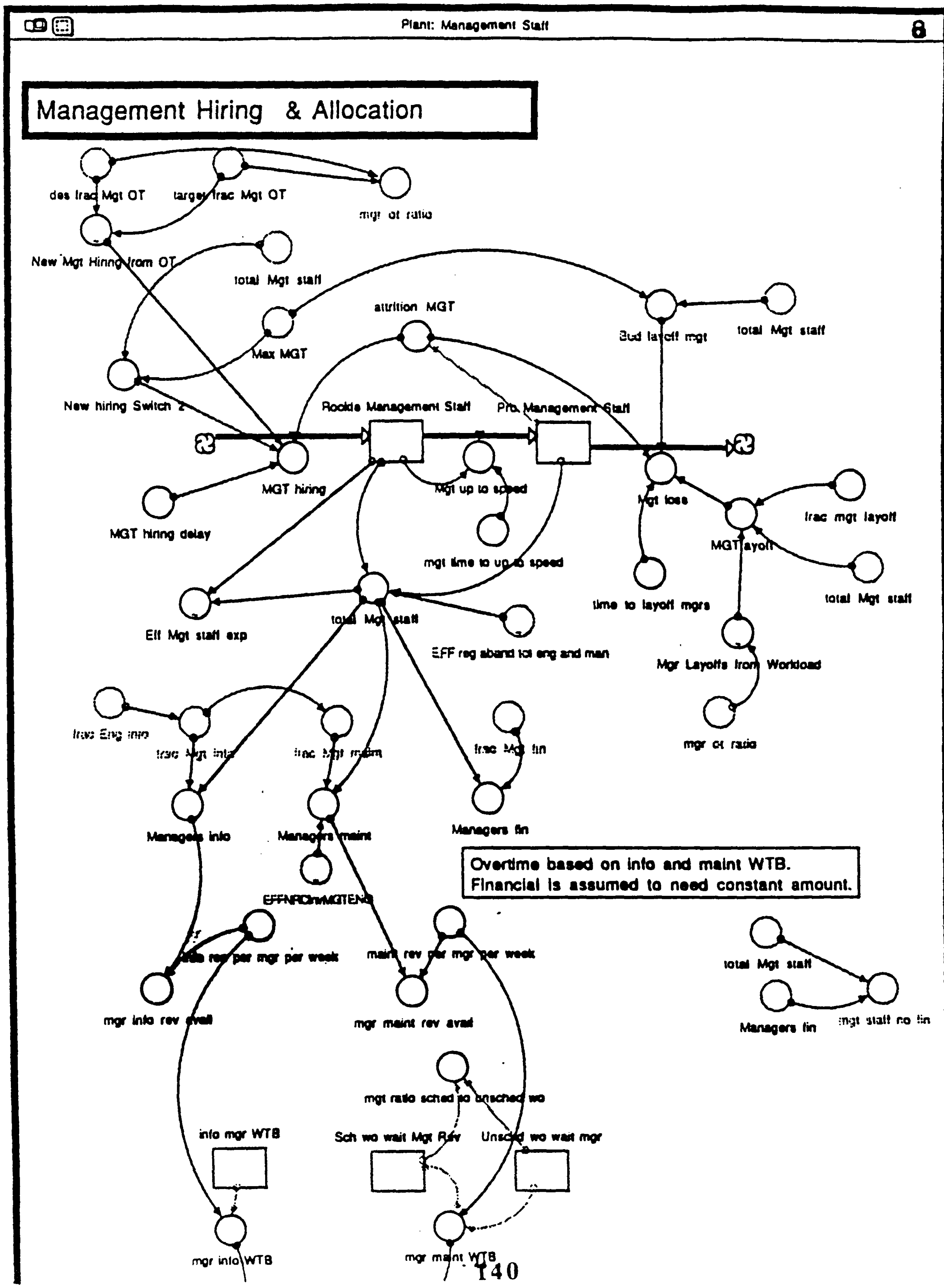
Table 2
Total Investment
CROI
investment
Suit Filing Rate
LS cost
Cost per LS
capacity utilization
Max bud Parts
$ of Ed
HL Waste MGT
Cap Inv Mult
Cost Mech Labor
Cost NonMech Labor
Labor Costs
Maint Parts Cost
Power Rating
Bought Eq Cap Inv$
Max Bud Lobby
Forced Shutdown Cst
O&MCosts
Ops
Fuel Costs
Unit $ Fuel
Capital Costs
Debt
dollar deliveries
EFFForcOut
NRC Insp Cost
Ops overhead
Cptl Imp Cash
U IN Rt
week fix ct
Bougth Pow rat
Overhead effect
Debt payments
hrly cost
labor MGT Annual Sal
Bought Pow Cost
Bought Power
Power Rating
total insp manpower
ave overtime
Plnts Maint
total Mgt staff
Ct per Insp
maint staff avail mech work
standard hours
EFF reg aband tot eng and man
NRC Insp Cost
Mech EX Fact
Cost Mech Labor
maint labor cost
Cost NonMech Labor
total Estaff
Eng Yr Sal
cost of Eng
NRC Investigation In Progress
Labor Costs
ATOI ex Maint
week fix ct
maint materials cost
Expect Dwntme%
maint labor cost
Annual Fixed Costs
annual materials cost
capacity Online
Cst Dwntme per prcn
Depreciation
NPV Downtime
Chg NPV Downtime
Maint NPV
Plant Demand
Downtime CF
Weeks
Discount Factor
Chg NPV Costs
NPV Costs
capacity utilization
Downtime%
capacity dwn
annual materials cost
Discount Factor
replacement investment
maint cost per ERV
maint labor cost

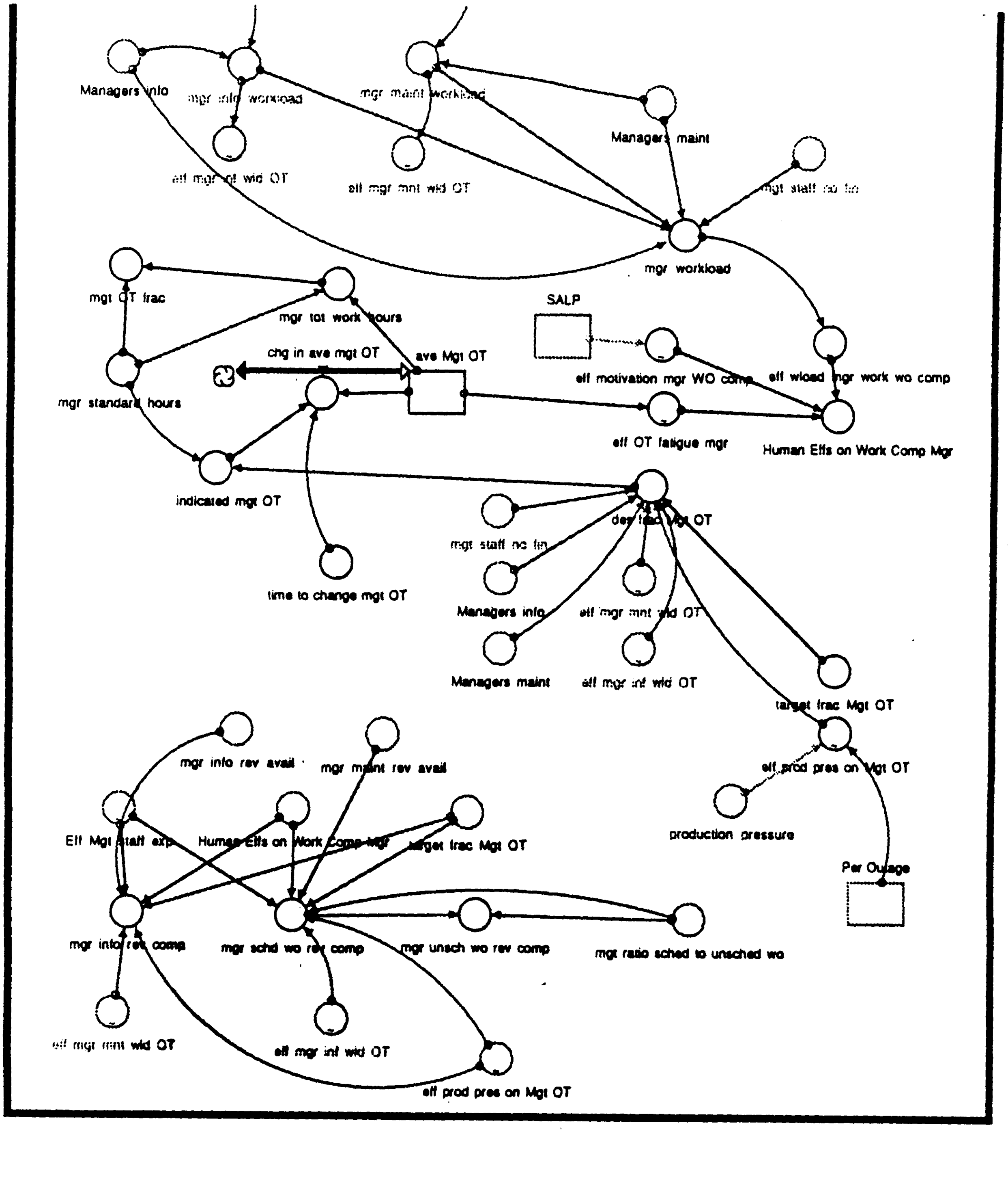


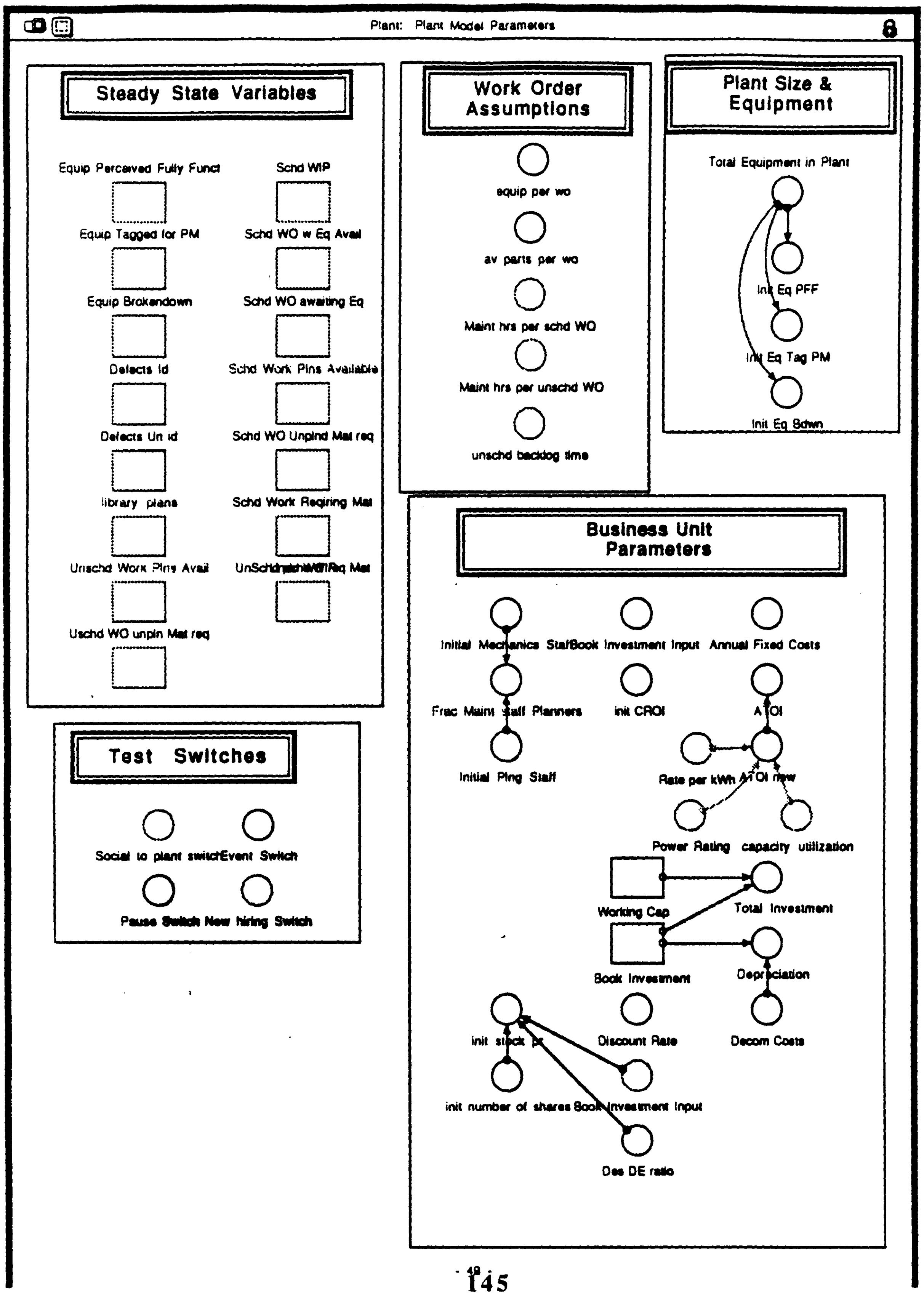
Finance: Model Parameters chosen by Management
Budgeting Parameters
Budgeted Taxes
Des Weekly Profit
Book Value Assets
Required costs
Ops
week fix ct
Debt payments
Bought Pow Cost
cb switch
Frac Bud Mech
Layoff Fraction
Test Yr Rev Evilness
Week budget
.09 of Disc bud is profit
Trng Budget
Max Budget Maint
Discretionary budget
Des Profit Margin
Des Weekly Profit
Insp budget
Frac Bud Trng
Frac Bud MGT
MGT Annual Sal
Max MGT
Table 3
Fr Lab bud All Disc insp
Frac Bud Eng
Max bud MGT
Eng Yr Sal
MAX Eng
Di ch from base
Max Mech Budget
Frac Bud Parts
Max bud Eng
Bud Maint parts
Max bud Parts
Frac Part bud maint parts
Frac Bud Lob
Max Bud Lobby
$ on Ed
Max Mech Budget
Mech EX Fact
Max Mech Staff
standard hours
Overhead effect
hrly cost labor
frac Mgt info
frac Mgt maint
frac Mgt fin
frac Eng info
frac Eng plans
frac Eng Maint
Budget Max
Frac Bud MGT
Frac Bud Parts
Frac Bud Mech
Frac Bud Eng
Frac Bud Lob
Profit Message
Des Profit Margin
Desired Return on Equity
Total Equity
Des Weekly Profit
Bud Div
Frac Div

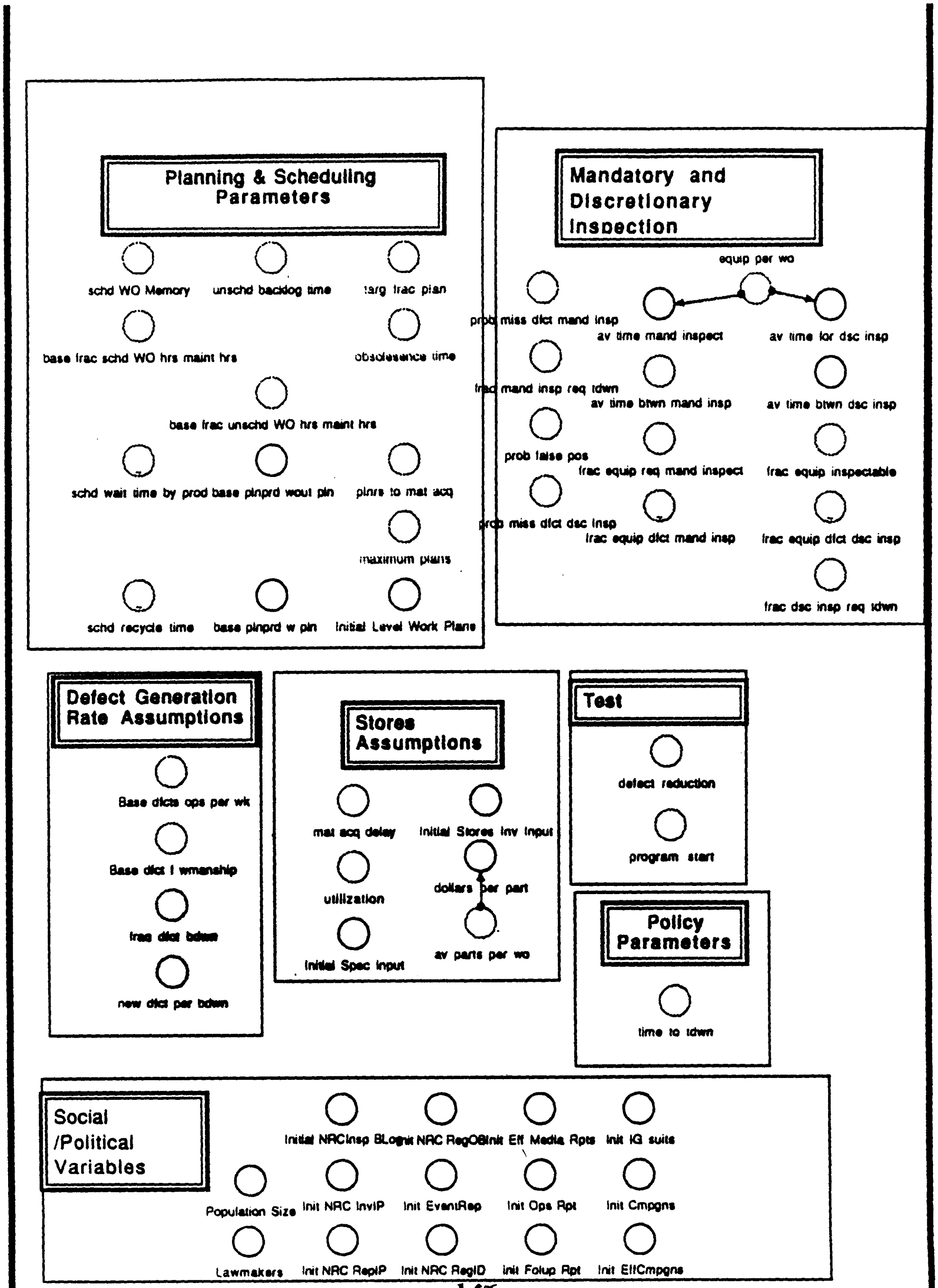

Credit Agencys Perceived Fin Soundness
Debt
Bond DT
Bond Rating
EEFBRStock
DE Ratio
Ind of Credit PFS
Time to Change BR
EffBRPUC
Total Equity
Puc Agreeability
System Reliability
PerSafByFinMark


Finance: Economy and Random effects subsector
Economy Cycles
Random Effects
Market Effects
Time Increase in Value
Speculation Factor
U INt Rt
Bond Rating
Inflation Rate

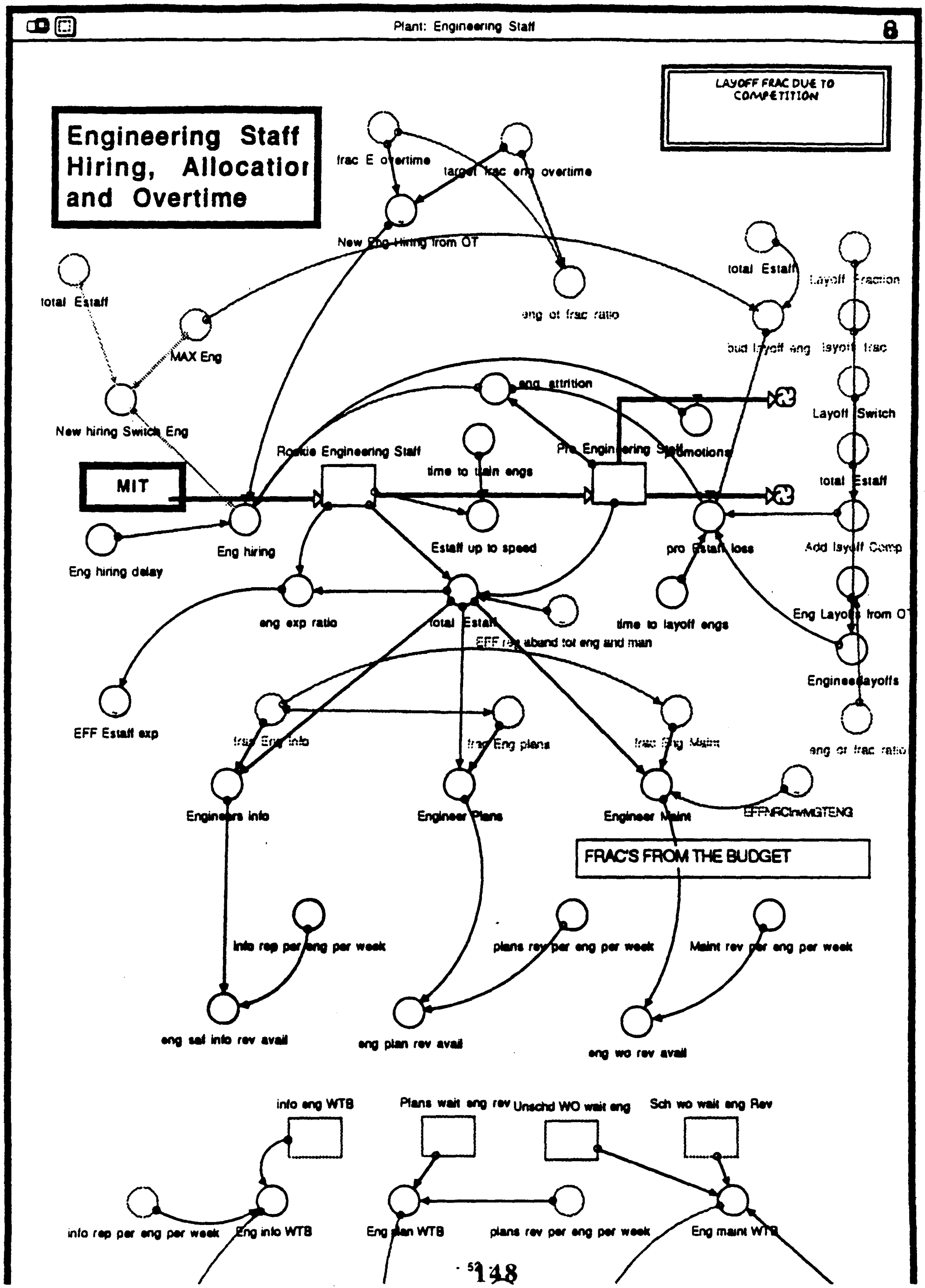

Plant: Management Staff
Management Hiring & Allocation
des frac Mgt OT
target frac Mgt OT
mgr ot ratio
New Mgt Hiring from OT
total Mgt staff
attrition MGT
Bud layoff mgt
total Mgt staff
Max MGT
New hiring Switch 2
Rookie Management Staff
Pro. Management Staff
MGT hiring
Mgt up to speed
Mgt loss
frac mgt layoff
MGT hiring delay
MGT layoff
mgt time to up to speed
time to layoff mgrs
total Mgt staff
Eff Mgt staff exp
total Mgt staff
EFF reg aband tot eng and man
Mgr Layoffs from Workload
frac Eng info
frac Mgt info
frac Mgt maint
frac Mgt fin
mgr ot ratio
Managers info
Managers maint
Managers fin
Overtime based on info and maint WTB.
Financial is assumed to need constant amount.
info rev per mgr per week
maint rev per mgr per week
total Mgt staff
mgr info rev avail
mgr maint rev avail
Managers fin
mgt staff no fin
mgt ratio sched to unsched wo
info mgr WTB
Sch wo wait Mgt Rev
Unschd wo wait mgr
mgr info WTB
mgr maint WTB

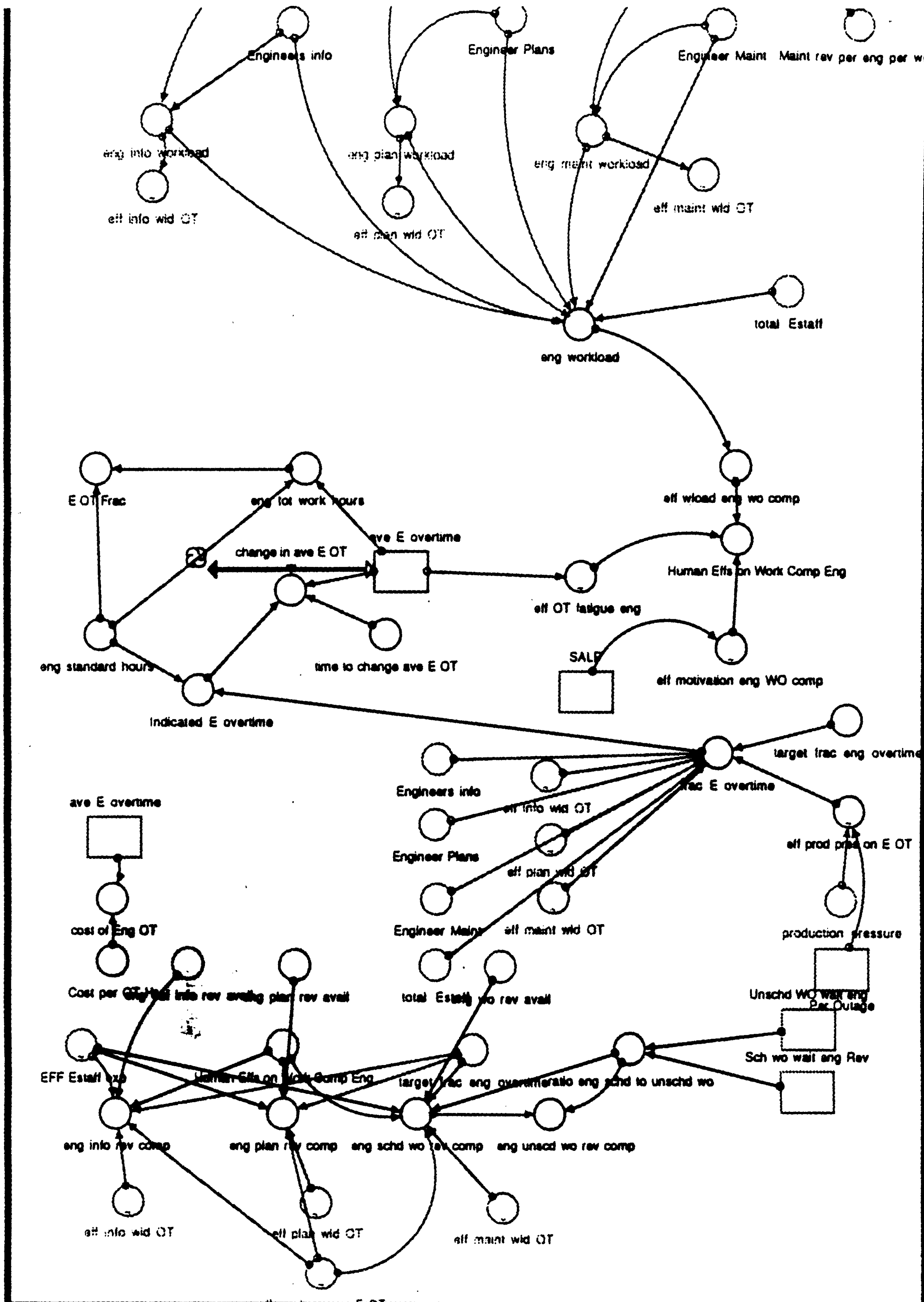

Managers info
mgr info workload
mgr maint workload
Managers maint
eff mgr inf wld OT
eff mgr mnt wld OT
mgt staff no fin
mgr workload
mgt OT frac
mgr tot work hours
SALP
chg in ave mgt OT
ave Mgt OT
eff motivation mgr WO comp
eff wload mgr work wo comp
mgr standard hours
eff OT fatigue mgr
Human Effs on Work Comp Mgr
indicated mgt OT
des frac Mgt OT
mgt staff no fin
time to change mgt OT
Managers info
eff mgr mnt wld OT
Managers maint
eff mgr inf wld OT
target frac Mgt OT
eff prod pres on Mgt OT
mgr info rev avail
mgr maint rev avail
production pressure
Eff Mgt staff exp
Human Effs on Work Comp Mgr
target frac Mgt OT
Per Outage
mgr info rev comp
mgr schd wo rev comp
mgr unsch wo rev comp
mgt ratio sched to unsched wo
eff mgt mnt wld OT
eff mgr inf wld OT
eff prod pres on Mgt OT


Plant: Plant Model Parameters
Steady State Variables
Equip Perceived Fully Funct
Schd WIP
Equip Tagged for PM
Schd WO w Eq Avail
Equip Brokendown
Schd WO awaiting Eq
Defects Id
Schd Work Plns Available
Defects Un id
Schd WO Unplnd Mat req
library plans
Schd Work Reqiring Mat
Unschd Work Plns Avail
Uschd WO unpln Mat req
Work Order Assumptions
equip per wo
av parts per wo
Maint hrs per schd WO
Maint hrs per unschd WO
unschd backlog time
Plant Size & Equipment
Total Equipment in Plant
Init Eq PFF
Init Eq Tag PM
Init Eq Bdwn
Business Unit Parameters
Initial Mechanics Staff
Book Investment Input
Annual Fixed Costs
Frac Maint Staff Planners
init CROI
ATOI
Initial Plng Staff
Rate per kWh
ATOI new
Power Rating
capacity utilization
Working Cap
Total Investment
Book Investment
Depreciation
init stock px
Discount Rate
Decom Costs
init number of shares
Book Investment Input
Des DE ratio
Test Switches
Social to plant switch
Event Switch
Pause Switch
New hiring Switch



Planning & Scheduling Parameters
schd WO Memory
unschd backlog time
targ frac plan
base frac schd WO hrs maint hrs
obsolesence time
base frac unschd WO hrs maint hrs
schd wait time by prod
base plnprd wout pln
plnrs to mat acq
maximum plans
schd recycle time
base plnprd w pln
Initial Level Work Plans
Mandatory and Discretionary Inspection
equip per wo
prob miss dfct mand insp
av time mand inspect
av time for dsc insp
frac mand insp req tdwn
av time btwn mand insp
av time btwn dsc insp
prob false pos
frac equip req mand inspect
frac equip inspectable
prob miss dfct dsc insp
frac equip dfct mand insp
frac equip dfct dsc insp
frac dsc insp req tdwn
Defect Generation Rate Assumptions
Base dfcts ops per wk
Base dfct f wmanship
frac dfct bdwn
new dfct per bdwn
Stores Assumptions
mat acq delay
Initial Stores Inv Input
utilization
dollars per part
Initial Spec Input
av parts per wo
Test
defect reduction
program start
Policy Parameters
time to tdwn
Social /Political Variables
Initial NRCInsp BLog
Init NRC RegOB
Init Eff Media Rpts
Init IG suits
Population Size
Init NRC InvIP
Init EventRep
Init Ops Rpt
Init Cmpgns
Lawmakers
Init NRC RepIP
Init NRC RegID
Init Folup Rpt
Init EffCmpgns


Plant: Engineering Staff
LAYOFF FRAC DUE TO COMPETITION
Engineering Staff Hiring, Allocatior and Overtime
frac E overtime
target frac eng overtime
New Eng Hiring from OT
total Estaff
eng ot frac ratio
MAX Eng
bud layoff eng
Layoff Fraction
layoff frac
eng attrition
promotions
Layoff Switch
New hiring Switch Eng
Rookie Engineering Staff
Pro Engineering Staff
time to train engs
MIT
Eng hiring
Eng hiring delay
Estaff up to speed
pro Estaff loss
Add layoff Comp
eng exp ratio
total Estaff
time to layoff engs
Eng Layoffs from OT
EFF rep aband tot eng and man
Engineerlayoffs
EFF Estaff exp
frac Eng info
frac Eng plans
frac Eng Maint
eng ot frac ratio
Engineers info
Engineer Plans
Engineer Maint
EFFNRCInvMGTENG
FRAC'S FROM THE BUDGET
info rep per eng per week
plans rev per eng per week
Maint rev per eng per week
eng sat info rev avail
eng plan rev avail
eng wo rev avail
info eng WTB
Plans wait eng rev
Unschd WO wait eng
Sch wo wait eng Rev
info rep per eng per week
Eng info WTB
Eng plan WTB
plans rev per eng per week
Eng maint WTB



Engineers info
Engineer Plans
Engineer Maint
Maint rev per eng per week
eng info workload
eng plan workload
eng maint workload
eff info wld OT
eff plan wld OT
eff maint wld OT
total Estaff
eng workload
E OT Frac
eng tot work hours
ave E overtime
change in ave E OT
eff wload eng wo comp
Human Effs on Work Comp Eng
eff OT fatigue eng
eng standard hours
time to change ave E OT
SALP
eff motivation eng WO comp
Indicated E overtime
target frac eng overtime
frac E overtime
eff prod pres on E OT
production pressure
cost of Eng OT
Cost per OT Hour
eng info rev avail
eng plan rev avail
eng wo rev avail
Unschd WO wait eng
Per Outage
Sch wo wait eng Rev
EFF Estaff exp
ratio eng schd to unschd wo
eng info rev comp
eng plan rev comp
eng schd wo rev comp
eng unscd wo rev comp

APPENDIX B: EQUATION GLOSSARY

Finance: Stock

MV_per_Share_stable(t) = MV_per_Share_stable(t - dt) + (DT_Market_Value) * dt
INIT MV_per_Share_stable = init_stock_pr+25
INFLOWS:
DT_Market_Value = ((Ind_of_Market_Value-MV_per_Share_stable)/Delay_in_Adj_MV)/100

Shares(t) = Shares(t - dt) + (Share_Issue_Rate) * dt
INIT Shares = init_number_of_shares

DOCUMENT: Number of shares total
Units: shares

INFLOWS:
Share_Issue_Rate = Desired_number_of_shares_to_sell/Time_Sell_Shares

Total_Equity(t) = Total_Equity(t - dt) + (Ch_Total_Eq) * dt
INIT Total_Equity = Assets-Debt

DOCUMENT: Total Equity
Units: (mins $'s)
This is the measure of assets-debt to determine the capital the utility owns outright. These assets are claimed by the shareholders.

INFLOWS:
Ch_Total_Eq = Equity_Raised

Act_share_Price = MV_per_Share_stable*Market_Effects
DOCUMENT: Actual Share Price
units: ($'s)
This is the actual weekly price per share that would be listed in the stock market, it incorporates economic, risk and random factors.

Anal_Ut_Risk = EFFDES$Risk*EFFPOS$Risk*EFFPSS$Risk*EFFPUCS$Risk*EFFLPOS$Risk
DOCUMENT: Analysts Utility Risk

THis is the required return by utility based on risk as perceived by analysts relative to S&P 500. ? Is this a measure of volatility instead? Check.

Beta_D = .2*EEFBRStock
Beta_Eq = Beta_AST+((Beta_AST-Beta_D)*DE_Ratio)
DOCUMENT: Equity Beta
(unitless)
This is the relative risk of investing in utility stock. The equation comes from pg. 186 of ref 1. (Brealey:Princ of Corp Finance)1987

Book_Value_per_Share = ((Assets-Debt)/Shares)*1E6
Cost_of_Cap = St_Dis_Rate+1
DOCUMENT: Cost of Capital
units: %
this is the average cost of obtaining equity or borrowing for the utility. The PUC uses it to determine a fair rate of return

Delay_in_Adj_MV = (.2*Ind_of_Market_Value/MV_per_Share_stable)+.01
Desired_number_of_shares_to_sell = (Des_New_Eq*1E6)/Act_share_Price
Des_New_Eq = IF(Net_cash_flow<0)
THEN((ABS(Net_cash_flow)+Taxes)*Equity_Factor*EFFMBRONE)
ELSE(0)
Dividend_Forecast = ((SMTH1(Dividends,52,1))*1E6)/(Shares)
DJ_Forecast = SMTH1(((FORCST(DJIA,52,52,.003))/DJIA)-1,52)
Equity_Factor = .4
Equity_Raised = Act_share_Price*Share_Issue_Rate/1E6
DOCUMENT: Equity Raised
Units: (mins $'s/week)
this is the cash raised through the sale of shares.

Exp_Growth = Allowed_ROE
DOCUMENT: Is expected growth determined by a forecast

Ind_of_Market_Value = MAX(Dividend_Forecast/(Rel_Growth),.005)
DOCUMENT: Indicator of market value is the result of dividend forecast and Beta for the utility or relative required return based on the risk of the investment compared to the return on bonds. If interest rates rise the relative return from utilities fall and thus the stock price because utility stocks are dividend stocks and not growth stocks

Market_to_Book_Ratio = Act_share_Price/Book_Value_per_Share
Rel_Growth = MAX(MIN(St_Dis_Rate-Exp_Growth,.5),.01)

Stock_mkt_SS = .1

St_Dis_Rate = SMTH1(T_Bill_Rate+(Beta_Eq*(Stock_mkt_SS-T_Bill_Rate)),3)

Time_Sell_Shares = 1
DOCUMENT: Time to sell Shares
Units: Weeks

T_Bill_Rate = .0535
DOCUMENT: 1 year Treasure Bill Rate
(%/100)

This the one year treasure bill rate when starting the run of the model. Must be inserted by the user.

Beta_AST = GRAPH(Anal_Ut_Risk)
(0.00, 0.208), (0.2, 0.212), (0.4, 0.22), (0.6, 0.228), (0.8, 0.242), (1, 0.264), (1.20, 0.288), (1.40, 0.322), (1.60, 0.364), (1.80, 0.422), (2.00, 0.598)
DOCUMENT: Beta is a measure of volatility and risk relative to the stock market. If Analysists Utility Risk is 1 and interest rate is .04 then Beta will be 1. Why
?

DJIA = GRAPH(TIME)
(0.00, 1000), (1.00, 962), (2.00, 920), (3.00, 900), (4.00, 900), (5.00, 920), (6.00, 910), (7.00, 900), (8.00, 900), (9.00, 890), (10.0, 900), (11.0, 950), (12.0, 1000), (13.0, 980), (14.0, 975), (15.0, 975), (16.0, 960), (17.0, 970), (18.0, 950), (19.0, 950), (20.0, 940), (21.0, 910), (22.0, 875), (23.0, 930), (24.0, 975), (25.0, 1000), (26.0, 900), (27.0, 860), (28.0, 830), (29.0, 820), (30.0, 820), (31.0, 910), (32.0, 900), (33.0, 925), (34.0, 960), (35.0, 975), (36.0, 1000), (37.0, 978), (38.0, 925), (39.0, 900), (40.0, 860), (41.0, 880), (42.0, 850), (43.0, 850), (44.0, 880), (45.0, 900), (46.0, 870), (47.0, 880), (48.0, 900), (49.0, 910), (50.0, 890), (51.0, 900), (52.0, 880)...
DOCUMENT: This is S&P total to compare against utility.

EFFDEStRisk = GRAPH(DE_Ratio)
(0.00, 0.992), (0.5, 1.00), (1.00, 1.00), (1.50, 1.00), (2.00, 1.00), (2.50, 1.01), (3.00, 1.01), (3.50, 1.02), (4.00, 1.02), (4.50, 1.05), (5.00, 1.13)

EFFMBRONE = GRAPH(Market_to_Book_Ratio)
(0.00, 0.01), (0.5, 0.35), (1.00, 0.623), (1.50, 0.84), (2.00, 1.03), (2.50, 1.25), (3.00, 1.46), (3.50, 1.61), (4.00, 1.74), (4.50, 1.85), (5.00, 1.98)

EFFSPPUC = GRAPH(Act_share_Price/INIT(Act_share_Price))
(0.00, 1.10), (1.38, 0.97), (2.76, 0.61), (4.14, 0.325), (5.52, 0.225), (6.90, 0.18), (8.28, 0.145), (9.66, 0.135), (11.0, 0.14), (12.4, 0.135), (13.8, 0.13), (15.2, 0.125), (16.6, 0.12), (17.9, 0.12), (19.3, 0.125), (20.7, 0.135), (22.1, 0.115), (23.4, 0.1), (24.8, 0.1), (26.2, 0.1), (27.6, 0.1), (29.0, 0.1), (30.3, 0.1), (31.7, 0.1), (33.1, 0.1), (34.5, 0.1), (35.9, 0.1), (37.2, 0.1), (38.6, 0.1), (40.0, 0.1)
DOCUMENT: Effect of Stock Price on PUC
If the SP of the utility falls too much the PUC will look kindly on the utility. or if it rises too fast, it will reduce the ROE.

Finance: Accounting

Accum_Dep_XA(t) = Accum_Dep_XA(t - dt) + (Dep_XA) * dt
INIT Accum_Dep_XA = 0

DOCUMENT: Accumulated Depreciation XA
Units: Millions of $'s
This is the Accumulated Contra-Asset of Straight Line Depreciation of the Utility's Capital Equipment and Property.

INFLOWS:

Dep_XA = Depreciation
DOCUMENT: Depreciation
Units: (mlns $'s/week).
Straight line reduction in worth of property plant and equipment.

ATOI_ex_Maint(t) = ATOI_ex_Maint(t - dt)
INIT ATOI_ex_Maint = ATOI +maint_labor_cost +annual_materials_cost

DOCUMENT: After tax operating income excluding maintenance cost. This includes fuel costs. No it doesn't

Book_Value_Assets(t) = Book_Value_Assets(t - dt) + (Investment - Dep_XA) * dt
INIT Book_Value_Assets = Book_Investment_Input

DOCUMENT: Net Present Value of business in millions of dollars.

Units:Millions of dollars (Mlns $'s)

INFLOWS:

- 2 -

investment = IF(Liquid_Assets)<=0 THEN(0) ELSE(Bought_Eq_Cap_Inv$+Cptl_Imp_Cash)
DOCUMENT: Investment
Unit: {mins $'s/week}
The millions of dollars investment into plant and equipment.

OUTFLOWS:

Dep_XA = Depreciation
DOCUMENT: Depreciation
Units: {mins $'s/week}
Straight line reduction in worth of property plant and equipment.

Liquid_Assets(t) = Liquid_Assets(t - dt) + (Revenues + Cash_prov_by_Financing_Activities - Costs - investment - Taxes - Dividends - Ch_RE) * dt
INIT Liquid_Assets = 5

DOCUMENT: Liquid Assets
{mins $s}

This is the amount of short term cash the utility has. If it goes negative this represents short term borrowing the utility undertakes. Eventually this is made up for by long term borrowing. Unfortunately interest charges for short term borrowing are not calculated yet.

INFLOWS:

Revenues = Bought_Revs+Prod_Revs
DOCUMENT: Revenues
{min $/week}

this is the cash flow to the utility per week. Constants:100-converts % cap util to fraction, 1000 converts per kwhs to per Mwhs, 168 converts hours to weeks, and 1E6 converts $'s to millions of dollars.

Cash_prov_by_Financing_Activities = Debt_Inc+Equity_Raised
DOCUMENT: Cash Provided by Financing Activities
Units: {mins $'s/week}
This is the total cash received by the utility to make up for cash shortfall or for investment.

OUTFLOWS:

Costs = O&MCosts+Cap_Costs
DOCUMENT: Costs
Units: {Mins $'s/week}
Total Spending by the utility.

investment = IF(Liquid_Assets)<=0 THEN(0) ELSE(Bought_Eq_Cap_Inv$+Cptl_Imp_Cash)
DOCUMENT: Investment
Unit: {mins $'s/week}
The millions of dollars investment into plant and equipment.

Taxes = .35*(Gross_Mrgin-Depreciation)+.0005*Book_Value_Assets
DOCUMENT: Taxes
Units: {mins $'s/week}

Dividends = Net_Income*Dividend_Factor
DOCUMENT: Dividends
Units: {mins $'s/week}
Dividend paid to stockholders.

Ch_RE = Net_Income-Dividends
DOCUMENT: Change in Retained Earnings
Units: {min $'s/week}
This is the left over profits which increase the value of the utility.

New_Part_Cap_Inv$(t) = New_Part_Cap_Inv$(t - dt) + (Cptl_Imp_Cash - NP_Sp_Rate) * dt
INIT New_Part_Cap_Inv$ = Book_Investment*.01
INFLOWS:

Cptl_Imp_Cash = Frac__max_alloc*Des_$_to_NP_Cap
DOCUMENT: Capital Improvement Cash
Units: {mins $'s/week}
This is the money invested in capital equipment such a new Steam Generators.

OUTFLOWS:

NP_Sp_Rate = New_Part_Cap_Inv$/4
DOCUMENT: New Part Spending Rate
Units: (mln $'s/week)
This takes into account the time it takes to actually invest the money in new parts and improve operations..

NPV_Costs(t) = NPV_Costs(t - dt) + (Chg_NPV_Costs) * dt
INIT NPV_Costs = 0

DOCUMENT: NPV of decrease or increase in Maintenance Cost above or below the initial conditions

INFLOWS:

Chg_NPV_Costs = (INIT(maint_labor_cost) +INIT(annual_materials_cost) -maint_labor_cost -annual_materials_cost)*Discount_Factor/52

NPV_Downtime(t) = NPV_Downtime(t - dt) + (Chg_NPV_Downtime) * dt
INIT NPV_Downtime = 0

DOCUMENT: Net Present Value Cost of Downtime above or below the initial level of down time

INFLOWS:

Chg_NPV_Downtime = (Downtime_CF)*Discount_Factor/52

NPV_INcome(t) = NPV_INcome(t - dt) + (Income_ch) * dt
INIT NPV_INcome = 0

DOCUMENT: Net Present Value Income
Units: (mln $'s)
This is the calculation of the NPV income for a model run. It is used for comparing different options to take into account the discounting of future operations.

INFLOWS:

Income_ch = Net_Income/((1+(.03/52))^TIME)
DOCUMENT: Net Income Change Calculation
Units: (mln $'s/week)
This sums the net income divided by the interest rate. To obtain the NPV of Income.

Retained_Earnings(t) = Retained_Earnings(t - dt) + (Ch_RE) * dt
INIT Retained_Earnings = 1

DOCUMENT: Retained Earnings
Units: (mln $'s)
These are $'s left over and retained by the utility. Their use is not specified.

INFLOWS:

Ch_RE = Net_Income-Dividends
DOCUMENT: Change in Retained Earnings
Units: (mln $'s/week)
This is the left over profits which increase the value of the utility.

annual_materials_cost = maint_materials_cost*52

Assets = Book_Value_Assets+Liquid_Assets

Bought_Eq_Cap_Inv$ = Max_bud_Parts*.1*Cap_Inv_Mult
DOCUMENT: Bought Equipment Capital Investment Dollars
(Millions of Dollars)

This is the amount of money the utility wishes to spend outright on new equipment outright instead of fixing it in the PMS system. In return the time down is assumed to be a small fraction of PMS (ignored) and the defects due to operations are assumed to go down with new equipment.

Bought_Pow_Cost = (Bought_Power/100)*Power_Rating*168*1000*(Bougth_Pow_rat/1E6)*1.2
DOCUMENT: Bought Power Cost
Units: (mln $'s/week)
This is the cost of buying electricity from other utilities.

Bought_Revs = (Bought_Power/100)*Rate_per_kWh*1000*168*Power_Rating/1E6
DOCUMENT: Bought Revenues
Units: (mlns $'s/week)
This is the cash raised through wheeling to make up for power not generated by the plant.

○ Bougth_Pow_rat = 07
DOCUMENT: Bought Power Rate
unit: ($'s/kwh)
This is the cost of buying electricity wholesale. It is higher than the total cost of producing it.

○ capacity_utilization = Min(Plant_Demand,100-Downtime%)
DOCUMENT: Capacity Utilization
units: %
This the maximum actual capacity required by the plant.

○ Capital_Costs = Cptl_Imp_Cash+Bought_Eq_Cap_Inv$

○ Cap_Costs = -Debt_payments
DOCUMENT: Capital Costs
Units: (mlns $'s/week)
These are costs which are spent on repaying debt, mostly from building the nuclear plants.

○ Cap_Inv_Mult = 1

○ Cost_Mech__Labor =
((maint_staff_avail_mech_work+total_insp_manpower)*(standard_hours+(ave_overtime))*hrly_cost_labor*Mech_EX_Fact)*Overhead_e
ffect
DOCUMENT: Cost Mechanical Labor
(million dollars/week)

○ Cost_NonMech_Labor =
(Plnrs_Maint*(standard_hours+ave_overtime)*hrly_cost_labor+((total_Estaff/EFF_reg_aband_tot_eng_and_man)*(cost_of_Eng_OT+(En
g_Yr_Sal/52))+(MGT_Annual_Sal*(total_Mgt_staff/EFF_reg_aband_tot_eng_and_man)/52)))*Overhead_effect
DOCUMENT: Cost Non-Mechanical Labor
(million dollars/week)

○ Cost_per_LS = 1
DOCUMENT: Cost per IG lawsuit
Units: Millions of Dollars

○ CROI = PCT(Investment*52/Total_Investment)
DOCUMENT: Cash Return On Investment
(percent/year)

○ Cst_Dwntme_per_prcn = (ATOI_ex_Maint+Depreciation+Annual_Fixed_Costs*.66 -maint_labor_cost
-annual_materials_cost)/(100-Expect_Dwntme%)
DOCUMENT: Downtime cost per percentage point of downtime

○ Ct_per_Insp = .02
DOCUMENT: Cost per Inspection
Units: (mlns $'s/inspection/week)
This is the cost per week of having an NRC investigation.

○ Debt_payments = PMT(U_INt_R/52,30*52,Debt,0)
DOCUMENT: Debt Payments
Units: (mln $'s/week)
These are the weekly payments to lower debt.

○ Des_$_to_NP_Cap = IF(Liquid_Assets>0) THEN(Max_bud_Parts*.1*Cap_Inv_Mult) ELSE(0)

○ Discount_Factor = 1/(((1+(Discount_Rate/(52*100)))^(Time))

○ Dividend_Factor = .75
DOCUMENT: Dividend Factor
Units: none
This is the percent of after tax profits which go to the shareholders.

○ Downtime% = capacity_dwn
DOCUMENT: Percentage of capacity down

○ Downtime_CF = IF Plant_Demand≥(100-Downtime%) then Cst_Dwntme_per_prcn*(Expect_Dwntme% -Downtime%) else 0
DOCUMENT: Cash Flow cost of downtime

○ Eng_Yr_Sal = 50000/1000000
DOCUMENT: Engineers Yearly Salary
Units: (mln $'s/year)
THis is the allocated average salary for engineers.

○ Expect_Dwntme% = 100-INIT(capacity_Online)
DOCUMENT: Expected Downtime percent

○ Fin_Error = Assets-(Liabilities+Shareholders'_Equity)
○ Forced_Shutdown_Cst = EFFForcOut*1
DOCUMENT: Forced ShutDown Cost
(Million $)
Cost of each shut down.

○ Frac_ch_RE = (Ch_RE/Retained_Earnings)*52
○ Fuel_Costs = (capacity_utilization/100)*(Power_Rating*168)*(Unit_$_Fuel+HL_Waste_MGT)
DOCUMENT: Fuel Costs
Units: (mln $'s/week)
The cost of fuel based on capacity.

○ Gross_Mrgin = Revenues-Costs
DOCUMENT: Gross Margin
Units: (mln $'s/week)
This is just Revenues minus Costs.

○ HL_Waste_MGT = 5/1E6
DOCUMENT: Waste Management Cost
(mln $s/MWe-hr)

Since waste MGT is calculated based on the amount of waste generated. It depends on amount of fuel burned thus a $/MW-hr figure is used

○ hrly_cost_labor = (30.58)/1000000
DOCUMENT: Hourly Cost Mechanic
(million dollars/year)

Originally Yearly Cost Mechanic (million dollars/year) = 4.25/81(The Yearly labor cost at the ADN Area at Sabine is 4.25 million.) Changing to hourly cost of maintenance personnel so as to account for increasing cost of overtime, etc.

○ Labor_Costs = Cost_Mech__Labor+Cost_NonMech_Labor
DOCUMENT: Labor Costs
Units: (mln $'s/week)

○ Liabilities = Debt
○ LS_cost = (Suit_Filing_Rate/100)*Cost_per_LS
DOCUMENT: Lawsuit Costs
Units: (mln $'s/week)
This is the price of lawsuits brought by anti-nuclear groups.

○ maint_cost_per_ERV = PCT((annual_materials_cost+maint_labor_cost)/replacement_investment)
○ maint_labor_cost = (Cost_Mech__Labor+Cost_NonMech_Labor)*52
○ Maint_NPV = NPV_Downtime+NPV_Costs
○ Maint_Parts_Cost = dollar_deliveries
DOCUMENT: Maintenance Parts Cost
Units: (mln $'s/week)
This is total spending on parts.

○ Net_cash_flow = Gross_Mrgin-Investment
DOCUMENT: Net Cash Flow
Units: (mln $'s/week)
This is cash after investment is taken out.

○ Net_Income = Gross_Mrgin-Taxes-Dep_XA
DOCUMENT: Net Income after Taxes.
Units: (mlns $'s/week)
This is the net profits after taxes of the utility.

○ NRC_Insp_Cost = Ct_per_Insp*NRC_Investigation_In_Progress
DOCUMENT: NRC Inspection costs
Units: (mln $'s/week)
Cost of NRC Inspections: salaries of NRC personnel, material costs supportign the local office. It does not include the utility labor costs incurred.

O&MCosts = Forced_Shutdown_Cst+Ops+Labor_Costs+LS_cost+Maint_Parts_Cost+week_fix_ct+NRC_Insp_Cost+Sought_Pow_Cost+$_on_Ed+Max_Bud_Lobby
DOCUMENT: Operations and Maintenance Costs
Units: (mins $'s/week)
Total spending on day to day generation of power.

Ops = (Ops_overhead*capacity_utilization/100)+Fuel_Costs
DOCUMENT: Operations
Units: (min $'s/week)
This is the total cost of operating the rx based on capacity.

Ops_overhead = 5
DOCUMENT: Operations Overhead
Units: (min $'s/week)
This is additional costs incurred in operations such as janitorial services, some paperwork.

Overhead_effect = 1.3

Prod_Revs = (capacity_Online/100)*(Rate_per_kWh*1000*168)*Power_Rating/1E6
DOCUMENT: Produced Revenues
Units: (mins $'s)
This is the dollars raised through power produced at the plant.

Shareholders'_Equity = Retained_Earnings+Total_Equity

Unit_$_Fuel = ((.005*1000)/1E6)
DOCUMENT: Unit Price for Fuel
(min $s/MW-hr)

This reflect .5¢/kw-hr *1000 to change to MW-hrs /1E6 to change to mins of dollars.

Weeks = TIME

week_fix_ct = Annual_Fixed_Costs/52
DOCUMENT: Weekly Fixed Cost
Units: (min $'s/week)
This is the cost of maintaining the plant, grounds and bus equipment. It is the same whether or not the plant produces electricity.

Frac__max_alloc = GRAPH(Liquid_Assets)
(0.00, 0.114), (10.0, 1.00)
DOCUMENT: Fraction of Maximum Allocation
unitless
This determines what percentage of maximum investment into capital based on the amount of liquid assets. If there are no liquid assets, no investment is made.

Plant_Demand = GRAPH(Weeks)
(0.00, 100), (24.8, 100), (49.5, 100), (74.3, 100), (99.0, 100), (124, 100), (149, 100), (173, 100), (198, 100), (223, 100), (248, 100), (272, 100), (297, 100), (322, 100), (347, 100), (371, 100), (396, 100), (421, 100), (446, 100), (470, 100), (495, 100), (520, 100)
DOCUMENT: Demand
[percent of production capacity that could be sold]

Product demand as a per cent of capacity

Finance: Bond subsector

Credit_Agencys_Perceived_Fin_Soundness(t) = Credit_Agencys_Perceived_Fin_Soundness(t - dt) + (Bond_DT) * dt
INIT Credit_Agencys_Perceived_Fin_Soundness = 70

DOCUMENT: Credit Agency's Perceived Financial Soundness
Units: (none)
This is the perceived risk of the utility defaulting on its debt on a 0-100 scale. O is default- 100 is no risk-equivalent to a AAA rating.

INFLOWS:

- Bond_DT = ((Ind_of_Credit_PFS-Credit_Agencys_Perceived_Fin_Soundness)/Time_to_Change_BR)
  DOCUMENT: Change in Bond rating with time
  Units: (/week)
  this is the change in perceived financial soundness per week.

DE_Ratio = Debt/Total_Equity
DOCUMENT: Debt to Equity Ratio
Units: (none)
This is the most common measure of financial soundness, used to determine how much relative debt a utility has.

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Time_to_Change_BR = 26*((Ind_of_Credit_PFS+Credit_Agencys_Perceived_Fin_Soundness) /Credit_Agencys_Perceived_Fin_Soundness)
DOCUMENT: Time to change Bond Rating
(weeks)
This is the time it takes the Bond Raters to change the rating of a utility. It can change rapidly if the utility's finances deteriorate but normally takes ~6 months.

Bond_Rating = GRAPH(FORCST(Credit_Agencys_Perceived_Fin_Soundness,208,104,0))
(0.00, 0.18), (11.1, 2.82), (22.2, 4.06), (33.3, 4.92), (44.4, 6.78), (55.6, 8.16), (66.7, 9.18), (77.8, 10.4), (88.9, 11.6), (100, 11.6)
DOCUMENT: This will be on a scale of 1-12 representing a rating from CCC, B-, B+, BB-, BB+, BBB-, BBB+, A-,A+, AA-,AA+, AAA.
Unit: None

EEFBRStock = GRAPH(Bond_Rating)
(0.00, 1.09), (1.20, 1.07), (2.40, 1.04), (3.60, 1.02), (4.80, 1.00), (6.00, 0.981), (7.20, 0.966), (8.40, 0.956), (9.60, 0.952), (10.8, 0.951), (12.0, 0.951)
DOCUMENT: Effect of Bond Rating on Debt Risk
(unitless)
This is the effect on Beta Debt that the bond rating generates.

EffBRPUC = GRAPH(Bond_Rating)
(0.00, 1.01), (1.20, 0.988), (2.40, 0.983), (3.60, 0.981), (4.80, 0.982), (6.00, 0.988), (7.20, 0.996), (8.40, 0.997), (9.60, 1.00), (10.8, 1.00), (12.0, 1.01)
DOCUMENT: Effect of Bond Rating of on the Public Utility Commission
Units: none
This the effect of a good bond rating on the PUC's deciding the utility management is being prudent. Also, if the the bond rating is bad enough it has the effect of artificially improving the ROE so that the utility can meet its debt obligations.

Ind_of_Credit_PFS =
GRAPH((DE_Ratio)+(PerSafByFinMark/50)+Puc_Aggreability+SMTH1(DERIVN(Total_Equity,2),26)+System_Reliability/4)
(1.00, 1.50), (1.30, 3.00), (1.60, 5.00), (1.90, 8.50), (2.20, 16.0), (2.50, 36.5), (2.80, 54.0), (3.10, 80.5), (3.40, 96.5), (3.70, 97.0), (4.00, 100)
DOCUMENT: Indicator of Credit Agency's Perceived Financial Soundness
Unit: none
This is the current indication of what the Credit agency will rate the utility if there is no delay in determination.

Finance: Debt

Debt(t) = Debt(t - dt) + (Debt_Ins - Debt_Ret) * dt
INIT Debt = 682.5

DOCUMENT: Debt
Units: (Mlns of $'s)

INFLOWS:

Debt_Ins = IF(DE_Ratio<=10) THEN(Des_Liab) ELSE(PAUSE)
DOCUMENT: Debt Incorporated
Units: (Mlns of $'s/week)
This is the amount of dollars per week incorporated.

OUTFLOWS:

Debt_Ret = ABS(Debt_payments)
DOCUMENT: Debt Retired
Units: (Mlns. $'s/week)
This is the dollars spent of debt payments.

Debt_Factor = .6
Des_Liab = IF(Net_cash_flow<0) THEN((ABS(Net_cash_flow)+Taxes)*(Debt_Factor+(Equity_Factor*(1-EFFMBRDNE))))
ELSE(0)
Stock_Equity = Book_Value_Assets-Debt

Finance: Economy and Random effects subsector

Economy_Cycles = SINWAVE(.2,520)+1
DOCUMENT: Economy Cycle Represents the cyclic effect the economy has on the stock and bond prices during expansions and recessions. 1 indicates no effect and greater than 1 indicates expansion which will tend to inflate the price and ratings

Inflation_Rate = IF(TIME>156)THEN(.04)ELSE(0)
DOCUMENT: Inflation Rate

○ Market_Effects = Economy_Cycles*(Random_Effects^1.3)*Speculation_Factor^(U_INt_Rt*TIME)
DOCUMENT: Market Effects
unitless multiplier
Total of all the other effects.

○ Random_Effects = ABS(NORMAL(1,.03))
DOCUMENT: Random Effects
unitless multiplier
This is the random jitters which occur in the stock market daily.

○ Speculation_Factor = 1
DOCUMENT: Use this factor as an additional factor to represent speculations on the financial future of the utility. Depending on the volatility of the market, this factor can give further unreliability of predition. It will be set to 1 at the start of this model.

○ Time_increase_in_Value = ((Inflation_Rate*TIME+U_INt_Rt*TIME)/2)+1
DOCUMENT: Time increase in value
%/year
this is the increase in value of stock, debt and invested assets.

○ U_INt_Rt = .04+((10-Bond_Rating)/200)
DOCUMENT: Utility INterest RAte
units: %
This is the rate the utility must pay investors on average for its bonds.

Finance: Model Parameters chosen by Management

○ Budgeted_Taxes = Des_Weekly_Profit*.36+.0006*Book_Value_Assets
DOCUMENT: Budgeted Taxes
Units: (mln $'s/week)
This is estimated taxes based on last year revenues.

○ Budget_Max = Frac_Bud_Eng+Frac_Bud_Lob+Frac_Bud_Mech+Frac_Bud_MGT+Frac_Bud_Parts
DOCUMENT: Budget Maximum
Units: none
this is the total allowed discretionary budget.

○ Bud_Div = Des_Weekly_Profit*Frac_Div
DOCUMENT: Budgeted Dividends
Units: (mln $'s/week)
This is the estimated weekly outlay for shareholders.

○ Bud_Maint_parts = Frac_Part_bud_maint_parts*Max_bud_Parts
DOCUMENT:

Maint Parts as opposed to new parts

○ cb_switch = 0
DOCUMENT: Cutback Switch
unitless
this turns on across the board utility cutbacks.

○ Desired_Return_on_Equity = .08
DOCUMENT: Desired Return on Equity
unitless
This is the utility's goal for return on Equity.

○ Des_Profit_Margin = Des_Weekly_Profit/Discretionary_budget
DOCUMENT: Desired Profit Margin
Units: %
this is the amount of profit percentage the utility desires.

○ Des_Weekly_Profit = Total_Equity*Desired_Return_on_Equity/52
DOCUMENT: Desired Weekly Profit
Units: (mln $'s/week)
This is the utility's goal of return in investment per week.

○ Discretionary_budget = (Week_budget-Required_costs-Des_Weekly_Profit)
DOCUMENT: Discretionary budget
Units: (mln $'s/week)
This is the amount of money the manager can play with each week.

○ DI_ch_from_base = 0

○ Frac_Bud_Eng = .175
DOCUMENT: Fraction of Budget for Engineers
unitless
Thsi is the desired portion of the discretionary budget for engineering.

○ Frac_Bud_Lob = .01
DOCUMENT: Fraction Budgetted for Lobbying
unitless
This is the portion of the discretionary budget allocated for lobbying

○ Frac_Bud_Mech = .525
DOCUMENT: Frac of Budget for Mechanics
unitless
Fraction of Budget allocated for Mechanical Labor.

○ Frac_Bud_MGT = .1

○ Frac_Bud_Parts = .1
DOCUMENT: Fraction Budgetted for parts.
unitless
this is the portion of the discretionary budget allocated for parts.

○ Frac_Bud_Trng = .1

○ Frac_Div = .75
DOCUMENT: Fraction for Dividends
unitless
This is the fraction of profits which go to dividends instead of retained earnings.

○ Frac_Part_bud_maint_parts = .8
DOCUMENT: Fraction of Parts budget for maintenance parts
unitless
This is the fraction of the parts budget to be spent on only maintenance parts as opposed to capital parts.

○ Fr_Lab_bud_All_Disc_insp = (.1-STEP(DI_ch_from_base,160)+STEP(DI_ch_from_base,390))

○ Insp_budget = Discretionary_budget*Frac_Bud_Mech*Fr_Lab_bud_All_Disc_insp
DOCUMENT: Inspection Budget
Units: (min $'s/week)

○ Max_Budget_Maint = (Discretionary_budget*Frac_Bud_Mech)-Insp_budget-Trng_Budget
DOCUMENT: Desired Budget Mechanics
(min $s/week)
This is the weekly desired amount of money allocated initially to mechanics.

○ Max_bud_Eng = Discretionary_budget*Frac_Bud_Eng
DOCUMENT: Maximum Budget Engineer
Units: (min $'s/week)
this is the maximum amount of money to be spent on engineers.

○ Max_Bud_Lobby = Discretionary_budget*Frac_Bud_Lob
DOCUMENT: Maximum Budget for Lobbying
Units: (min $'s/week)

○ Max_bud_MGT = Discretionary_budget*Frac_Bud_MGT
DOCUMENT: Maximum Budget Management
Units: (min $'s/week)
This is the maximum amount of money allowed to be spent on managers.

○ Max_bud_Parts = Discretionary_budget*Frac_Bud_Parts
DOCUMENT: Maximum Budget for Parts
Units: (min $'s)
This is the maximum allowed to be spent on parts.

○ MAX_Eng = Max_bud_Eng/(Eng_Yr_Sal/52)
DOCUMENT: Maximum Engineers
units: (engineers)
this is the maximum number of engineers allowed to be hired.

○ Max_Mech_Budget = Insp_budget+Max_Budget_Maint+Trng_Budget

Max_Mech_Staff = Max_Mech_Budget/(Overhead_effect*standard_hours*hrly_cost_labor*Mech_EX_Fact)
DOCUMENT: Maximum Mechanical Staff
units: (workers)
This is the maxmun number.

Max_MGT = Max_bud_MGT/(MGT_Annual_Sal/52)
MGT_Annual_Sal = 100000/1E6
DOCUMENT: Manager Annual Salary
Units: (Mlns $'s)

Profit_Message = 1-(Des_Profit_Margin+Frac_Bud_Eng+Frac_Bud_Lob+Frac_Bud_Mech+Frac_Bud_MGT+Frac_Bud_Parts)
Required_costs = (-INIT(Debt_payments)+INIT(Ops)+INIT(week_fix_ct)+INIT(Budgeted_Taxes))+INIT(Bought_Pow_Cost)
DOCUMENT: Required costs
Units: (mln $'s/week)
These are costs which the utility has little control over in the model.

Trng_Budget = Discretionary_budget*Frac_Bud_Mech*Frac_Bud_Trng*(1-STEP(Layoff_Fraction*3,200))
DOCUMENT: Training Budget
units: ($'s/week)

Week_budget = (Test_Yr_Rev/(52*1E6))*(1-Evilness)
DOCUMENT: Weekly Budget
Units: (mln $'s/week)
This is the amount of money predicted for the utility based on test year revenues.

Finance: Public Utility Commission

Ave_U_Rate(t) = Ave_U_Rate(t - dt) + (Rate_Change) * dt
INIT Ave_U_Rate = .065

DOCUMENT: Average Utility Rate
units: $'s
this is the typical utility rate in the area around the consumer which he uses to compare his utility bill to.

INFLOWS:
Rate_Change = CGROWTH(Inflation_Rate/52)*Ave_U_Rate

Cust_Per_RelRate(t) = Cust_Per_RelRate(t - dt) + (Ch_CusPer_Rate) * dt
INIT Cust_Per_RelRate = 1

DOCUMENT: customer Perceived Relative Rate
unitless
This takes into account the time delay of receiving the bills and checking out inflation etc.

INFLOWS:
Ch_CusPer_Rate = (Rel_Rate-Cust_Per_RelRate)/Delay_Rate

Puc_pere_Prud(t) = Puc_pere_Prud(t - dt) + (Change_Pere_Prud) * dt
INIT Puc_pere_Prud = .4

DOCUMENT: PUC perceived Prudence
(units of Prudence)

This is the Public Utilities Commision's decision to reward or punish the utility. Several competing factors work to raise or lower the utility's ROE. If the utility is operating safely the PUC will reward it. If it is looked at kindly in the financial markets it will also reward it respecting the opinions of advisors.

However if the utility makes too much money, the PUC will realise it is rewarding it too much so will lower the Return of Equity. Likewise if the utility is really hurting it will increase the ROE.

INFLOWS:
Change_Pere_Prud = ((Curind_Prud-Puc_pere_Prud)/Delay_Adj_PP)
DOCUMENT: Change in Perceived Prudence

Puc_Rate(t) = Puc_Rate(t - dt) + (Ch_Puc_Rate) * dt
INIT Puc_Rate = .065

DOCUMENT: PUC rate
units: $'s
this is the maximum average computed legal rate the utility may be charged based on the utility's fair rate of return.

INFLOWS:

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Ch_Puc_Rate = (All_Rate-Puc_Rate)/Puc_Delay
DOCUMENT: Change in PUC allowed Rate
Units: ($'s/week)

Rate_Base(t) = Rate_Base(t - dt) + (Con&Cap_Inv - PUC_Ch_RB - Decomm) * dt
INIT Rate_Base = Book_Investment_Input

DOCUMENT: Rate Base
(millions of Dollars)

Dollar Amount of Capital which the PUC decides to include in determining Rate of Return

INFLOWS:

Con&Cap_Inv = investment
DOCUMENT: Construction and Capital Investment
Units: (mln $'s/week)
this is the total investmetn in the utility

OUTFLOWS:

PUC_Ch_RB = -EffPUCRB*(Rate_Base/INIT(Rate_Base))/RBDECdelay
DOCUMENT: PUC change in Rate Base
Units: (mln $'s/week)
This is the change in rate base determined only by the PUC's decision to disallow additions to the rate base.

Decomm = Dep_XA
DOCUMENT: Decommisioning
Units: (mln $'s/week)
This is how depreciation of plant flows out of the rate base.

Allowed_ROE = (Cost_of_Cap-1)*EFFPucROE*(1-Evilness)
DOCUMENT: Allowed Return on Equity
(%)

This is the allowed return on ratebase proposed as derived from the PUC's perceived prudence.

All_Rate =
((((Allowed_ROE/52)*Rate_Base)+(Utility_Req_Total*(1-Evilness)*(Test_Yr_$%kwh/Est_Yr_costperkwh))+Pass_Through)*1E6)/(Power_Rating*1E3*168)
DOCUMENT: Allowed Rate
($/kwh)
This is the average cost per kwh indicated by the PUC's decision standard. Allowed_ROE/5200+1

Comp_Rate = (.05+(1-Comp_switch)*.06)+(-.001*RAMP(.06,100)+.001*RAMP(.06,300))*Comp_switch
DOCUMENT: Competitor's rate
This is the rate a competitor is charging. the utility must come close to matching this rate or lose customers. IN the model the utility automatically makes it's price 1.1*Comp Rate.

Comp_switch = 0

Curind_Prud = EFFSPPUC*EFFCaprel_frost*EffBRPUC*EFFCUSPUC*EffPSPUC*EFFPIPUC*(1-Evilness)
DOCUMENT: Current Indicator of Prudence
units: prudes
This is the product of all of the factors which influence the PUC's perceived view of how the utility management is running the plant.

Current_Yr_Costs = SMTH1(((Costs+Taxes)*52*1E6,13)
DOCUMENT: Current Year Costs
Units: (mln $'s/week)
That is the total weekly costs averaged over the past year.

Current_Yr_MW_Sales = SMTH1(((capacity_utilization+Bought_Power)/100)*Power_Rating*52*1000*168,13)+1
DOCUMENT: Current Year MegaWatt Sales
Units: (Megawatts)
This is the estimated number of megawatts the utility believes it will sell this year.

Cust_Sat = System_Reliability*EFFPOCusest*EFFCPRCS
DOCUMENT: Customer Satisfaction
unitless
this is the product of the three factors which influence customer satisfaction.

Delay_Adj_PP = MAX((Curind_Prud*EffPSPUC)/Puc_perc_Prud,52)
DOCUMENT: Delay in Adjusting perceived prudence

Delay_Rate = (Cust_Per_RelRate/Rel_Rate)*4
DOCUMENT: Delay Rate
(weeks)
This is the delay from enactment that a change in rates starts to affect customer perception. For minor changes it is the time it takes him to get the bill. For increases it gets shorter since the newspapers will invariably cover them.

Est_Yr_costperkwh = Current_Yr_Costs/Current_Yr_MW_Sales
DOCUMENT: Estimated Yearly cost per Kwh
Units: ($'s/kwhr)
This is the predicted future rate requirements to make up for costs based on the last year's performance.

Est_Yr_Rev = SMTH1(Revenues*52*1E6,52)+1000000
DOCUMENT: Estimated Yearly Revenues
Units: (min $'s/week)
This is the average weekly revenues averaged over the last year to determine if the utility believes it will have a shortfall in which case it will markup its request.

Evilness = Evil_Amount*(0+STEP(Evil_Puc_Fun,100))
DOCUMENT: Evilness
Units: hades
This is in the utility's view, a measure of how much the PUC suddenly reduces the rate of return. It is not dependent on any outside variables and can change based on PUC political changes.

Evil_Amount = .055
DOCUMENT: Evil Amunt
This is the percentage reductions in ROE the change in PUC political makeup has on the utility.

Evil_Puc_Fun = 0
DOCUMENT: Evil Puc Function
1 turns evil PUC on, 0 is a benevolent PUC (to the utility)

For_Cap = .80

Markup = IF(Current_Yr_Costs/Est_Yr_Rev<1)THEN(1)ELSE((Current_Yr_Costs+Bud_Div*52)/Est_Yr_Rev)
DOCUMENT: Markup
unitless
the utility adds on some extra requirements for income if it has not received enough award in the past from the PUC.

O&M = Ops

Pass_Through = O&M
DOCUMENT: Pass Through costs
Units: (min $'s/week)
This is the rate portion that rate payers automatically pay for.

Power_Rating = 1000
DOCUMENT: Power Rating
(kwh)
This is the number of kwh generated per time period (week) to determine revenues.

Puc_Aggreability = Puc_Rate/Utility_Req_Total
DOCUMENT: PUC Aggreability
Units: none
This the ratio of the utility's requested rate to the PUC's awarded rate. It is a measure of how financial institutions rate whether the utility will receive future rate hikes.

Puc_Delay = ((All_Rates/(Puc_Rate+.0001))*26)+8

Rate_per_kWh = MAX(MIN(Puc_Rate,Comp_Rate*1.1),.01)
DOCUMENT: Rate per KiloWatt-Hour
units: ($/kWh)
This is the rate in dollars per kilowatt hour on average for the electricity the nuclear plant sells. It is, in effect, just allowed revenues/net power produced.

RBDECdelay = 52
DOCUMENT: Rate Base Decision Delay
units: weeks
This is the time is normally takes to determine a rate base decision.

○ Rel_Rate = Rate_per_kWh/Ave_U_Rate
DOCUMENT: Relative Rate
unitless
this it the ratio of the utility's rate to the average rate in the area to determine how angry the customersare

○ System_Reliability = .995
DOCUMENT: It represents the capacity relative to demand not made up for by purchased power.

○ Test_Yr_$%kwh = Test_Yr_Rev/Test_Yr_Sales
DOCUMENT: Test year cents per kilowatt hour
units: $'s/kw-hr
This is the average cost of electricity during an average year picked by the PUC.

○ Test_Yr_Rev = INIT(Revenues)*52*1E6
DOCUMENT: Test Year Revenues
Units: (min $'s/week)
this is the total average dollars earned per week in an average year chosen by the PUC.

○ Test_Yr_Sales = INIT(capacity_utilization)/100*INIT(Power_Rating)*52*1000*168
DOCUMENT: Test Year Sales
Units: (min $'s)
Based on a previous operating year, usually switched every 5 years or so, the average revenues of the utility are determined to see how much money the utility would normally earn and to budget costs.

○ Utility_Req_Total = SMTH3(Markup*(Costs+Taxes-Ops),26)
DOCUMENT: Utility Requested Total
Units: (min $'s/week)
this is the utility presented revenue requirement minus pass Through.

⊘ EFFCaprel_frcst = GRAPH(((capacity_utilization/100)+.8*Per_Outage)/For_Cap)
(0.00, 0.971), (0.15, 0.978), (0.3, 0.986), (0.45, 0.993), (0.6, 1.00), (0.75, 1.01), (0.9, 1.01), (1.05, 1.02), (1.20, 1.02), (1.35, 1.02), (1.50, 1.03)
DOCUMENT: Effect of Capacity Relative to Forcast
unitless
This is the negative or positive effect on the PUC of the utility correctly predicting its capacity factor.

⊘ EFFCPRCS = GRAPH(Cust_Per_RelRate)
(0.00, 1.07), (0.5, 1.04), (1.00, 1.00), (1.50, 0.756), (2.00, 0.552), (2.50, 0.426), (3.00, 0.342), (3.50, 0.222), (4.00, 0.108), (4.50, 0.036), (5.00, 0.00)
DOCUMENT: Effect of Customer Perceived Relative Rate on Customer Satisfaction

⊘ EFFCUSPUC = GRAPH(Cust_Sat)
(0.00, 0.214), (0.1, 0.569), (0.2, 0.684), (0.3, 0.731), (0.4, 0.749), (0.5, 0.754), (0.6, 0.767), (0.7, 0.786), (0.8, 0.83), (0.9, 0.916), (1.00, 1.00), (1.10, 1.10)

⊘ EffPUCRB = GRAPH(Pus_perc_Prud)
(0.00, -0.194), (0.0345, -0.129), (0.069, -0.064), (0.103, -0.039), (0.138, -0.018), (0.172, -0.01), (0.207, -0.006), (0.241, -0.004), (0.276, 0.00), (0.31, 0.00), (0.345, 0.00), (0.379, 0.00), (0.414, 0.00), (0.448, 0.00), (0.483, 0.00), (0.517, 0.00), (0.552, 0.00), (0.586, 0.00), (0.621, 0.00), (0.655, 0.00), (0.69, 0.00), (0.724, 0.00), (0.759, 0.00), (0.793, 0.00), (0.828, 0.00), (0.862, 0.00), (0.897, 0.00), (0.931, 0.006), (0.966, 0.016), (1, 0.088)
DOCUMENT: Effect of the PUC's Perceived Prudence on the Rate Base.
unitless
This is how the PUC will change the rate base if they don't feel the utility is prudent.

⊘ EFFPucROE = GRAPH(Pus_perc_Prud)
(0.00, -0.808), (0.1, [illegible]), (0.2, 0.068), (0.3, 0.306), (0.4, 0.572), (0.5, 0.812), (0.6, 0.982), (0.7, 1.04), (0.8, 1.23), (0.9, 1.33), (1, 1.38)
DOCUMENT: Effect of [illegible] on Return on Equity
units: %/prude
This is the effect on the Fair Rate of Return the PUCs attitude toward the utility is.

⊘ EFFPUCStRisk = GRAPH(Pus_Aggreability)
(0.00, 1.36), (0.1, 1.28), (0.2, 1.20), (0.3, 1.16), (0.4, 1.11), (0.5, 1.07), (0.6, 1.04), (0.7, 1.01), (0.8, 0.997), (0.9, 1.00), (1, 1.00)
DOCUMENT: Effect of PUC Aggreability on Stock
(unitless)

A graph of the effect from the previous allowed ROE on Stock Price

Finance: Safety Fin subsector

PerSafByFinMark(t) = PerSafByFinMark(t - dt) + (ChPerSaf) * dt
INIT PerSafByFinMark = CurIndPerSaf

DOCUMENT: Perceived Safety By Financial Markets
Units: none
This is a measure of how the Financial Markets measure the risk of loosing the reactor due to an accident. It is different than what the public, engineers, or NRC use to determine the risk of a core melt.

INFLOWS:
ChPerSaf = (CurIndPerSaf-PerSafByFinMark)/Delay_in_adj_Saf_perc

EffPSPUC = IF(Evil_Puc_Fun)THEN(EFFPSPUC_E)ELSE(EFFPSPUC_G)
DOCUMENT: Effect of Perceived Safety on PUC
If the plant is safe the PUC will believe that the management is prudent.

Utility_Ave_SALP = SMTH3(SALP,208,3)*Event_Effect
DOCUMENT: Utility Average SALP
unitless
This is the average nationwide salp rating financial people use to compare our utility in terms of performance.

CurIndPerSaf = GRAPH(EFFFOPS*EFFLPOPerSaf*EFFOpsPS*EFFPOPerSaf*EFFSRPS*Event_Effect)
(0.00, 0.00), (0.22, 5.00), (0.44, 30.0), (0.66, 40.0), (0.88, 55.0), (1.10, 65.0), (1.32, 80.0), (1.54, 95.0), (1.76, 99.0), (1.98, 99.0), (2.20, 100)
DOCUMENT: Perceived Safety represents the public, financial and PUC's relative perception of how safe a utility is. The model assumes that although the absolute value of the effects of the safety indicators are different, their rough relative value is the same. Thus if the Puc thinks that a utility is unsafe so do the financial markets. This "perceived safety" measures the safety of the plant as well as the rest of the industry because if other plants are unsafe, public perception of even safe plants is obviously affected.

Delay_in_adj_Saf_perc = GRAPH(CurIndPerSaf-PerSafByFinMark)
(-100, 13.5), (-80.0, 15.0), (-60.0, 16.0), (-40.0, 18.0), (-20.0, 21.0), (0.00, 39.0), (20.0, 52.0), (40.0, 78.0), (60.0, 104), (80.0, 117), (100, 129)

EFFFOPS = GRAPH(EFFForcOut)
(0.00, 0.999), (0.1, 0.988), (0.2, 0.981), (0.3, 0.976), (0.4, 0.973), (0.5, 0.97), (0.6, 0.966), (0.7, 0.961), (0.8, 0.957), (0.9, 0.954), (1, 0.951)
DOCUMENT: Effect of Forced Outages on Perceived Safety
This is the effect recent Forced Outages have on perceived safety by the financial community.

EFFOpsPS = GRAPH(capacity_Online+(Per_Outage*100))
(0.00, 0.948), (10.0, 0.952), (20.0, 0.957), (30.0, 0.96), (40.0, 0.963), (50.0, 0.968), (60.0, 0.975), (70.0, 0.989), (80.0, 1.00), (90.0, 1.01), (100, 1.02)
DOCUMENT: Effect of Ops on Perceived Safety
unitless
This is the effect of capacity rating on perception of reactor safety by financial community.

EFFPSFM = GRAPH(DERIVN(PerSafByFinMark,1))
(-20.0, -30.0), (-16.0, -21.8), (-12.0, -15.1), (-8.00, -8.90), (-4.00, -2.52), (0.00, 0.00), (4.00, 1.68), (8.00, 2.73), (12.0, 3.42), (16.0, 4.30), (20.0,, 5.00)
DOCUMENT: This factor represents the impact a change in perceived safety has on the financial markets. It creates the sawtooth reference mode of the impact on financial markets being drastically negative when safety drops but lukewarm positive when safety improves.

EFFPSPUC_E = GRAPH(PerSafByFinMark)
(0.00, 0.2), (10.0, 0.206), (20.0, 0.206), (30.0, 0.336), (40.0, 0.43), (50.0, 0.511), (60.0, 0.601), (70.0, 0.7), (80.0, 0.8), (90.0, 0.96), (100, 1.06)
DOCUMENT: Effect of Perceived Financial Safety of Utility on PUC
(unitless)
This is the effect the financial perceived safety of the reactor has on the PUC's prudence. As safety drops, the prudence drops. However, at a certain point, the safety drops so low that punishing the utility monetarily will probable cause them to go bankrupt with no hope of ever getting better safety. So, assuming a benevolent PUC, when safety becomes low enough it starts giving the utility rate increases under the auspices of improving the utility.

EFFPSPUC_G = GRAPH(PerSafByFinMark)
(0.00, 0.983), (5.00, 0.3), (10.0, 0.2), (15.0, 0.281), (20.0, 0.322), (25.0, 0.344), (30.0, 0.367), (35.0, 0.396), (40.0, 0.425), (45.0, 0.443), (50.0, 0.466), (55.0, 0.502), (60.0, 0.56), (65.0, 0.66), (70.0, 0.7), (75.0, 0.75), (80.0, 0.8), (85.0, 0.85), (90.0, 0.9), (95.0, 0.96), (100, 1.10)
DOCUMENT: Effect of Perceived Financial Safety of Utility on PUC
(unitless)
This is the effect the financial perceived safety of the reactor has on the PUC's prudence. As safety drops, the prudence drops. However, at a certain point, the safety drops so low that punishing the utility monetarily will probable cause them to go bankrupt with no hope of ever getting better safety. So, assuming a benevolent PUC, when safety becomes low enough it starts giving the utility rate increases under the auspices of improving the utility.

EFFPSStRisk = GRAPH(PerSafByFinMark)
(0.00, 1.55), (10.0, 1.55), (20.0, 1.51), (30.0, 1.39), (40.0, 1.29), (50.0, 1.21), (60.0, 1.12), (70.0, 1.05), (80.0, 1.01), (90.0, 0.96), (100, 0.96)
DOCUMENT: Effect of Perceived Safety on Stock Risk
This si the effect the risk of core melt has on stock price.

EFFSRPS = GRAPH(SALP)
(1.00, 1.20), (1.30, 1.17), (1.60, 1.15), (1.90, 1.11), (2.20, 1.06), (2.50, 0.96), (2.80, 0.906), (3.10, 0.856), (3.40, 0.832), (3.70, 0.812), (4.00, 0.8)
DOCUMENT: Effect of Safety Rating on Perceived Safety
This is the combination of Salp scores to influence Perceived Safety.

Event_Effect = GRAPH(Event_Switch*(STEP(1,156)-SMTH3(STEP(.96,166),62)))
(0.00, 0.999), (0.1, 0.979), (0.2, 0.953), (0.3, 0.915), (0.4, 0.881), (0.5, 0.856), (0.6, 0.834), (0.7, 0.809), (0.8, 0.794), (0.9, 0.775), (1, 0.75)
DOCUMENT: Event Effect
This takes into account the time over which the event's effects impact the public significantly (~10 weeks)

Government: NRC

NRC_Inspection_Backlog(t) = NRC_Inspection_Backlog(t - dt) + (Insp_Planning - PlantInspecting) * dt
INIT NRC_Inspection_Backlog = BaseInspRate
INFLOWS:
Insp_Planning = AdjustedInspectionRate
OUTFLOWS:
PlantInspecting = NRC_Inspection_Backlog/Time_to_Inspect

NRC_Investigation_In_Progress(t) = NRC_Investigation_In_Progress(t - dt) + (Investigations_Initated - Investigations_Completed) * dt
INIT NRC_Investigation_In_Progress = Init_NRC_InvIP

DOCUMENT: NRC Processed Information
[pages/year]

Before initiating any action the NRC performs various investigations and studies. This level provides and indication of the amount of research being undertaken

INFLOWS:
Investigations_Initated = (Indicated_NRC_Invest_IP-NRC_Investigation_In_Progress)/Response_Time
DOCUMENT: Investigations Initiated
[investigations/week]

OUTFLOWS:
Investigations_Completed = NRC_Investigation_In_Progress/Ave_Res_Proj_Duration
DOCUMENT: Investigations Completed
[investigations/week]

NRC_Regulations_in_Development(t) = NRC_Regulations_in_Development(t - dt) + (initiating_regulation - Abandoning_Reg_Effort - enacting_regulation) * dt
INIT NRC_Regulations_in_Development = Init_NRC_RegID

DOCUMENT: NRC Regulations in Development
[pages regulations or statutes]

INFLOWS:
initiating_regulation = Report_Ratio*Ave_Regulations_Sought_per_Report*Reports_Completed
DOCUMENTR: Initiating Regulation
[pages regulations/week]

OUTFLOWS:
Abandoning_Reg_Effort = NRC_Regulations_in_Development/(Ave_Life_of_Unsuccessful_Reg_Efforts)+regulations_abandoned_from_NEI_effort
DOCUMENT: Discarding (Pages/month)

enacting_regulation = NRC_Regulations_in_Development/time_to_enact_regulation
DOCUMENT: Enacting Regulation
[pages regulations/week]

☐ NRC_Reports_In_Progress(t) = NRC_Reports_In_Progress(t - dt) + (NRC_Reports_Initiated - Reports_Completed) * dt
INIT NRC_Reports_In_Progress = Init_NRC_RepIP

DOCUMENT: NRC Reports In Progress
[Reports]

INFLOWS:

NRC_Reports_Initiated = Ave_No_Reports_Per_Res_Proj*Investigations_Completed
DOCUMENT: NRC Reports Initiated
[reports/week]

OUTFLOWS:

Reports_Completed = NRC_Reports_In_Progress/Ave_Time_to_Publish_Report
DOCUMENT: Reports Completed
[Reports/week]

☐ Regulations_on_Books(t) = Regulations_on_Books(t - dt) + (enacting_regulation - Discarding_Regulations) * dt
INIT Regulations_on_Books = Init_NRC_RegOB

DOCUMENT: Regulations on Books
[thousands pages regulations]

INFLOWS:

enacting_regulation = NRC_Regulations_In_Development/time_to_enact_regulation
DOCUMENT: Enacting Regulation
[pages regulations/week]

OUTFLOWS:

Discarding_Regulations = Regulations_on_Books/800
DOCUMENT: Discarding Regulations
[pages/week]

Changed from /520 to /800

○ AdjustedInspectionRate = IndicatedInspectionRate*SocialEffNRC*EFFCLNRC
DOCUMENT: Adjusted Inspection Rate
[Inspections/week]

○ Ave_Life_of_Unsuccessful_Reg_Efforts = 2*52
DOCUMENT: Average Life of Unsuccessful Regulatory Efforts
[weeks]

○ Ave_No_Reports_Per_Res_Proj = 1
DOCUMENT: Average Number Reports per Research Project
[reports/investigation]

○ Ave_Regulations_Sought_per_Report = .1
DOCUMENT: Average Regulations Sought per Report
[Statute per NRC Report]

○ Ave_Res_Proj_Duration = 1*52
DOCUMENT: Average NRC Research Project Duration
[weeks]

○ Ave_Time_to_Publish_Report = 1*52
DOCUMENT: Average Time to Publish Report
[weeks]

○ BaseInspRate = 3/52
DOCUMENT: Base Inspection Rate
[inspections/week]

Base level of inspections per plant per week
(3 per year)

○ Desired_NRC_Research = INIT(NRC_Investigation_In_Progress)

IndicatedInspectionRate = BaseInspRate+Special_Requirement_for_Inquiry
DOCUMENT: Indicated Inspection Rate
[inspections/week]

Indicated_NRC_Invest_IP = EFFBdwnNRCInv*EFFBdwnNRCInv_P2_2*EffOpsNRCInv*Insp_Ratio*Desired_NRC_Research
DOCUMENT: Indicated NRC Investigations in Progress
[investigations]

Insp_Ratio = PlantInspecting/BaseInspRate

NRC_Evilness = 0.0
DOCUMENT: .15 is nice effect !
Run with and without removal of regs within the info sector

Reg_Ratio = Regulations_on_Books/SMTH3(Regulations_on_Books,26)

Response_Time = 3*4
DOCUMENT: Response Time
[weeks]

(3 months * 4 weeks/month)

SocialEfNRC = EFFMNRC*EFFPINRC

Special_Requirement_for_Inquiry = (EFFBdwnNRCIn+EFFOpsNRCIn+EFFBdwnNRCIn_2+EFFsitealandemerg_NRCIns)*(1+NRC_Evilness)
DOCUMENT: Special Requirement for Inquiry
[Inspections/week]

Events and informants at plants that create added incentives to inspect.

time_to_enact_regulation = 1*52
DOCUMENT: Time to Enact Regulation
[weeks]

Time_to_Inspect = 4
DOCUMENT: Time to Inspect
[weeks]

EFFBdwnNRCIn = GRAPH(frac_equip_bdown)
(0.00, 0.00), (0.1, 0.00), (0.2, 0.00), (0.3, 0.005), (0.4, 0.0175), (0.5, 0.0775), (0.6, 0.168), (0.7, 0.307), (0.8, 0.45), (0.9, 0.492), (1, 0.5)
DOCUMENT: Effect of Events on NRC
[Inspections/week]

The number of additional inspections initiated because of consistant equipment breakdowns.

EFFBdwnNRCInv = GRAPH(frac_equip_bdown)
(0.00, 0.937), (0.1, 0.987), (0.2, 1.01), (0.3, 1.02), (0.4, 1.04), (0.5, 1.12), (0.6, 1.19), (0.7, 1.24), (0.8, 1.28), (0.9, 1.29), (1, 1.30)
DOCUMENT: Effect Breakdowns NRC Investigation
[unitless multiplier]

EFFBdwnNRCInv_P2 = GRAPH(t_bdwns_P2)
(0.00, 1.00), (0.1, 1.00), (0.2, 1.01), (0.3, 1.02), (0.4, 1.05), (0.5, 1.12), (0.6, 1.19), (0.7, 1.24), (0.8, 1.28), (0.9, 1.29), (1, 1.30)
DOCUMENT: Effect Breakdowns NRC Investigation
[unitless multiplier]

EFFBdwnNRCInv_P2_2 = GRAPH(t_bdwns_P2)
(0.00, 1.00), (0.1, 1.00), (0.2, 1.01), (0.3, 1.04), (0.4, 1.31), (0.5, 1.73), (0.6, 2.07), (0.7, 2.48), (0.8, 2.71), (0.9, 2.86), (1, 2.98)
DOCUMENT: Effect Breakdowns NRC Investigation
[unitless multiplier]

EFFBdwnNRCIn_2 = GRAPH(t_bdwns_P2)
(0.00, 0.00), (0.1, 0.00), (0.2, 0.00), (0.3, 0.005), (0.4, 0.0175), (0.5, 0.0775), (0.6, 0.168), (0.7, 0.307), (0.8, 0.45), (0.9, 0.492), (1, 0.5)
DOCUMENT: Effect of Events on NRC
[Inspections/week]

The number of additional inspections initiated because of consistant equipment breakdowns.

EFFGAPO = GRAPH(Reg_Ratio*Insp_Ratio)
(0.7, 1.03), (0.76, 1.00), (0.82, 1.00), (0.88, 1.00), (0.94, 1.00), (1.00, 1.00), (1.06, 0.988), (1.12, 0.982), (1.18, 0.979), (1.24, 0.973), (1.30, 0.955)
DOCUMENT: Effect of Government Action on Public Concern
[unitless]

Government action or inaction may heighten or lessen public fears.

EFFNRCInvMGTENG = GRAPH(Investigations_Initated/INIT(Investigations_Initated))
(0.00, 0.998), (0.5, 0.986), (1.00, 0.981), (1.50, 0.948), (2.00, 0.908), (2.50, 0.848), (3.00, 0.752), (3.50, 0.692), (4.00, 0.64), (4.50, 0.618), (5.00, 0.602)
DOCUMENT: As investigations increase engineers and managers are siphoned off for working with the NRC for answering questions, etc. They are taken from the maintenance staff.

EFFNRCInvminsp = GRAPH(NRC_Investigation_In_Progress/INIT(NRC_Investigation_In_Progress))
(1.00, 1.02), (2.00, 1.10), (3.00, 1.15), (4.00, 1.25), (5.00, 1.48), (6.00, 1.82), (7.00, 2.30), (8.00, 2.85), (9.00, 3.90), (10.0, 5.97)

EFFNRCminsp = GRAPH(1*Regulations_on_Books/INIT(Regulations_on_Books))
(1.00, 1.00), (4.00, 6.00)

EFFNRCRDDIMI = GRAPH(NRC_Regulations_In_Development/INIT(NRC_Regulations_In_Development))
(1.00, 1.00), (1.50, 1.15), (2.00, 1.32), (2.50, 1.70), (3.00, 2.00), (3.50, 2.35), (4.00, 2.70), (4.50, 3.23), (5.00, 4.00), (5.50, 4.85), (6.00, 5.90)
DOCUMENT: Effect of NRC Regulations in Development on Desired Discretionary Inspections and Mandatory Inspections

EFFNRCrepmi = GRAPH(NRC_Reports_In_Progress/INIT(NRC_Reports_In_Progress))
(1.00, 1.00), (1.10, 1.03), (1.20, 1.12), (1.30, 1.29), (1.40, 1.38), (1.50, 1.43), (1.60, 1.51), (1.70, 1.57), (1.80, 1.61), (1.90, 1.66), (2.00, 1.70)
DOCUMENT: Effect of NRC reports on Mandatory and Discretionary Inspections

This is a multiplier to increase inspections based on reports.

EFFOpsNRCIn = GRAPH(capacity_Online+(100*Per_Outage))
(0.00, 0.5), (10.0, 0.138), (20.0, 0.05), (30.0, 0.0275), (40.0, 0.0125), (50.0, 0.005), (60.0, 0.00), (70.0, 0.00), (80.0, 0.00), (90.0, 0.00), (100, 0.00)
DOCUMENT: Effect of Informants on NRC
[Inspections/week]

The number of inspections added because of poor operating performance.

EffOpsNRCInv = GRAPH(capacity_Online+(100*Per_Outage))
(0.00, 1.24), (10.0, 1.17), (20.0, 1.10), (30.0, 1.06), (40.0, 1.03), (50.0, 1.02), (60.0, 1.00), (70.0, 1.00), (80.0, 1.00), (90.0, 0.997), (100, 0.709)
DOCUMENT: Effect Operations NRC Inventory
[unitless multiplier]

Report_Ratio = GRAPH(NRC_Reports_In_Progress/Init_NRC_RepIP)
(0.00, 0.04), (0.2, 0.12), (0.4, 0.27), (0.6, 0.47), (0.8, 0.71), (1, 1.00), (1.20, 1.09), (1.40, 1.19), (1.60, 1.42), (1.80, 1.72), (2.00, 1.98)

Government: Congress

Concerned_Lmkrs(t) = Concerned_Lmkrs(t - dt) + (Changing_Opposition - FadingLmkrConcern) * dt
INIT Concerned_Lmkrs = .1*Lawmakers

DOCUMENT: Concerned Lawmakers
[Congress people]

The number of lawmakers in congress who are significantly concerned over nuclear power plant safety.

INFLOWS:

Changing_Opposition = (C_Ind_Lmkr_Limits-Concerned_Lmkrs)/Lmkr_Adj_Time
DOCUMENT: Changing Opposition
[lawmakers/weeks]

The rate at which congressional opposition to nuclear power changes in the U.S. House and Senate.

OUTFLOWS:

FadingLmkrConcern = Concerned_Lmkrs/AveLmkrMemory
DOCUMENT: Fading Lawmaker Concern
[lawmakers/week]

Number of lawmakers whose fear of nuclear safety dissipates.

EFFForcOut(t) = EFFForcOut(t - dt) + (PBeff_Rate - Fade_PB_eff) * dt
INIT EFFForcOut = 0

DOCUMENT: Effect of Forced Outage
Eff from forced outage is a stock to represent the time to buildup of the effect on other sectors and the time to cool off. It represents the time to determine the cause of S/D and resume start up. An average length of S/D per forced outage is used.

INFLOWS:
PBeff_Rate = (Plant_Force_Out-.5)
OUTFLOWS:
Fade_PB_eff = EFFForcOut/Fade_Time

AveLmkrMemory = 20

C_Ind_Lmkr_Limits = MAX(MIN(535,Indicated_Concerned_Lmkrs),40)
DOCUMENT: Indicated Lawmaker Concern Limits
[lawmakers]

Upper and lower bounds for the number of concerned lawmakers (0 to 535).

Fade_Time = MAX(NORMAL(1.5,.25),0)

Indicated_Concerned_Lmkrs = Concerned_Lmkrs*Net_Effect_on_Lmkrs
DOCUMENT: Indicated Concerned Lawmakers
[lawmakers]

Lmkr_Adj_Time = 6*Concerned_Lmkrs/Indicated_Concerned_Lmkrs
DOCUMENT: Lawmaker Adjustment Time
[weeks]

The average time to shift congressional support from one position to another. (3 months)

Net_Effect_on_Lmkrs = EFFBdwnLM*EFFMLM*EFFPOLM*EFFPILM*EFFBdwnLM_P2*EFFLOB_LM*EFFSALPnet_pub_opp
DOCUMENT: Net Effect on Lawmakers
[unitless]

A variety of factors affect a congress person's position regarding nuclear power. This variable calculates the net effect of various factors operating on congress in relation to nuclear power.

EFFBdwnLM = GRAPH(frac_equip_bdown+EFFForcOut)
(0.00, 0.982), (0.1, 1.00), (0.2, 1.00), (0.3, 1.00), (0.4, 1.00), (0.5, 1.01), (0.6, 1.04), (0.7, 1.07), (0.8, 1.10), (0.9, 1.13), (1. 1.15)
DOCUMENT: Effect plant Breakdowns on Lawmakers
[unitless multiplier]

EFFBdwnLM_P2 = GRAPH(t_bdwns_P2)
(0.00, 0.946), (0.1, 1.00), (0.2, 1.00), (0.3, 1.00), (0.4, 1.00), (0.5, 1.01), (0.6, 1.04), (0.7, 1.10), (0.8, 1.21), (0.9, 1.26), (1. 1.29)
DOCUMENT: Effect plant Breakdowns on Lawmakers
[unitless multiplier]

EFFCLM = GRAPH(Concerned_Lmkrs)
(0.00, 1.00), (25.0, [illegible]), (50.0, [illegible]), (75.0, 1.07), (100, 1.10), (125, 1.12), (150, 1.15), (175, 1.17), (200, 1.20), (225, 1.22), (250, 1.25)

EFFCLNRC = GRAPH(Concerned_Lmkrs)
(0.00, 0.7), (25.0, [illegible]), (50.0, 1.0[illegible]), (75.0, 1.04), (100, 1.06), (125, 1.07), (150, 1.10), (175, 1.15), (200, 1.21), (225, 1.26), (250, 1.30)
DOCUMENT: Effect of Concerned Lawmakers on NRC Concern
[unitless multiplier]

Multiplier

EFFCLPI = GRAPH(Concerned_Lmkrs)
(0.00, 1.00), (25.0, 1.02), (50.0, 1.05), (75.0, 1.07), (100, 1.10), (125, 1.12), (150, 1.15), (175, 1.18), (200, 1.20), (225, 1.23), (250, 1.25)

EFFLOB_LM = GRAPH(Max_Bus_Lobby)
(0.00, 1.20), (1.00, 0.985), (2.00, 0.979), (3.00, 0.977), (4.00, 0.974), (5.00, 0.972), (6.00, 0.97), (7.00, 0.967), (8.00, 0.968), (9.00, 0.965), (10.0, 0.96)

Government: RATING DET

SALP(t) = SALP(t - dt) + (CHSALP) * dt
INIT SALP = 2.5

DOCUMENT: Safety Assessment and Liscensing Procedure.
this is the rating 1-4, 1 being best of the operations of the nuclear plant.

INFLOWS:

CHSALP = (SALPBounds-SALP)/Time_to_ChSalp

CurIndSALP = (Engineering+Maintenance+Plant_Operations+Support)/4

SALPBounds = MIN(MAX(CurIndSALP,1),4)

Time_to_ChSalp = 52*CurIndSALP/SALP

EFF_rep_analysis_ratio_SALP = GRAPH(report_analysis_ratio)
(0.00, 2.49), (0.1, 2.44), (0.2, 2.25), (0.3, 2.02), (0.4, 1.51), (0.5, 1.23), (0.6, 1.14), (0.7, 1.08), (0.8, 1), (0.9, 0.929), (1, 0.807)

EFF_SALP_info = GRAPH(SALP)
(1.00, 0.00), (1.50, 0.00), (2.00, 0.00), (2.50, 0.00), (3.00, 0.05), (3.50, 0.1), (4.00, 0.1)

Engineering = GRAPH(IF eng_workload<.60 THEN .60*INIT(av_qual_specs)/av_qual_specs ELSE eng_workload*INIT(av_qual_specs)/av_qual_specs)
(0.2, 1.00), (0.58, 2.00), (0.96, 2.00), (1.34, 2.00), (1.72, 2.00), (2.10, 3.00), (2.48, 3.00), (2.86, 4.00), (3.24, 4.00), (3.62, 4.00), (4.00, 4.00)

Maintenance = GRAPH((1-frac_equip_bdown)*Running_Ave_Cap/100)
(0.00, 4.00), (0.1, 4.00), (0.2, 3.00), (0.3, 3.00), (0.4, 3.00), (0.5, 2.00), (0.6, 2.00), (0.7, 2.00), (0.8, 2.00), (0.9, 1.00), (1, 1.00)

Plant_Operations = GRAPH(Running_Ave_Cap*Operator_Astuteness*INIT(Ev_Rt_Op_Er_Exp)/Ev_Rt_Op_Er_Exp*INIT(Ev_Rt_Op_Misinf)/Ev_Rt_Op_Misinf)
(0.00, 4.00), (10.0, 4.00), (20.0, 4.00), (30.0, 3.00), (40.0, 3.00), (50.0, 3.00), (60.0, 2.00), (70.0, 2.00), (80.0, 2.00), (90.0, 1.00), (100, 1.00)

Support = GRAPH(IF mgr_workload<.4 THEN .4*(EFF_rep_analysis_ratio_SALP)*MRperwk/INIT(MRperwk) ELSE mgr_workload*(EFF_rep_analysis_ratio_SALP)*MRperwk/INIT(MRperwk))
(0.00, 1.00), (0.2, 2.00), (0.4, 2.00), (0.6, 3.00), (0.8, 3.00), (1, 3.00), (1.20, 3.00), (1.40, 4.00), (1.60, 4.00), (1.80, 4.00), (2.00, 4.00)

Information Defect Reduction Curve

Cumulative_Info_CA_Performed(t) = Cumulative_Info_CA_Performed(t - dt) + (info_CA_performed) * dt
INIT Cumulative_Info_CA_Performed = 30*52*5

INFLOWS:

info_CA_performed = proc_CA_validated+train_CA_validated

DEF_RED(t) = DEF_RED(t - dt) + (def_red_rate_decreasing) * dt
INIT DEF_RED = .96
INFLOWS:

def_red_rate_decreasing = IF(TIME>5)THEN(-DEF_RED*fractional_info_CA_completion*modified_learning_curve_info) ELSE (0)

fractional_info_CA_completion = info_CA_performed/Cumulative_Info_CA_Performed

lc_frac_info = .03

modified_learning_curve_info = -LOGN(1-(lc_frac_info*Training_Hours))/LOGN(2)
DOCUMENT: Modified Learning Curve Fraction

Modifies the learning curve fraction for use in the learning curve equations.

EFF_DEFRED_repeat_reps = GRAPH(DEF_RED)
(0.6, 1.50), (0.64, 1.49), (0.68, 1.47), (0.72, 1.44), (0.76, 1.38), (0.8, 1.21), (0.84, 1.13), (0.88, 1.06), (0.92, 1.02), (0.96, 1.00), (1.00, 1.00)

Information Labor Needed

info_eng_WTB(t) = info_eng_WTB(t - dt) + (chg_info_eng_WTB) * dt
INIT info_eng_WTB = 6
INFLOWS:

chg_info_eng_WTB = info_engs_work_des-info_eng_WTB

info_mgr_WTB(t) = info_mgr_WTB(t - dt) + (chg_info_safety_WTB) * dt
INIT info_mgr_WTB = 0
INFLOWS:

chg_info_safety_WTB = info_mgr_work_des-info_mgr_WTB

info_engs_work_des = SMTH1((Mod_CA_in_Progress+Proc_CA__in_Progress+Reps_Waiting_for_Screening+Evaluations_in_Progress+SOERs_Waiting_for_Screening+Train_CA_in_Progress+Prob_Screening_in_Progress+(Regulations_Under_Technical_Review+Reg_Eval_In_Progress)*info_eng_per_reg*info_rep_per_eng_per_week),2)

info_eng_per_reg = 26

info_eng_unavail_ratio = IF(TIME<1)OR Per_Outage=1THEN(1)ELSE(info_eng_WTB/(eng_info_rev_comp+1))

- 21 -

info_mgr_unavail_ratio = IF (TIME<.5) OR Per_Outage=1 THEN 1 ELSE (info_mgr_WTB/mgr_info_rev_comp+1)

info_mgr_work_des =
SMTH1(managers_applied_per_job*(CA_Waiting_for_Assignment+Evals_Waiting_for_Validation+Proc_CA_Waiting_for_Val+Train_CA_Waiting_for_Val+Reg_Reviews_Waiting_for_Assign*mgr_per_reg*info_rep_per_mgr_per_week),2)

managers_applied_per_job = .20

mgr_per_reg = 10

Information: Industry Problem Reporting and Other Agencies

EPRI_Research_in_Progress(t) = EPRI_Research_in_Progress(t - dt) + (EPRI_res_initiation - EPRI_res_completion) * dt
INIT EPRI_Research_in_Progress = 0
INFLOWS:
EPRI_res_initiation = base_EPRI_res_projects*EFFidprobEPRI
OUTFLOWS:
EPRI_res_completion = EPRI_Research_in_Progress/time_to_comp_EPRI_res

NRC_IN_in_Progress(t) = NRC_IN_in_Progress(t - dt) + (NRC_IN_initiation - NRC_IN_comp) * dt
INIT NRC_IN_in_Progress = 0
INFLOWS:
NRC_IN_initiation = frac_probs_need_IN*ident_probs_sent_to_NRC
OUTFLOWS:
NRC_IN_comp = NRC_IN_in_Progress/time_to_comp_IN

VEN_Research_in_Progress(t) = VEN_Research_in_Progress(t - dt) + (VEN_res_initiation - VEN_res_completion) * dt
INIT VEN_Research_in_Progress = 0

DOCUMENT: Vendor Research in Progress
[research programs]

INFLOWS:
VEN_res_initiation = base_VENDOR_res+ident_probs_sent_to_vendors
DOCUMENT: Vendor Research Initiation
[research programs/week]

Total amount of new research initiated at vendors each week. Included both the base rate and research of new identified problems.

OUTFLOWS:
VEN_res_completion = VEN_Research_in_Progress/time_to_comp_VEN
DOCUMENT: Vendor Reseach Completion
[research program/week[

The number of reseach programs being completed per week at the vendors. Completion includes the completion of the research and the writing/sending of the reseach results.

WANO_Reps_in_Progress(t) = WANO_Reps_in_Progress(t - dt) + (WANO_rep_init - WANO_rep_comp) * dt
INIT WANO_Reps_in_Progress = 0
INFLOWS:
WANO_rep_init = base_WANO_rep_production*EFFidprobWANO
OUTFLOWS:
WANO_rep_comp = WANO_Reps_in_Progress/time_to_comp_WANO_rep

base_EPRI_res_projects = 1

base_VENDOR_res = 2
DOCUMENT: Base Vendor Research Rate
[research progs/week]

This is the base rate at which vendors initiate new research to solve problems or develope new solutions.

base_WANO_rep_production = 2

frac_probs_need_IN = .8
DOCUMENT: Fraction of Problems Need IN

Fraction of incoming problems to the NRC that initiate the writing of IN's. This fraction may reduces the number of problem reports that produce IN's because the problem may be only plant specific, problem may have already initiated an IN, or may not be worthwhile for the industry to know.

frac_probs_sent_to_INPO = 1.0
DOCUMENT: Fraction of Problems Sent to INPO

Fraction of total problems identified that are sent to INPO for analysis.

frac_probs_sent_to_NRC = 1.0
DOCUMENT: Fraction of Problems Sent to NRC

Fraction of total identified problems sent to NRC for analysis.

frac_probs_sent_to_vendors = .1
DOCUMENT: Fraction of Problems Sent to Vendors

Fraction of total identified problems that are sent to vendors to initiate research.

ident_probs_sent_to_INPO = frac_probs_sent_to_INPO*identified_problems
DOCUMENT: Identified Problems Sent to INPO
[problems[

Number of problems given to INPO for analysis. Will eventually produce produce Significant Event Notifications (SEN), Significant Event Reports (SER), and Significant Operating Experience Reports (SOER).

ident_probs_sent_to_NRC = frac_probs_sent_to_NRC*identified_problems
DOCUMENT: Identified Problems Sent to NRC
[problems]

Numer of problems sent to NRC to be reviewed for Information Notifications (IN).

ident_probs_sent_to_vendors = frac_probs_sent_to_vendors*identified_problems
DOCUMENT: Identified Problems sent to Vendors
[problems]

Number of problems sent to vendors that will initiate research on problems with their products.

time_to_comp_EPRI_res = 12
time_to_comp_IN = 4
time_to_comp_VEN = 26
DOCUMENT: Time to Complete Vendor Research
[weeks]

Time it takes to complete research and write report of results.

time_to_comp_WANO_rep = 4

Information: Action Process

CA_Waiting_for_Assignment(t) = CA_Waiting_for_Assignment(t - dt) + (new_CA_waiting - CA_assignment - CA_abandon) * dt
INIT CA_Waiting_for_Assignment = 36

DOCUMENT: Corrective Actions Waiting for Assignment
[CA]

Corrective actions waiting to be assigned to correct groups that will perform the actions. Some may be lost if time delays increase too much.

INFLOWS:

new_CA_waiting =
evals_performed_correctly*frac_of_evals_need_CA*(1+frac_evals_need_mult_CA)+quick_CA_to__prob_needed+CA_from_regs
DOCUMENT: New Corrective Actions Waiting
[CA]

New corrective actions coming to the managers for assignment to various groups that will perform the actions (procedure changes, modifications, training).

OUTFLOWS:

CA_assignment = CA_Waiting_for_Assignment/adj_time_to_assign_CA
DOCUMENT: Corrective Action Assignment
[CA]

CA assignment to the correct groups.

CA_abandon = IF (info_mgr_unavail_ratio>assign_man_unavil_lim) OR (info_eng_unavail_ratio>assign_eng_unavail_lim) THEN CA_Waiting_for_Assignment*frac_CA_abandon ELSE 0
DOCUMENT: Corrective Actions Abdonded
[CA]

CA abdonded because managers are unavailable to to assign them or because the manager feels that engineers are too busy with other work (from the engineer unavailibity increasing).

Mod_CA_in_Progress(t) = Mod_CA_in_Progress(t - dt) + (new_mod_CA - mod_CA_planned) * dt
INIT Mod_CA_in_Progress = 80

DOCUMENT: Modification Corrective Actions in Progress
[mod CA]

Planning of modification coirrective actions in progress.

INFLOWS:

new_mod_CA = CA_assignment*frac_CA_mod
DOCUMENT: New Modification Corrective Actions
[mod CA]

New corrective actions to be performed through plant modifications.

OUTFLOWS:

mod_CA_planned = Mod_CA_in_Progress/adj_time_to_plan_mod_CA
DOCUMENT: Modification Corrective Actions Planned
[mod CA]

Completion of planning of modification CAs.

Proc_CA_Waiting_for_Val(t) = Proc_CA_Waiting_for_Val(t - dt) + (proc_CA__completed - proc_CA_validated - proc_CA_incorrect) * dt
INIT Proc_CA_Waiting_for_Val = 25

DOCUMENT: Procedure Change Waiting for Validation
[proc CA]

Procedure changes waiting to be validated for correctness by safety managers.

INFLOWS:

proc_CA__completed = Proc_CA__in_Progress/adj_time_to_comp_proc_CA
DOCUMENT: Procedure Change Corrective Actions Completed
[proc CA/week]

Procedure change CAs implemented by the engineers. (Incorporated them into procedures and making employees aware of them).

OUTFLOWS:

proc_CA_validated = frac_proc_CA_correct*Proc_CA_Waiting_for_Val/adj_time_to_val_proc_CA
DOCUMENT: Procedure Change Corrective Actions Validated
[proc CA/week]

Procedure change corrective actions validated to be correct and effective for the utility.

proc_CA_incorrect = proc_CA_validated*((1-frac_proc_CA_correct)/frac_proc_CA_correct)
DOCUMENT: Procedure Change Corrective Actions Incorrect
[proc CA/week]

Procedure Corrective actions that were performed incorrectly.

Proc_CA__in_Progress(t) = Proc_CA__in_Progress(t - dt) + (proc_CA - proc_CA__completed) * dt
INIT Proc_CA__in_Progress = 200

DOCUMENT: Procedure Change Corrective Actions in Progress
[proc CA]

Procedure change corrective actions that are being written and tested.

INFLOWS:

proc_CA = CA_assignment*frac_CA_proc+proc_CA_incorrect*EFF_mainOT_info
DOCUMENT: Procedure Corrective Actions
[proc CA/week]

CA's that are to be performed through procedure changes. Comes from newly validated evaluations, and from incorrectly performed changes.

OUTFLOWS:

proc_CA__completed = Proc_CA__in_Progress/adj_time_to_comp_proc_CA
DOCUMENT: Procedure Change Corrective Actions Completed
[proc CA/week]

Procedure change CAs implemented by the engineers. (Incorporated them into procedures and making employees aware of them).

Train_CA_in_Progress(t) = Train_CA_in_Progress(t - dt) + (train_CA - train_CA__completed) * dt
INIT Train_CA_in_Progress = 200

DOCUMENT: Training Change Corrective Actions in Progress
[train CA]

Traiing changes being worked on by engineers.

INFLOWS:

train_CA = CA_assignment*frac_CA_train+train_CA_incorrect*EFF_mainOT_info
DOCUMENT: Training Change Corrective Actions
[train CA/week]

Training change corrective actions. Come from evaluted reports and from incorrect training changes.

OUTFLOWS:

train_CA__completed = Train_CA_in_Progress/adj_time_to_comp_train_CA
DOCUMENT: Training Chnage Corrective Actions Completed
[train CA/week]

Completion of training changes. Includes studying, writing, and discussing CAs with training personnel.

Train_CA_Waiting_for_Val(t) = Train_CA_Waiting_for_Val(t - dt) + (train_CA__completed - train_CA_validated - train_CA_incorrect) * dt
INIT Train_CA_Waiting_for_Val = 15

DOCUMENT: Training Change Corrective Actions Waiting for Validation
[train CA]

Training changes waiting to be validated for correctness by managers.

INFLOWS:

train_CA__completed = Train_CA_in_Progress/adj_time_to_comp_train_CA
DOCUMENT: Training Chnage Corrective Actions Completed
[train CA/week]

Completion of training changes. Includes studying, writing, and discussing CAs with training personnel.

OUTFLOWS:

train_CA_validated = frac_train_CA_correct*Train_CA_Waiting_for_Val/adj_time_to_val_train_CA
DOCUMENT: Training Change Corrective Actions Validated
[train CA/week]

Training changes validated to be correct by managers.

train_CA_incorrect = train_CA_validated*((1-frac_train_CA_correct)/frac_train_CA_correct)
DOCUMENT: Training Change Corrective Actions Incorrect
[train CA/week]

Training changes that were performed incorrectly, as determined by managers.

adj_time_to_assign_CA = time_to_assign_CA*info_mgr_unavail_ratio*info_eng_unavail_ratio
DOCUMENT: Adjusted Time to Assign Corrective Actions
[weeks]

Time it takes for a manager to assign CA, adjuseted for manager availability.

○ adj_time_to_comp_proc_CA = time_to_comp_prov_CA*info_eng_unavail_ratio
DOCUMENT: Adjusted Time to Complete Procedure Change Corrective Actions
[week]

Time it takes to implement procedure changes, adjusted for engineer availability.

○ adj_time_to_comp_train_CA = time_to_comp_train_CA*info_eng_unavail_ratio
DOCUMENT: Adjusted Time to Complete Training Corrective Action
[week[

Time to complete training corrective actions, adjusted for enigneer availability.

○ adj_time_to_plan_mod_CA = time_to_plan_mod_CA*info_eng_unavail_ratio
DOCUMENT: Adjusted Time to Plan Modification CA
[weeks]

Time to plan modifications, adjusted for availability of engineers.

○ adj_time_to_val_proc_CA = time_to_val_proc_CA*info_mgr_unavail_ratio
DOCUMENT: Adjusted Time to Validated Procedure Corrective Actions
[week]

Time it takes a manager to validate correct completion of corrective actions, adjusted for manager availability.

○ adj_time_to_val_train_CA = time_to_val_train_CA*info_mgr_unavail_ratio
DOCUMENT: Time to Validate Training Corrective Actions
[week]

Time to validate training changes, adjusted for manager availability.

○ assign_eng_unavail_lim = 3
DOCUMENT: Assigment Engineer Unavailability Limit

Maxmimum value of engineer unavailability ratio before CA's are abandoned because managers believe that their engineers are too busy.

○ assign_man_unavil_lim = 2
DOCUMENT: Assignement Manager Unavailability Limit

Maximum value of manager unavailability allowed. If it becomes greater than this value, CAs are abandoned.

○ frac_CA_abandon = .2
DOCUMENT: Fraction of Corrective Actions Abandoned
[CA abandoned/CA]

Fraction of CA abdandoned when managers decide to begin to abandon CAs.

○ frac_CA_mod = .2
DOCUMENT: Fraction Corrective Actions Modifications
[mod CA/CA]

Fraction of corrective actions that are peformed through modifications. Note that mods dan not get performed in this flow, they are sent to sceduled work orders.

○ frac_CA_proc = .6
DOCUMENT: Fraction of Corrective Actions-Procedure
[proc CA/CA]

Fraction of corrective actions that will be procedure changes.

○ frac_CA_train = .2
DOCUMENT: Fraction Corrective Actions Training
[train CA/CA]

Fraction of corrective actions that will be performed through training.

○ frac_evals_need_mult_CA = .2
DOCUMENT: Fraction of Evals That Need Multiple CA
[ca/evaluations]

Fraction of evaluations that need multiple corrective actions to solve the problem.

○ frac_of_evals_need_CA = .75
DOCUMENT: Fraction of Evaluations That Need Corrective Actions
[CA/evaluations]

Fraction of validated evalautions that require corrective actions within the utility.

○ frac_proc_CA_correct = .90*eff_OT_fatigue_eng
DOCUMENT: Fraction of Procedure Corrective Actions Correct
[correct CA/proc CA]

Fraction of procedure change CAs that are correct.

○ frac_train_CA_correct = .90*eff_OT_fatigue_eng
DOCUMENT: Fraction Training Change Corrective Actions Correct
[correct CA/train CA]

Fration of corrective actions for training that are being performed correctly.

○ time_to_assign_CA = 1
DOCUMENT: Time to Assign Corrective Actions
[weeks]

Time it takes a manager to assign corrective actions to procedure, modifications, or training changes.

○ time_to_comp_prov_CA = 10
DOCUMENT: Time to Complete Procedure Change Corrective Actions
[week]

Time it takes to implement procedure changes within the utility.

○ time_to_comp_train_CA = 26
DOCUMENT: Time to Complete Training Corrective Actions
[week]

Time it takes an engineer to complete the training changes.

○ time_to_plan_mod_CA = 12
DOCUMENT: Time to Plan Modification Corrective Actions
[weeks]

Time it takes to plan modifications for corrective actions.

○ time_to_val_proc_CA = 1
DOCUMENT: Time to Validate Procedure Change Corrective Actions
[weeks]

Time it takes a manager to validate that a procedure change was performed correctly.

○ time_to_val_train_CA = 2
DOCUMENT: Time to Validate Training Corrective Actions
[weeks]

Time it takes a manager to validate that the training changes.

Information: Analysis Ratio Calc

□ Cumulative_Reports_Available(t) = Cumulative_Reports_Available(t - dt) + (new_reps) * dt
INIT Cumulative_Reports_Available = 1

DOCUMENT: Cumulative Reports Available
[reports]

Cumulative number of available reports for the utility to learn from.

INFLOWS:

new_reps = Incoming_Reps++Incoming_SOERs+new_incoming_problems
DOCUMENT: New Reports
[reports/week]

Increase in the number of new reports that have come into the utility.

☐ Total_Report_Analyses_Abandoned(t) = Total_Report_Analyses_Abandoned(t - dt) + (report_analyses_abandoned - report__analyses_reopened) * dt
INIT Total_Report_Analyses_Abandoned = 0

DOCUMENT: Total Report Analyses Abandoned
[reports]

Total number of report analyses abandoned.

INFLOWS:

report_analyses_abandoned = CA_abandon+evals_abadoned+reps_abandoned
DOCUMENT: Reports Analyses Abandoned
[reports/week]

Reports abandoned because of unavailability of managers and engineers. Comes from abandonment during evaluation or when corrective actions are assigned.

OUTFLOWS:

report__analyses_reopened = EFF_SALP_info*Total_Report_Analyses_Abandoned
DOCUMENT: Report Analyses Reopened
[reports/week]

Report analyses reopened because of pressure to improve performance and safety.

○ report_analysis_ratio = (Cumulative_Reports_Available-Total_Report_Analyses_Abandoned)/Cumulative_Reports_Available
DOCUMENT: Report Analysis Ratio
[reps anayzed/reps available to utility]

Ratio of the number of reports anayzed (available-abandoned) to the number of reports available.

Information: Evaluiation Process

☐ Evals_Waiting_for_Validation(t) = Evals_Waiting_for_Validation(t - dt) + (eval_validation_initi - evals_performed_correctly - evals_performed_incorrectly) * dt
INIT Evals_Waiting_for_Validation = 45

DOCUMENT: Evalutation Validations in Progress
[evaluations]

Validations of evaluations perfomed by safety managers in progress.

INFLOWS:

eval_validation_initi = items_evaluated
DOCUMENT: Evaluation Validation Initiation
[evaluations/week]

New items sent to managers to have their evaluations validated for completness and correctness.

OUTFLOWS:

evals_performed_correctly = frac_correctly_eval*Evals_Waiting_for_Validation/adj_time_to_val_evals
DOCUMENT: Evaluations Performed Correct
[evaluations]

Items that were validated (by managers) to have been evaluated correcly by the engineering staff.

evals_performed_incorrectly = evals_performed_correctly*((1-frac_correctly_eval)/frac_correctly_eval)
DOCUMENT: Evaluations Performed Incorrectly
[evals]

Items that were evaluated incorrectly: Sent back for further evaluation.

☐ Evaluations_in_Progress(t) = Evaluations_in_Progress(t - dt) + (new_item_evaluations - items_evaluated - evals_abadoned) * dt
INIT Evaluations_in_Progress = 275

DOCUMENT: Evaluations in Progress
[evals]

Number of evaluations in progress by engineers.

INFLOWS:

new_item_evaluations = (app_reps+concerns_from_app_SOER)+significant_problems+evals_performed_incorrectly
DOCUMENT: New Item Evaluations
[evals/week]

New items to be evaluated. These are problems or potential problems, applicable reports and concerns/reccomendations from applicable SOERs.

OUTFLOWS:

items_evaluated = Evaluations_in_Progress/adj_time_to_eval
DOCUMENT: Items Evaluated
[evals/week]

Completion of correctiveaction evalution of items.

evals_abadoned = IF (info_eng_unavail_ratio>eval_eng_unavail_lim) THEN (frac_evals_abandoned*Evaluations_in_Progress) ELSE (
DOCUMENT: Evaluations Abandonded
[evals]

Item evaluations abandoned becuase the unavailability of engineers becomes too high. This dynamically represents the lessening level of evaluation that occurs as engineers become busier.

adj_time_to_eval = time_to_eval*info_eng_unavail_ratio
DOCUMENT: Adjusted Time to Evaluate
[weeks]

Time it takes to evaluation events for corrective actions, adjusted for availability of engineers.

adj_time_to_val_evals = time_to_val_evals*info_mgr_unavail_ratio
DOCUMENT: Adjusted Time to Validate Evaluations
[weeks]

Time to validate evalutations, adjusted for the manager availability.

eval_eng_unavail_lim = 3
DOCUMENT: Evaluation Engineer Unavailability Limit

Maximum level that the engineer unavailability can be, before evaluations start becoming adbandoned.

frac_correctly_eval = .85*eff_OT_fatigue_eng
DOCUMENT: Fraction Correctly Evaluated
[correct evals/total evals]

Fraction of evaluations that are performed (and validated) to be correct.

frac_evals_abandoned = .10
DOCUMENT: Fraction of Evaluations Abandoned
[evals abandoned/evals]

This is the fraction of evaluations that are abandoned because the time delays in evaluation are becoming too long.

time_to_eval = 6
DOCUMENT: Time to Evaluate
[weeks]

Time it takes to evaluation reports for corrective actions, independant of engineer usage.

time_to_val_evals = 1
DOCUMENT: Time To Validate Evaluations
[weeks]

Time for a manager to validate evaluations.

Information: Industry Events

Cumulative_Alerts(t) = Cumulative_Alerts(t - dt) + (site_alert) * dt
INIT Cumulative_Alerts = 0

DOCUMENT: Cumulative Alerts
[alerts]

Total number of site alerts that have occurred.

INFLOWS:

site_alert = site_alert'
DOCUMENT: Site Alert
[alerts/week]

Site alert occurances.

Cumulative_Emergencies(t) = Cumulative_Emergencies(t - dt) + (site_emergencies) * dt
INIT Cumulative_Emergencies = 0

DOCUMENT: Cumulative Emergencies
[emergencies]

Total number of site emergencies that have occurred.

INFLOWS:

site_emergencies = site_emergencies'
DOCUMENT: Site Emergencies
[emergencies/week]

Site emergency occurances.

Cumulative_Events(t) = Cumulative_Events(t - dt) + (new_event_occurances) * dt
INIT Cumulative_Events = 0

DOCUMENT: Cumulative Events
[events]

Total number of events (all types) that occured.

INFLOWS:

new_event_occurances = event_occurance
DOCUMENT: New Event Occurances
[events/week]

Events occuring per week.

Cumulative_Problems_Reported(t) = Cumulative_Problems_Reported(t - dt) + (increase_in_probs_reported) * dt
INIT Cumulative_Problems_Reported = 0

DOCUMENT: Cumulative Problems Reported
[problems]

Total number of problems reported.

INFLOWS:

increase_in_probs_reported = identified_problems
DOCUMENT: Increase in Problems Reported
[problems/week]

This the number of problems reported each week.

Cumulative_Unusual_Events(t) = Cumulative_Unusual_Events(t - dt) + (unusual_event) * dt
INIT Cumulative_Unusual_Events = 0

DOCUMENT: Cumulative Unusual Events
[minor events]

The total number of unusual events that occured.

INFLOWS:

unusual_event = unusual_event'
DOCUMENT: Unusual Event
[unusual events/week]

Unusual event occurances.

○ base_prob_sa = 10*dt
DOCUMENT: Base Probability for Site Alert

This is the base probabeility for site alerts to occur. Based on information from the NRC it is 1 alert every 10 events.(1/10=10%)

○ base_prob_se = .25*dt
DOCUMENT: Base Probabaility of Site Emergency

Probability that a site emergency will occur. Based on data from the NRC-1 emergency every 2-3 years. (1/340=.25%)

○ events_per_year = 140
DOCUMENT: Events per Year
[events[

This is the maximum number of events that are allowed to occur each year.

○ identified_problems =
unusual_event*probs_disc_per_unusual_event+site_alert*prob_disc_per__alert+site_emergencies*prob_disc_per_emergency+problems_from_major_event
DOCUMENT: Identified Problems
[problems]

Total number of identified problems from the three different type of event occurances.

○ ident_prob_ratio = SMTH1(identified_problems,2,1)/SMTH1(identified_problems,time_horizon_to_comp_ind_probs,10)
DOCUMENT: Identified Problem Ratio

Ratio of a smooth of the last 2 weeks problems to a smooth of the problems occuring in the time horizon to compare problems in the industry. Used as input to effect report, research and investigation initiation based on the ratio of recent problems to past history.

○ problems_from_major_event = IF (TIME=156) AND Event_Switch=1 THEN 1000 ELSE 0

○ probs_disc_per_unusual_event = 1
DOCUMENT: Problems Discovered per Unusual Event
[problems/unusual event]

Number of problems discovered per for each unusual event occurance. Set at 10^0.

○ prob_disc_per_emergency = 100
DOCUMENT: Problems Discovered per Emergency
[problems/emergency]

Problems discovered because of a site emergency. Set at 10^2.

○ prob_disc_per__alert = 10
DOCUMENT: Problems Discovered per Site Alert
[problems/alert]

Number of problems discovered from the site alert. Set at 10^1.

○ rand_for_num_events = RANDOM(0,1,rand_seed+1000)

DOCUMENT: Random Number for Events

Generates random number that is used in determining the number of events occuring per week.

○ rand_seed = 5000
DOCUMENT: Random Seed

This is the random numbe seed for all random numbers in the information sector. Each random number is generated based on this seed plus an arbitrart constant. This way each random number is different.

○ time_horizon_to_comp_ind_probs = 12
DOCUMENT: Time Horizon to Compare Industry Problems
[weeks]

This is the number of weeks that people within the inudstry rememeber problems over when comparing the number of recent problems to those that have occurred in the past.

EFFidprobEPRI = GRAPH(ident_prob_ratio)
(1.00, 1.04), (1.10, 1.10), (1.20, 1.10), (1.30, 1.10), (1.40, 1.12), (1.50, 1.16), (1.60, 1.28), (1.70, 1.62), (1.80, 2.37), (1.90, 3.32), (2.00, 5.00)
DOCUMENT: Effect of Identified Porblems on EPRI

As the industry identified problem ratio increases, increasingly more research is initiated by EPRI to reduce problems.

EFFidprobWANO = GRAPH(ident_prob_ratio)
(1.00, 1.00), (1.10, 1.01), (1.20, 1.02), (1.30, 1.02), (1.40, 1.02), (1.50, 1.03), (1.60, 1.05), (1.70, 1.09), (1.80, 1.16), (1.90, 1.30), (2.00, 1.49)
DOCUMENT: Effect of Identified Problems on WANO

As more problems are identified in the US, more become identified by WANO as signicifcant, so more reports will be produced. Notice that this is less than the inspection and EPRI effect because WANO is not that large of a contributor for problem information.

EFFsitealandemerg_NRCIns = GRAPH(SMTH1(site_alert+10*site_emergencies,12,1))
(1.00, 0.00), (1.40, 0.00), (1.80, 0.00), (2.20, 0.002), (2.60, 0.017), (3.00, 0.034), (3.40, 0.048), (3.80, 0.072), (4.20, 0.105), (4.60, 0.148), (5.00, 0.198)
DOCUMENT: Effect of identified problems on NRC Inspections

As the ratio of industry problems increases, the NRC initiates more inspections in hope that they will be able to identify and correct more problems through regulations.

event_occurances = GRAPH(rand_for_num_events)
(0.00, 1.00), (0.05, 1.00), (0.1, 1.00), (0.15, 1.00), (0.2, 1.00), (0.25, 1.00), (0.3, 1.00), (0.35, 2.00), (0.4, 2.00), (0.45, 2.00), (0.5, 2.00), (0.55, 3.00), (0.6, 3.00), (0.65, 4.00), (0.7, 4.00), (0.75, 4.00), (0.8, 5.00), (0.85, 5.00), (0.9, 5.00), (0.95, 6.00), (1.00, 6.00)
DOCUMENT: Event Occurances
[events]

Number of events per week occuring. 1 to 6 events can occur per week based on the random number input to the lookup graph.

Event_Processing = Event_Pool
DOCUMENT: EVENT PROCESSING SUB-MODEL

This sub-model produces industry events based on data obtained from the NRC. Variables within it generate random numbers to test each event occurance individually for its possible level. The sub-model produces the following:

100-140 events/year
10% chance of event being a site alert (prob ss)
.25% chance of being a site emergency (1 every 2-3 years) (prob ss)

INFLOWS:

event_pool_reset = PULSE(events_per_year,1,52)-PULSE(Event_Pool,52,52)
DOCUMENT: Event Pool Reset
[events/week]

This flow resets the even pool stock in the sub-model. At the eng and beginning of each year it zero's out the pool and then resets it the the events per year value.

OUTFLOWS:

unusual_event = unusual_event'
DOCUMENT: Unusual Event
[unusual events/week].

Unusual event occurances.

site_alert = site_alert'
DOCUMENT: Site Alert
[alerts/week]

Site alert occurances.

site_emergencies = site_emergencies'
DOCUMENT: Site Emergencies
[emergencies/week]

Site emergency occurances.

Event_Pool(t) = Event_Pool(t - dt) + (event_pool_reset' - site_emergencies' - site_alert' - unusual_event') * dt
INIT Event_Pool = 0

DOCUMENT: Events Pool
[events]

Holds events that will eventually occur. Event occurances flow out when the probabilities dictate occurances. Limits the total number of events in a year to the event per year level.

INFLOWS:

event_pool_reset' = event_pool_reset
DOCUMENT: New Events To Occur
[events/week]

Rolls into the sub-model the number of events to occur each year. Builds up the Event Pool stock at the beginning of the year.

OUTFLOWS:

site_emergencies' = se
site_alert' = sa
unusual_event' = event_occurance-site_alert'-site_emergencies'

event_occurance = event_occurances
DOCUMENT: Event Occurances
[even]

Based on a random number this is the number of events occurring each week.

rand_1 = RANDOM (0,100,rand_seed+100)
rand_2 = RANDOM (0,100,rand_seed+200)
rand_3 = RANDOM (0,100,rand_seed+300)
rand_4 = RANDOM (0,100,rand_seed+400)
rand_5 = RANDOM (0,100,rand_seed+500)
rand_6 = RANDOM (0,100,rand_seed+600)
sa = (test_1+test_2+test_3+test_4+test_5+test_6)
DOCUMENT: Site Alerts
[alerts[

Sums up the site alert occurances from the probababiliity processing of each event.

sa_prob_lim = 100-base_prob_sa
DOCUMENT: Site Alert Probability Limit

Calculates the value that the random number must be greater than, and less than 100, for a site alert to occur.

se = test_10+test_11+test_12+test_7+test_8+test_9
DOCUMENT: Site Emergencies
[emergencies]

Sums up the possibilities of site emergencies from the probability processing of each event.

se_prob_lim = 50-base_prob_se
DOCUMENT: Site Emergency Probability Limit

Calculates the value that the random number must be greater than,and less than 50, for a site emergency to occur.

test_1 = IF (event_occurance<1) OR (rand_1<(sa_prob_lim)) THEN (0) ELSE (1)
test_10 = IF (event_occurance<4) OR (rand_4<(se_prob_lim)) OR (rand_4>50) THEN (0) ELSE (1)
test_11 = IF (event_occurance<5) OR (rand_5<(se_prob_lim)) OR (rand_5>50) THEN (0) ELSE (1)
test_12 = IF (event_occurance<6) OR (rand_6<(se_prob_lim)) OR (rand_6>50) THEN (0) ELSE (1)
test_2 = IF (event_occurance<2) OR (rand_2<(sa_prob_lim)) THEN 0 ELSE (1)
test_3 = IF (event_occurance<3) AND (rand_3<(sa_prob_lim)) THEN (0) ELSE (1)
test_4 = IF (event_occurance<4) OR (rand_4<(sa_prob_lim)) THEN (0) ELSE (1)
test_5 = IF (event_occurance<5) OR (rand_5<(sa_prob_lim)) THEN (0) ELSE (1)
test_6 = IF (event_occurance<6) OR (rand_6<(sa_prob_lim)) THEN (0) ELSE (1)
test_7 = IF (event_occurance<1) OR (rand_1<(se_prob_lim)) OR (rand_1>50) THEN (0) ELSE (1)
test_8 = IF (event_occurance<2) OR (rand_2<(se_prob_lim)) OR (rand_2>50) THEN (0) ELSE (1)
test_9 = IF (event_occurance<3) OR (rand_3<(se_prob_lim)) OR (rand_3>50) THEN (0) ELSE (1)

Information: INPO

☐ INPO_Field_Invests_in_Progress(t) = INPO_Field_Invests_in_Progress(t - dt) + (field_invest_planned - INPO_rec_field_invest_completed) * dt
INIT INPO_Field_Invests_in_Progress = 3

DOCUMENT: INPO Field Investigations in Progress
[investigations]

Number of field investigations on problems/recommendations in progress.

INFLOWS:

field_invest_planned(i) = field_invest_planned(o) * CONVERSION MULTIPLIER
CONVERSION MULTIPLIER = 0.5

DOCUMENT: Field Investigations Planned
[investigations]

INPO initiates field investigations of SOER recommendations when it feels that the recommendations are extrememely important or can be enhanced by further investigation.

OUTFLOWS:

INPO_rec_field_invest_completed = INPO_Field_Invests_in_Progress/INPO_time_to_comp_fi
DOCUMENT: INPO Recommendation Field Investigation Completed
[investigations/week]

Number of investigations completed per week.

☐ INPO_Prob_Analysis_in_Progress(t) = INPO_Prob_Analysis_in_Progress(t - dt) + (INPO_prob_analysis_init - INPO_prob_analysis_comp) * dt
INIT INPO_Prob_Analysis_in_Progress = 15

DOCUMENT: INPO Problem Analysis in Progress
[analysis]

Number of problem analyses in progress. May become backlogged if INPO is overloaded with problems.

INFLOWS:

INPO_prob_analysis_init = INPO_significant_problems
DOCUMENT: INPO Problem Analysis Initiation
[analysis/week]

Initiation of further problem analysis. All significant problem are analyzed to see if corrective actions for corrective actions/recommendations.

OUTFLOWS:

INPO_prob_analysis_comp = INPO_Prob_Analysis_in_Progress/adj_INPO_time_to_analyze_probs
DOCUMENT: INPO Problem Analysis Completion
[analysis]

Completion of INPO problem analyses. A fraction of these analyses yield recommendations to be sent out in SOER's.

☐ Probs_Waiting_for_Screen_by_INPO(t) = Probs_Waiting_for_Screen_by_INPO(t - dt) + (problems_reported_to_INPO - INPO_probs_screened) * dt
INIT Probs_Waiting_for_Screen_by_INPO = 10

DOCUMENT: Problems Waiting for Screeing by INPO
[problems[

Problems waiting for an INPO engineer to screen whether the events are significant to the industry or not. This may become backlogged if many problems are being analyzed in the INPO sector.

INFLOWS:

problems_reported_to_INPO = ident_probs_sent_to_INPO
DOCUMENT: Problems Reported to INPO
[problems/week]

Problems discovered from site incidents that are reported that will initiate INPO reports.

OUTFLOWS:

INPO_probs_screened = Probs_Waiting_for_Screen_by_INPO/adj_INPO_time_to_screen_event
DOCUMENT: INPO Problems Screened
[problems/week]

Problem screening by an INPO is completed. Problem is determined to be significant or non-significant.

Recs_Waiting_for_Further_Investigation(t) = Recs_Waiting_for_Further_Investigation(t - dt) + (new_recs_to_inform - quick_SOER_responses - field_invest_planned) * dt
INIT Recs_Waiting_for_Further_Investigation = 5

DOCUMENT: Recommendations Waiting for Further Investigations
[recs]

Recommendations waiting to be analyzed further. May immediately lead to SOER production or initiation of a field investigation.

INFLOWS:

new_recs_to_inform = INPO_prob_analysis_comp*frac_sig__probs_req_recs
DOCUMENT: New Recommendations to inform
[recs required/week]

New! recs to appear in SOER reports.

OUTFLOWS:

quick_SOER_responses =
Recs_Waiting_for_Further_Investigation*frac_recs_req_quick_SOER/adj_INPO_time_to_produce_quick_SOER
DOCUMENT: Quick SOER Responses
[SOER]

This flow creates SOER reports without any further investigation.

field_invest_planned(o) =
(1-frac_recs_req_quick_SOER)*Recs_Waiting_for_Further_Investigation/adj_INPO_time_to_plan_field_invest
DOCUMENT: Field Investigations Planned
[investigations]

INPO initiates field investigations of SOER recommendations when it feels that the recommendations are extrememely important or can be enhanced by further investigation.

SER_Writing_in_Progress(t) = SER_Writing_in_Progress(t - dt) + (SER_initiation - SER_reports) * dt
INIT SER_Writing_in_Progress = 20

DOCUMENT: SER Writing in Progress
[SER[

Number of SERs being written.

INFLOWS:

SER_initiation = INPO_significant_problems
DOCUMENT: SER Initiation
[SER]

All significant problems initiate the writing of a SER.

OUTFLOWS:

SER_reports = SER_Writing_in_Progress/adj_time_to_produce_SER
DOCUMENT: SER Reports

SER (Significant Event Reports). Reports from INPO that contain breif descriptions of a significant event or problem and why it was considered significant.

adj_INPO_time_to_analyze_probs = INPO_eng_unavail_ratio*INPO_time_to_analyze_probs
DOCUMENT: Adjusted INPO time to Analyze Problem
[weeks]

INPO time to analyze problems adjusted by the engineer availability.

○ adj_INPO_time_to_plan_field_invest = INPO_time_to_plan_fi*INPO_eng_unavail_ratio
DOCUMENT: Adjusted INPO Time to Plan Field Investigations
[weeks]

Time it takes for INPO to plan a field investigation, adjusted by the availability of its engineers.

○ adj_INPO_time_to_produce_quick_SOER = INPO_time_to_produce_quick_SOER*INPO_eng_unavail_ratio
DOCUMENT: Adjusted INPO time to produce quick SOER
[weeks]

Time for INPO to quickly produce a SOER report adjusted for availability of engineers.

○ adj_INPO_time_to_screen_event = INPO_time_to_screen_event*INPO_eng_unavail_ratio
DOCUMENT: Adjusted INPO to Screen Event
[weeks]

Base INPO screening time adjusted for the engineer availability.

○ adj_time_to_produce_SER = time_to_produce_SER*INPO_eng_unavail_ratio
DOCUMENT: Adjusted Time to Produce SER
[weeks]

Time it takes to produce a SER adjusted for the engineer availability.

○ eng_needed_per_field_invest = 3
DOCUMENT: Engineers Needed per Field Investigation
[engineers]

Number of engineers INPO needs to be on site for investigation of problems.

○ fract_prob_req_SEN = .2
DOCUMENT: Fraction of Problems Require SEN

Fraction of problems that dicatate informing the utilities quickly of the problem.

○ frac_recs_req_quick_SOER = .60
○ frac_sig_probs = .80
DOCUMENT: Fraction Significant Problems
[significant problems/problems screened]

Fraction of screened problems that are significant to the industry, as determined by INPO.

○ frac_sig__probs_req_recos = .50
DOCUMENT: Fraction of Significant Problems Require Recommendations
[recs required/significant probs]

Fraction of significant problems that dictate INPO recommendations and will produce a SOER (highest level for an INPO report).

○ INPO_eng_available = IF (INPO_eng_needed<max_INPO_eng_available) AND (INPO_eng_needed>4) THEN INPO_eng_needed ELSE IF (INPO_eng_needed<4) THEN (4) ELSE (max_INPO_eng_available)
DOCUMENT: INPO Engineers Available
[engineers]

Number of engineers that INPO is able to provide for problem processing, report writing, inspections, etc.

○ INPO_eng_needed =
INPO_eng_needed_per_action*(Probs_Waiting_for_Screen_by_INPO+INPO_Prob_Analysis_in_Progress+Recs_Waiting_for_Further_Investigation+SER_Writing_in_Progress)+eng_needed_per_field_invest*INPO_eng_needed_per_action*INPO_Field_Invests_in_Progress
DOCUMENT: INPO Engineers Needed
[engineers]

Total number of engineers needed to perform the pending actions.

○ INPO_eng_needed_per_action = .33
DOCUMENT: INPO Engineer Needed per Action
[engineer/action]

Fraction of engineer's time spent on performint an action. For example an engineer spends a quarter of his time in 2 weeks analyzing a new problem.

- INPO_eng_unavail_ratio = 1+0*(IF((INPO_eng_needed/INPO_eng_available)>.25) THEN INPO_eng_needed/INPO_eng_available ELSE .25)
  DOCUMENT: INPO Engineer Unavailability Ratio
  [engineers needed/engineers available]

  Ratio of engineers needed to engineers available in INPO. As this increases, the time delays in performing actions increases.

- INPO_significant_problems = INPO_probs_screened*frac_sig_probs
  DOCUMENT: INPO Significant Problems

  Problems that are determined to be significant to the industry by INPO. These will lead to SEN, SER and SOER reports.

- INPO_time_to_analyze_probs = 2
  DOCUMENT: INPO time to analyze problem
  [weeks]

  Base time it takes for an engineer to analyze a problem.

- INPO_time_to_comp_fi = 6
  DOCUMENT: INPO Time to Complete Field Investigation
  [weeks]

  Time it takes INPO to complete a field investigation (of recommendations/problems). It is not adjusted for enigneer availability because available engineers are on site. Leads to writing of SOER's.

- INPO_time_to_plan_fi = 2
  DOCUMENT: INPO Time to Plan Field Investigation
  [weeks]

  Base time it takes for INPO to plan a field investigation. Includes gathering of people, plans, equipment, etc.

- INPO_time_to_produce_quick_SOER = 1
  DOCUMENT: INPO time to produce quick SOER
  [weeks]

  This is the time it takes for INPO to produce a SOER report from its recommendations.

- INPO_time_to_screen_event = 1
  DOCUMENT: INPO time to screen event
  [weeks]

  Time it takes an INPO engineer to screen a problem for its significance.

- max_INPO_eng_available = 20
  DOCUMENT: Maximum INPO Engineers Available
  [engineers]

  Maximum number of engineers available at INPO to perform the actions within this sector.

- SEN_reports = INPO_significant_problems*fract_prob_req_SEN
  DOCUMENT: SEN Reports

  SEN (Significant Event Notifications). These are sent out as quickly as possible (after report screening) to identify to the utilities that a significant event has occurred. May not contain too many details of the event, which will be expanded upon in the SER.

- SOER_reports = INPO_rec_field_invest_completed+quick_SOER_responses
  DOCUMENT: SOER Reports

  SOER (Significant Operating Experience Reports). Reports contain INPO recommendations on actions to respond the the sigificant events and problems. Is both from quick SOER responses to recs and SOER responses from field investigations.

- time_to_produce_SER = 2
  DOCUMENT: Time to Produce SER
  [weeks]

  Time it takes to produce a SER.

Information: Interactions with NRC

☐ NEI_Abandon_Effort_in_Progress(t) = NEI_Abandon_Effort_in_Progress(t - dt) + (NEI_effort_to_aband_reg - regulations_abandoned_effort_comp) * dt
INIT NEI_Abandon_Effort_in_Progress = 0

DOCUMENT: NEI Abandon Effort in Progress
[regs]

The is the effort that NEI is putting in to get a regulation abandoned by the NRC.

INFLOWS:

NEI_effort_to_aband_reg = regs_des_aband

DOCUMENT: NEI Effort to Abandon Regulations
[regs/week]

If the utility dislikes regulations, they will have NEI work with other utilities to spend the effort to abandon the regulation before it hits the book.

OUTFLOWS:

regulations_abandoned_effort_comp = NEI_Abandon_Effort_in_Progress/time_to_influence_NRC
DOCUMENT: Regulation Abandoned Effort Completion
[regs/week]

This is the completion of abandoing effort by NEI. At this point a portion of the regulations will be abandoned before they become on the books.

☐ Regulations_Under_Technical_Review(t) = Regulations_Under_Technical_Review(t - dt) + (tech_review_of_new_regs_init - regs_des_aband - reg_reviews_completed) * dt
INIT Regulations_Under_Technical_Review = .2
INFLOWS:

tech_review_of_new_regs_init = reg_reviews_assigned
DOCUMENT: Technical Review of New Regulations Initiated
[regs]

Initiated of a technical review of regulations by the technical groups.
The review includes both a review of the regulation, its impact, and the changes that will have to be made at the company.

OUTFLOWS:

regs_des_aband = frac_regs_des_aband*Regulations_Under_Technical_Review/(time_to_comp_reg_rev/4)
DOCUMENT: Regulations Determined Incompatible
[regs]

Regulations determined incompatible with the utilities goals.

reg_reviews_completed = Regulations_Under_Technical_Review/adj_time_to_comp_reg_review
DOCUMENT: Regulation Reviews Completed
[regs/week]

Regulation reviews completed by the utility.

☐ Reg_Eval_in_Progress(t) = Reg_Eval_in_Progress(t - dt) + (new_regs_to_implement - new_reg_evals_completed) * dt
INIT Reg_Eval_in_Progress = 0

DOCUMENT: Regulation Evaluations in Progress
[regs]

This is the futher evaluation of regulations within the utility before they are implemented.

INFLOWS:

new_regs_to_implement = enacting_regulation
DOCUMENT: New Regulations to Implement
[regs]

This are newly booked regulations by the NRC that need to be implemented within the utility.

OUTFLOWS:

new_reg_evals_completed = Reg_Eval_In_Progress/adj_time_to_comp_reg_eval
DOCUMENT: New Regulation Evaluations Completed
[regs]

Completion of regulation evaluation leads to corrective actions within the utility.

Reg_Reviews_Waiting_for_Assign(t) = Reg_Reviews_Waiting_for_Assign(t - dt) + (new_regs_to_review - reg_reviews_assigned) * dt
INIT Reg_Reviews_Waiting_for_Assign = 0

DOCUMENT: Regulation Reviews Waiting for Assignment
[regs]

Regulation reviews waiting to be assigned (usually by the VP or managers) to technical groups for review.

INFLOWS:

new_regs_to_review = frac_of_regs_to_review*initiating_regulation
DOCUMENT: New Regulations to Review
[reg/week]

New regulations (initiated by the NRC) that will undergo review at the utility. Reviewing regulations as they are being created allows for faster implementation of them, and for the chance that the utility may be able to remove the regulation.

OUTFLOWS:

reg_reviews_assigned = Reg_Reviews_Waiting_for_Assign/adj_time_to_assign_reg_review
DOCUMENT: Regulation Reviews Assigned
[regs]

Regulation reviews assigned to technical groups for review/comments.

adj_time_to_assign_reg_review = time_to_assign_reg_review*info_mgr_unavail_ratio
DOCUMENT: Adjusted Time to Assign Regulation Reviews
[weeks]

Time it takes to assign regulation reviews, adjusted for the manager availability,

adj_time_to_comp_reg_eval = EFFregrev*info_eng_unavail_ratio*time_to_comp_reg_eval
DOCUMENT: Adjusted Time to Complete Regulation Evaluations

Time to complete the regulation evaluations, adjusted for engineer availability and for the fact that regulations are being reviewed while under development at the NRC.

adj_time_to_comp_reg_review = time_to_comp_reg_rev*info_eng_unavail_ratio
DOCUMENT: Adjusted Time to Complete Regulation Review
[week[

Time it to complete regulation review, adjusted for engineer availability.

CA_from_regs = new_reg_evals_completed*CA_per_reg
CA_per_reg = 253
frac_of_regs_to_review = .99
DOCUMENT: Fraction of Regulations to Review
[regs to review/regs}

Fraction of regulations initiated at the NRC that will be under review at the utility. As this decreases, it will take longer for the utility to review regulations once they are put on the books.

frac_regs_abandoned = 1.00
DOCUMENT: Fraction of Regulations Abandoned
[regs abandoned/regs]

This is the fraction of regulation abandon effort that is effective in getting a regulation abandoned by the NRC.

frac_regs_det_aband = 0
DOCUMENT: Fraction Regulations Determined Incompatible
[regulations incompatible/regulations]

Fraction of regulatins that are determined to be incompatible when the probability arises that they are incompatible.

○ regulations_abandoned_from_NEI_effort = frac_regs_abandoned*regulations_abandoned_effort_comp
DOCUMENT: Regulations Abandoned
[regs abandoned/week]

This is the number of regulations that are being abandoned by the NRC.

○ time_to_assign_reg_review = 1
DOCUMENT: Time to Assign Regulation Review
[weeks]

Time it takes for a manager/VP to assign a regulation review.

○ time_to_comp_reg_eval = 6
DOCUMENT: Time to Complete Regulation Eval
[weel]

Base time to complete regulation evaluations (of what needs to be done).

○ time_to_comp_reg_rev = 12
DOCUMENT: Time to Complete Regulation Review
[weeks]

Time it takes to complete regulation review by the technical division.

○ time_to_influence_NRC = 12
DOCUMENT: Time to Influence NRC
[week]

This is the time it takes for NEI to influence the NRC into abandoning a regulation.

⊘ EFFregrev = GRAPH(frac_of_regs_to_review)
(0.00, 3.50), (0.1, 3.33), (0.2, 3.10), (0.3, 2.79), (0.4, 2.31), (0.5, 1.89), (0.6, 1.52), (0.7, 1.31), (0.8, 1.18), (0.9, 1.06), (1, 1.00)
DOCUMENT: Effect of Regulation Review

As the reviewing of initiated regulations decreases, the effect will be to increase the time that it takes to evaluate and implement the regulations once they are put on the books at the NRC.

⊘ EFF_reg_aband_tot_eng_and_man = GRAPH(IF Regulations_Under_Technical_Review>.15 AND TIME>104 THEN frac_regs_des_aband ELSE 0)
(0.00, 1.00), (0.1, 0.875), (0.2, 0.725), (0.3, 0.405), (0.4, 0.24), (0.5, 0.1), (0.6, 0.025), (0.7, 0.015), (0.8, 0.005), (0.9, 0.00), (1, 0.005)
DOCUMENT: Effect of Regulation Abandonment on Total Engineer and Management
Unitless

Information: PR Screening

□ Probs_Waiting_for_Screening(t) = Probs_Waiting_for_Screening(t - dt) + (new_incoming_problems - prob_srcreened_by_NWE - probs_not_screened_by_NWE) * dt
INIT Probs_Waiting_for_Screening = 0

DOCUMENT: Problems Waiting for Screening
[problems]

All problems discovered are first sent to the Nuclear Watch Engineer for screening of the need for quick corrective actions.

INFLOWS:

new_incoming_problems = IF dfcts_discvrd_&_lost>0 THEN dfcts_discvrd_&_lost*problems_per_defect ELSE 0
DOCUMENT: New Incoming Problems
[problems/week]

Problems or potential problems discovered through defects or a combination of defects.

OUTFLOWS:

prob_srcreened_by_NWE = Probs_Waiting_for_Screening*frac_probs_screen_by_NWE/time_for_NWE_to_screen
DOCUMENT: Problems Screened by NWE
[problems/week]

Problems screened by the NWE. Screened for applicability and for need for quick CA's.

probs_not_screened_by_NWE = Probs_Waiting_for_Screening*(1-frac_probs_screen_by_NWE)
DOCUMENT: Problems Not Screened by NWE
[problems/week]

Problems not screened by the NWE. Occurs because of a lack of time or availability.

Prob_Screening_in_Progress(t) = Prob_Screening_in_Progress(t - dt) + (new_prob_screen - problem_screening_completion) * dt
INIT Prob_Screening_in_Progress = 30

DOCUMENT: Problem Screening in Progress
[problem]

Screening of problems or potential problems in progress.

INFLOWS:

new_prob_screen = probs_not_screened_by_NWE+prob_srcreened_by_NWE-quick_CA_to__prob_needed
DOCUMENT: New Problems Screened
[problems]

Problems screened by the NWE and not screened by the NWE will be screened by other groups (usually the technical programs division) for determination of whether the problem is significant.

OUTFLOWS:

problem_screening_completion = Prob_Screening_in_Progress/adj_time_to_screen_problem
DOCUMENT: Problem Screening Completion
[problems/week]

Completion of problem screening by the technical programs groups.
Determined whether problem is significant to the utility or not.

adj_time_to_screen_problem = time_to_screen_problems*info_eng_unavail_ratio
DOCUMENT: Adjusted Time to Screen Problems
[week]

Time to screen problems, adjusted by the enigneer availability.

EFFincprobsNWE = (new_incoming_problems/SMTH1(new_incoming_problems,4,20))^-1
DOCUMENT: Effect of Incoming Problems on NWE

This effect changes the fraction of problems screened by the NWE based on the ratio of incomoming problems to the number of incoming problems smoothed over time.

frac_of_probs_req_eval = .75
DOCUMENT: Fraction of Problems Require Evaluations
[evaluations required/problems screened]

Fraction of screened problems that will require further analysis.

frac_probs_screen_by_NWE = .25*EFFincprobsNWE
DOCUMENT: Fraction of Problems Screened by NWE
[problems screened by NWE/problems]

Fraction of problems that the NWE is able to screen, this number is adjusted if the number of incoming problems is greater than it has been in the past (smooth)

frac_prob_need_quick_CA = .25
DOCUMENT: Fraction of Problems Need Quick Corrective Actions
[corrective actions needed/problems]

Fraction of problems screened by the NWE that dictate that quick corrective actions be taken.

problems_per_defect = 1/50
DOCUMENT: Problems per Defect
[problems/defect]

Number of problems or potential problems discovered per defect. Many defects go on unoticed because the are so minor, or numerous defects combine to produce a problem or potential problem. (This is done this way also because the number of defects is so high in the model and this system would be completely over-loaded with problems and corrective actions from every single defect)

quick_CA_to__prob_needed = prob_srcreened_by_NWE*frac_prob_need_quick_CA
DOCUMENT: Quick Corrective Actions to Problems Needed
[corrective actions/week]

If the NWE sees a problem that dictates that corrective actions (determined by the NWE) be taken quickly, he will pass them on directly to the manager who dissemenates corrective actions to the groups.

significant_problems = problem_screening_completion*frac_of_probs_req_eval
DOCUMENT: Significant Problems
[evaluations required/week]

Problems determined significant to the utility, and need further analysis, and possible corrective actions.

time_for_NWE_to_screen = dt
DOCUMENT: Time for NWE to Screen Problems
[week]

Time it takes for NWE to review a problem and make recommendations about it. Ideally, this should be set as 1 day, but model does not behave correctly when it is set that low.

time_to_screen_problems = 2
DOCUMENT: Time to Screen Problems
[week[

Time it takes to screen problems under normal workload conditions.

Information: Public Reporting

Reported_SALP_Score(t) = Reported_SALP_Score(t - dt) + (report_score) * dt
INIT Reported_SALP_Score = 0

DOCUMENT: Reported SALP Score

This is the SALP score as reported. Changes the number of times set in 'SALP reporting per year'

INFLOWS:

report_score = PULSE (-Reported_SALP_Score+SALP,1,52/SALP_reporting_per_year)
DOCUMENT: Report Score

This flow acts to change the reported SALP score. Resets the previous value to the new current SALP rating.

defects_per_press_release = 1000
DOCUMENT: Defects Per Press Release
[defects/pr]

Number of defects that occur before a press release is made. Also can be though of as a number of defects that contribute to a problem or potential problem that.

defect__operating_reports = press_release_from_defects*frac_of_press_releases_print_as_op_reps
DOCUMENT: Defect Operating Reports
[printed reports]

Number of operating reports due to defects that are printed.

press_release_from_defects = total_new_defects/defects_per_press_release
DOCUMENT: Press Releases From Defects
[pr/week]

Number of press releases that are issued because of defects.

press_release_ratio = SMTH1(press_release_from_defects,4,1)/SMTH1(press_release_from_defects,26,1)
DOCUMENT: Press Release Ratio

Ratio of a smooth of the last 4 week's releases to a smooth of the last 26 week's releases.

SALP_reporting_per_year = 4
DOCUMENT: SALP Reporting per Year

Number of times that SALP scores are reported to the public each year.

⊘ EFFSALPlocpub_opp = GRAPH(Reported_SALP_Score)
(1.00, 1.00), (1.33, 1.00), (1.67, 1.00), (2.00, 1.00), (2.33, 1.00), (2.67, 1.00), (3.00, 1.00), (3.33, 1.00), (3.67, 1.00), (4.00, 1.00)
DOCUMENT: Effect of SALP Local Public Opposition

Effect of SALP score on local public opposition.

⊘ EFFSALPnat_pub_opp = GRAPH(SMTH1(Reported_SALP_Score,52,2))
(1.00, 1.00), (1.33, 1.00), (1.67, 1.00), (2.00, 1.00), (2.33, 1.00), (2.67, 1.00), (3.00, 1.00), (3.33, 1.00), (3.67, 1.00), (4.00, 11.0)
DOCUMENT: Effect of SALP Nationall Public Opposition

Effect of SALP score on national public opposition. National SALP average will be taken as a smooth over the year of the SALP scores.

⊘ frac_of_press_releases_print_as_op_reps = GRAPH(press_release_ratio)
(0.00, 0.0375), (0.2, 0.0375), (0.4, 0.065), (0.6, 0.09), (0.8, 0.15), (1, 0.21), (1.20, 0.295), (1.40, 0.365), (1.60, 0.485), (1.80, 0.69), (2.00, 0.995)
DOCUMENT: Fraction of Press Releases Printed as Operating Reports
[printed reps/pr/week]

Fraction of press releases that get printed in the papers. If more defects are occuring recently, than in the past, more printings will occur.

Plant: Defect Flows

☐ Defects_Id(t) = Defects_Id(t - dt) + (dfcts_discvrd_&_lost + new_dfct_pm_equip - dfcts_fixed_because_pm_equip_bdwn - dfcts_fixed_schd_WO) * dt
INIT Defects_Id = 619.51*5

DOCUMENT: Defects Identified
[defects]

Defects that have been identified through inspections or suspected by information gained from historical data. Defects included in this catagory would either be from equipment within the pm system or other equipment which for some reason was inspected. One assumption of this model is that the plant will have a general understanding of the status of equipment within the plant pm system, more knowledge than for equipment outside of the pm program. Equipment may still function with a defect. However, a defect implies that the equipment may not perform as designed and hence have a higher probability of failure.

INFLOWS:

- dfcts_discvrd_&_lost = IF TIME >52 THEN (dfcts_ID_frm_insp-dfcts_forgotten) ELSE 900
  DOCUMENT: The positive flow is defects identified by inspections. The negative flow are defects that are forgotten about because of inadequate record keeping and information systems.

- new_dfct_pm_equip = (new_defects_ops+new_dfcts_bdwn)*(frac_equip_tag_pm)
  DOCUMENT: New Defects Preventive Maintenance System
  [defects/week]

  Defects or potential defects in equipment within the pm system, the existance of which the plant becomes aware or suspects.

OUTFLOWS:

- dfcts_fixed_because_pm_equip_bdwn = Tagged_PM_equip_brkdwn*dfcts_per_dfct_equip_pm
  DOCUMENT: Defects Fixed Because PM Equipment Breakdowns
  [Defects/week]

  Some identified defects are eliminated because the equipment breaks down and is consequently repaired.

- dfcts_fixed_schd_WO = IF TIME >52 THEN(maintd_equip_pm*frac_equip_pm_dfct*dfcts_per_dfct_equip_pm) ELSE (960)
  DOCUMENT: Defects eliminated by the completion of unscheduled work.

☐ Defects_Un_id(t) = Defects_Un_id(t - dt) + (new_dfct_unid - dfcts_discvrd_&_lost - dfct_fixed_because_equip_bdwn) * dt
INIT Defects_Un_id = 62000

DOCUMENT: Defects Unidentified
[defects]

Defects in plant equipment that have gone unidentified. Equipment may still function with a defect. However, defects significantly increase the probability of equipment failure or the inability of equipment to fully function under design conditions.

INFLOWS:

new_dfct_unid = (new_defects_ops+new_dfcts_bdwn)*(1-frac_equip_tag_pm)+ (new_dfcts_from_wmanship+new_dfcts_parts)
DOCUMENT: New Defects Unidentified
[defects]

New unidentified (UNID) defects in equipment. Defects can occur in all equipment. However, defects from wear or cascading defects resulting upon breakdown of other equipment are assumed to occur only in equipment not in the PM program: i.e. the pm program is designed to eliminate breakdowns due to wear and tear.

OUTFLOWS:

dfcts_discvrd_&_lost = IF TIME >52 THEN (dfcts_ID_frm_insp-dfcts_forgotten) ELSE 900
DOCUMENT: The positive flow is defects identified by inspections. The negative flow are defects that are forgotten about because of inadequate record keeping and information systems.

dfct_fixed_because_equip_bdwn = online_brkdwns*dfcts_per_dfct_equip_pff
DOCUMENT: Defects Fixed Because Equipment Breakdown
[defects/week]

Unidentified defects are eliminated, identified and subsequently repaired, as a result of equipment failure.

dfcts_forgotten = schd_WO_aw_Eq_Forgotten*equip_per_wo*frac_equip_pm_dfct*dfcts_per_dfct_equip_pm
DOCUMENT: Defects Forgotten
[defects/week]

Some work orders may be forgotten, lost, misplaced, or simply discarded. Each of those forgotten WO represents a number of defects which then go from being identified to being unidentified.

dfcts_per_dfct_equip_pff = Defects_Un_id/dfct_equip_pff
DOCUMENT: Defects per Defective Equipment Perceived Fully Functional
[defects/equipment]

The number of defects per unit of defective equipment in the perceived fully functional state.

dfcts_per_dfct_equip_pm = Defects_id/(dfct_equip_pm_sys+10)
DOCUMENT: Defects per Defective Equipment Preventative Maintenance
[defects/defective equipment]

The number of defects per unit of defective equipment that is in the predictive and preventive system.

dfcts_per_equip_pff = Defects_Un_id/Equip_Perceived_Fully_Funct
DOCUMENT: Defects per Piece of Equipment Perceived Fully Functions
[defects/piece of equipment]

Caculates the number of defects per piece of equipment PFF.

dfcts_per_equip_pm_sys = Defects_id/(Equip_Tagged_for_PM+100)

dfct_equip_pff = Equip_Perceived_Fully_Funct*frac_equip_pff_dfct
DOCUMENT: defective Equipment Perceived Fully Functional
[defective equipment]

The equipment that is perceived as fully functional but in fact is defective.

dfct_equip_pm_sys = Equip_Tagged_for_PM*frac_equip_pm_dfct
DOCUMENT: Defective Equipment Preventative Maintenance System
[pieces of equipment]

Equipment in Preventative Maintenance System that is Defective.

frac_dfcts_unid = Defects_Un_id/(total_defects+100)
DOCUMENT: Fraction Defects Unidentified
[unidentified defects/defect]

The fraction of total defects which go undetected.

○ frac_dfct_bdwn = 1/12
DOCUMENT: fraction Defects Breakdown
[equip breakdowns/defect/week]

Fraction of defects that cause breakdowns per week. (All defects will cause breakdowns in 12 weeks if this raction is 1/12)

○ maintd_equip_pm = equip_per_wo*schd_WO_completed
DOCUMENT: Maintained Equipment under Preventative Maintenance
[equipment/week]

Equipment that has been maintained through the preventative maintenance system thereby eliminating the defect or postponing breakdown (extending life).

○ online_brkdwns = Defects_Un_id*frac_dfct_bdwn
DOCUMENT: Online Breakdowns
[equipment breakdowns/week]

Breakdown of equipment that is on-line.

○ share_new_defects_bdwn = new_dfcts_bdwn/total_new_defects
DOCUMENT: Share of new defects from breakdowns

○ share_new_defects_ops = new_defects_ops/total_new_defects
DOCUMENT: Share of new defects from operations

○ share_new_defects_stores = new_dfcts_parts/total_new_defects
DOCUMENT: Share of new defects from stores and parts problems

○ share_new_defects_wmanship = new_dfcts_from_wmanship/total_new_defects
DOCUMENT: Share of new defects from poor workmanship

○ Tagged_PM_equip_brkdwn = Defects_Id*frac_dfct_bdwn*EFFDefldbrkdn
DOCUMENT: Tagged Preventive Maintenance Equipment Breakdowns
[equipment/week]

The break down of equipment that is in the planning and predictive system (and currently under inspection or being maintained?).

○ total_defects = Defects_Id+Defects_Un_id
DOCUMENT: Total Defects
[defects]

The total number of defects in plant equipment, both identified and unidentified.

○ total_new_defects = new_defects_ops+new_dfcts_from_wmanship+new_dfcts_bdwn+new_dfcts_parts
⊘ EFFDefldbrkdn = GRAPH(Equip_Tagged_for_PM/(Equip_Perceived_Fully_Funct+100))
(0.00, 0.01), (0.02, 0.11), (0.04, 0.185), (0.06, 0.275), (0.08, 0.4), (0.1, 0.52), (0.12, 0.63), (0.14, 0.74), (0.16, 0.83), (0.18, 0.925), (0.2, 1.00)
⊘ frac_equip_pff_dfct = GRAPH(dfcts_per_equip_pff)
(0.00, 0.00), (0.2, 0.134), (0.4, 0.268), (0.6, 0.39), (0.8, 0.5), (1.00, 0.595), (1.20, 0.7), (1.40, 0.8), (1.60, 0.885), (1.80, 0.955), (2.00, 1.00)
DOCUMENT: Fraction Equipment Perceived Fully Functional that is in fact Defective
[defective equipment/equipment]

There may be more than one defect per piece of equipment. This function graphically relates the total unindentified defects/equip perceived fully functional to the fraction of pieces of equipment with defects.

⊘ frac_equip_pm_dfct = GRAPH(dfcts_per_equip_pm_sys)
(0.00, 0.00), (0.2, 0.134), (0.4, 0.268), (0.6, 0.39), (0.8, 0.5), (1.00, 0.595), (1.20, 0.7), (1.40, 0.8), (1.60, 0.885), (1.80, 0.955), (2.00, 1.00)
DOCUMENT: Fraction Equipment Preventative Maintenance Defective
[defective equipment/pm equipment]

There may be more than one defect per piece of equipment. This function graphically relates defects/equip within the pm system to the fraction of pieces of equipment with defects.

Plant: Plant Model Parameters

☐ Book_Investment(t) = Book_Investment(t - dt)
INIT Book_Investment = Book_Investment_Input

DOCUMENT: Book Investment Input
[million dollars]

☐ Working_Cap(t) = Working_Cap(t - dt)
INIT Working_Cap = -Book_Investment + 100*(ATOI+Depreciation)/Init_CROI

DOCUMENT: Working Capital
[million dollars]

Investment in Working Capital

○ Annual_Fixed_Costs = 40
DOCUMENT: Annual Fixed Cost
[million Dollars/year]

○ ATOI = ATOI_new
DOCUMENT: After Tax Operating Income
[million dollars/year]

After Tax Operating Income excluding maintenance cost

○ ATOI_new = Rate_per_kWh*Power_Rating*(capacity_utilization/100)/1E6

○ av_parts_per_wo = 5
DOCUMENT: Average Parts per Work Order
[parts/work order]

○ av_time_btwn_dec_insp = 20
DOCUMENT: Average time between discretionary inspections
[weeks]

○ av_time_for_dec_insp = 5/equip_per_wo
DOCUMENT: average time for discretionary inspection
[hours/equipment inspection]

The average time for a discretionary inspection. The average here is for all equipment inspected from feedwater pumps to motor operated valves. Here, average time is a function of equipment per work order; this is based on an assumption about the level of disaggregation of equipment on work orders: i.e. an equipment per work order of 1 implies, for example, a motor operated valve is one unit where as an equipment per work order of 3 implies that the same mov is separated into three pieces -- the motor being one piece, the gear box another, and the valve a third. Hence, fewer pieces of equipment per work order leads to more time per work order: the amount of aggregation or disaggregation of equipment.

○ av_time_mand_inspect = 10/equip_per_wo
DOCUMENT: Average Time Mandatory Inspection
[hours/equipment inspection]

Average time to do mandantory inspection. The average here is for all equipment inspected from feedwater pumps to motor operated valves. Here, average time is a function of equipment per work order; this is based on an assumption about the level of disaggregation of work on work orders: i.e. an equipment per work order of 1 implies, for example, a motor operated valve is one unit where as an equipment per work order of 3 implies that the same mov is separated into three pieces of equipment -- the motor being one piece, the gear box another, and the valve a third. Hence, fewer pieces of equipment per work order leads to more time per work order: the amount of aggregation or disaggregation of equipment.

○ base_plnprd_wout_pln = 8
DOCUMENT: Base Planner Productivity without Plan
[plans/planner/week]

The number of work orders that a planner can do in one week if he starts without a (historical) plan in the library.

○ base_plnprd_w_pln = 30
DOCUMENT: Base Planner Productivity with Plans
[plans/planner/week]

Baseline planner productivity if there is an existing (historical) plan in the library.

○ Book_Investment_Input = 2000
DOCUMENT: Book Investment Input
[millions dollars]

Initial investment in plant. Used to be 237.

○ Decom_Costs = 200

○ Depreciation = .025*(Book_Investment/52+Decom_Costs)/52
DOCUMENT: Depreciation
{Million $'s/week}

Straight line depreciation of assets including decomm costs. Depreciated over 40 years.

○ Des_DE_ratio = 1

○ Discount_Rate = 4
DOCUMENT: Discount Rate
[percent]

Cost of Money

○ dollars_per_part = (4.2/(52*374*av_parts_per_wo))
DOCUMENT: Dollars per Part
[million dollars/part]

Average cost per part. Current set up takes average parts per work order into account. If you assume that the more parts per work order implies ordering smaller parts -- gaskets, bolts, nuts, wires, bearings, grease, etc. -- where as ordering fewer parts per work order implies ordering large parts -- motors, valves, gear boxes, pumps, etc. --, more parts per work order implies a smaller average cost per part. (currently = $43.19 per part or .000043 $mil/part)

○ equip_per_wo = 4
DOCUMENT: Equipment per Work Order
[equipment/WO]

The average number of pieces of equipment covered by a work order.

○ Event_Switch = 1
DOCUMENT: Event Switch
[0 or 1 logic variable]

1 initiates major event at other nuclear facility in week 156.
0 turns event off.

○ Frac_Maint_staff_Planners = Initial_Plng_Staff/Initial_Mechanics_Staff
DOCUMENT: Fraction Maintenance Staff Planners
[fraction: planners/maintenance staff]

the fraction of maintenance personnel dedicated to planning. Exogenous variable.

○ Initial_Level_Work_Plans = 100
DOCUMENT: Initial Level Work Plans
[work orders]

Initial value variable for both schd and unschd work plans available.

○ Initial_Mechanics_Staff = 349

DOCUMENT: Initial Maintenance Staff
[people]

Initial number of people on maintenance staff.

○ Initial_NRCinsp_BLog = 5
DOCUMENT: Initial Inspection Backlog
[inspections]

- Initial_Plng_Staff = 25*3
  DOCUMENT: Initial Planning Staff
  [people]

  Input data based on plant.

- Initial_Spec_Input = 25000
  DOCUMENT: Number of specifications for parts in Stores.

- Initial_Stores_Inv_Input = 60000*5
  DOCUMENT: Initial number of total parts in stores inventory. Input from plant.

- Init_Cmpgns = .84
  DOCUMENT: Initial Antinuclear Campaigns
  [campaigns]

- init_CROI = 12
  DOCUMENT: Initial Cash Return On Investment
  [percent/year]

- Init_EffCmpgns = .56
  DOCUMENT: Initial Effective Anti-Nuclear Campaigns
  [campaigns]

- Init_Eff_Media_Rpts = 2
  DOCUMENT: Initial Effective Media Reports
  [articles]

- Init_Eq_Bdwn = .15*Total_Equipment_in_Plant
  DOCUMENT: Initial Equipment Brokendown
  [equipment]

  Initial Value

- Init_Eq_PFF = .8266*Total_Equipment_in_Plant
  DOCUMENT: Initial Equipment Perceived Fully Functional
  [equipment]

  Initial value.

- Init_Eq_Tag_PM = .0234*Total_Equipment_in_Plant
  DOCUMENT: Initial Equipment Tagged for Preventative Maintenance
  [equipment]

  Initial value.

- Init_EventRep = 0
- init_Folup_Rpt = .26
  DOCUMENT: Initial Follow-up Reports
  [articles]

- Init_IG_suits = 2
  DOCUMENT: Initial Interest Group Suits
  [suits]

- Init_NRC_InvIP = 16
  DOCUMENT: Initial NRC Investigations In Progress
  [investigations]

- Init_NRC_RegID = .5
- Init_NRC_RegOS = 3.8
- Init_NRC_RepIP = 16
- init_number_of_shares = .8E8
- Init_Ops_Rpt = .3
  DOCUMENT: Initial Operating Reports
  [articles/week]

- init_stock_pr = ((Book_Investment_Input*1E6)/init_number_of_shares)*(1/(Des_DE_ratio+1))*0+3
- Lawmakers = 536

○ Pause_Switch = 0

○ Population_Size = 250E6

○ Total_Equipment_in_Plant = 13400*5
DOCUMENT: Total Equipment in Plant
[equipment]

Exogenous Input to be correlated to size of plant (megawatts).
(13400 initial input)

○ Total_Investment = Working_Cap+Book_Investment

Plant: Training and Learning Curves

☐ Cum_Forced_outages(t) = Cum_Forced_outages(t - dt) + (Takedown_rate_4) * dt
INIT Cum_Forced_outages = 1

DOCUMENT: Cumulative Corrective Actions Taken
[corrective actions]

This is the cumulative value of coorective actions taken.
Each event that flows through the agency system produces
a corrective action.

INFLOWS:

Takedown_rate_4 = Plant_Force_Out
DOCUMENT: Completed Preventative Maintenance Rate
(Work orders/week)

☐ Cum_OPs(t) = Cum_OPs(t - dt) + (Ops_rate) * dt
INIT Cum_OPs = 75*52

DOCUMENT: Cumulative Corrective Actions Taken
[corrective actions]

This is the cumulative value of coorective actions taken.
Each event that flows through the agency system produces
a corrective action.

INFLOWS:

Ops_rate = capacity_Online
DOCUMENT: Completed Preventative Maintenance Rate
(Work orders/week)

☐ Cum_OPs_2(t) = Cum_OPs_2(t - dt) + (Ops_rate_2) * dt
INIT Cum_OPs_2 = 75*52

DOCUMENT: Cumulative Corrective Actions Taken
[corrective actions]

This is the cumulative value of coorective actions taken.
Each event that flows through the agency system produces
a corrective action.

INFLOWS:

Ops_rate_2 = capacity_Online
DOCUMENT: Completed Preventative Maintenance Rate
(Work orders/week)

☐ Cum_parts_used(t) = Cum_parts_used(t - dt) + (Part_use_Rate) * dt
INIT Cum_parts_used = 100*52

DOCUMENT: Cumulative Corrective Actions Taken
[corrective actions]

This is the cumulative value of coorective actions taken.
Each event that flows through the agency system produces
a corrective action.

INFLOWS:

Part_use_Rate = IF(TIME>program_start)THEN(parts_consumed)ELSE(0)
DOCUMENT: Completed Preventative Maintenance Rate
(Work orders/week)

☐ Cum_work_since_prog_start(t) = Cum_work_since_prog_start(t - dt) + (Takedown_rate) * dt
INIT Cum_work_since_prog_start = 50*52

DOCUMENT: Cumulative Corrective Actions Taken
[corrective actions]

This is the cumulative value of coorective actions taken.
Each event that flows through the agency system produces
a corrective action.

INFLOWS:

Takedown_rate = IF(TIME>program_start)THEN(schd_WO_completed)ELSE(0)
DOCUMENT: Completed Preventative Maintenance Rate
(Work orders/week)

☐ Defect_Occ_Rate_wkmanshp(t) = Defect_Occ_Rate_wkmanshp(t - dt) + (- Def_Occ_Rt_wkmanhsp_dec) * dt
INIT Defect_Occ_Rate_wkmanshp = Base_dfct_f_wmanship

DOCUMENT: Event Occurance Rate
[event/week]

Rate at which events occur. Begins with an initial value of 5, and
then decreases from the learning curve of corrective actions.

OUTFLOWS:

Def_Occ_Rt_wkmanhsp_dec =
IF(TIME>52)THEN(Defect_Occ_Rate_wkmanshp*modified_learning_curve_frac*fractional_work_comp)ELSE(0)

☐ Def_Rate_Ops(t) = Def_Rate_Ops(t - dt) + (- def_Rate_ops_dec) * dt
INIT Def_Rate_Ops = Base_dfcts_ops_per_wk

DOCUMENT: Event Occurance Rate
[event/week]

Rate at which events occur. Begins with an initial value of 5, and
then decreases from the learning curve of corrective actions.

OUTFLOWS:

def_Rate_ops_dec = IF(TIME>52)THEN(Def_Rate_Ops*modified_learning_curve_frac_ops_2*fractional_Ops_2)ELSE(0)
DOCUMENT: Event Occurance Rate Decreasing
[event/week/week]

This is the rate that event occurance rate decreases because of corrective actions taken.

☐ Events_with_CA_Taken_Cumulative(t) = Events_with_CA_Taken_Cumulative(t - dt) + (CA_rate) * dt
INIT Events_with_CA_Taken_Cumulative = 20*52

DOCUMENT: Cumulative Corrective Actions Taken
[corrective actions]

This is the cumulative value of coorective actions taken.
Each event that flows through the agency system produces
a corrective action.

INFLOWS:

CA_rate = CA_completed
DOCUMENT: Corrective Action Rate
[ca/week]

Rate of corrective action completion.

☐ Ev_Rt_Op_Er_Exp(t) = Ev_Rt_Op_Er_Exp(t - dt) + (- Event_Rt_ops_Exp_dec) * dt
INIT Ev_Rt_Op_Er_Exp = .019

DOCUMENT: Event Occurance Rate due to operator experience
[event/week]

Rate at which events occur due to operator experience or inexperience since it drops with operator experience.

OUTFLOWS:

Event_Rt_ops_Exp_dec = IF(TIME>52) THEN (Ev_Rt_Op_Er_Exp*modified_learning_curve_frac_ops*fractional_Ops) ELSE (0)
DOCUMENT: Event Occurance Rate Decreasing
[event/week/week]

This is the rate that event occurance rate decreases because of corrective actions taken.

☐ Ev_Rt_Op_Misinf(t) = Ev_Rt_Op_Misinf(t - dt) + (- event_occurance_rate_decreasing) * dt
INIT Ev_Rt_Op_Misinf = .019

DOCUMENT: Event Rate due to Operator Misinformation
[events/week]

This is the number of events per week caused by operator misinformation.

OUTFLOWS:

event_occurance_rate_decreasing = IF(TIME>52) THEN(Ev_Rt_Op_Misinf*modified_learning_curve_frac_2*fractional_analysis) ELSE(0)
DOCUMENT: Event Occurance Rate Decreasing
[event/week]

This is the rate that event occurances decrease because of corrective actions taken.

☐ FO_Occurance_Rate_Op(t) = FO_Occurance_Rate_Op(t - dt) + (- FO_rate_decreasing) * dt
INIT FO_Occurance_Rate_Op = .25/52

DOCUMENT: Fo Occurance Rate from Operators
[FO/week]

Reduced by learning curve.

OUTFLOWS:

FO_rate_decreasing = IF(TIME>52) THEN (FO_Occurance_Rate_Op*modified_learning_curve_FO*fractional_Outage) ELSE (0)
DOCUMENT: Event Occurance Rate Decreasing
[event/week/week]

This is the rate that event occurance rate decreases because of corrective actions taken.

☐ Frac_parts_def(t) = Frac_parts_def(t - dt) + (- def_parts_rate_decreasing) * dt
INIT Frac_parts_def = Base_frac_mat_dfct_at_delvry
OUTFLOWS:

def_parts_rate_decreasing = IF(TIME>52)THEN(Frac_parts_def*modified_learning_curve_frac_5*fractional_parts_use)ELSE(0)
DOCUMENT: Event Occurance Rate Decreasing
[event/week/week]

This is the rate that event occurance rate decreases because of corrective actions taken.

○ Base_frac_mat_dfct_at_delvry = .25
DOCUMENT: Base Fraction Materials Defective at Delivery
[defective materials/total materials]

○ CA_completed = proc_CA_validated+train_CA_validated
DOCUMENT: Corrective Actions Completed
[ca/week]

This is the number of corrective actions completed in the industry.

○ fractional_analysis = CA_rate/Events_with_CA_Taken_Cumulative
DOCUMENT: Fractional Analysis
[1/week]

This is the fraction corrective action rate, compared to the cumulative amount of actions taken already.

○ fractional_Ops = Ops_rate/Cum_OPs
DOCUMENT: Fractional Analysis
[1/week]

This is the fraction corrective action rate, compared to the cumulative amount of actions taken already.

○ fractional_Ops_2 = Ops_rate_2/Cum_OPs_2
DOCUMENT: Fractional Analysis
[1/week]

This is the fraction corrective action rate, compared to the cumulative amount of actions taken already.

○ fractional_Outage = Takedown_rate_4/Cum_Forced_outages
DOCUMENT: Fractional Analysis
[1/week]

This is the fraction corrective action rate, compared to the cumulative amount of actions taken already.

○ fractional_parts_use = Part_use_Rate/Cum_parts_used
DOCUMENT: Fractional Analysis
[1/week]

This is the fraction corrective action rate, compared to the cumulative amount of actions taken already.

○ fractional_work_comp = Takedown_rate/Cum_work_since_prog_start
DOCUMENT: Fractional Analysis
[1/week]

This is the fraction corrective action rate, compared to the cumulative amount of actions taken already.

○ LC_frac_Ops = (.05/3)*Training_Hours
DOCUMENT: Learning Curve Fraction

This is the percent reduction in events for doubling of corrective actions taken.

○ LC_frac_Ops_2 = (.01)*Training_Hours
DOCUMENT: Learning Curve Fraction

This is the percent reduction in events for doubling of corrective actions taken.

○ learning_curve_FO = (.1/3)*Training_Hours
DOCUMENT: Learning Curve Fraction

This is the fractional reduction in events for doubling of corrective actions taken.

○ learning_curve_frac = (.05/3)*Training_Hours
DOCUMENT: Learning Curve Fraction

This is the percent reduction in events for doubling of corrective actions taken.

○ learning_curve_frac[illegible] = (.01)*Training_Hours*EFFLREX
DOCUMENT: Learning Curve Fraction

This is the percent reduction in events for doubling of corrective actions taken.

○ learning_curve_frac_5 = (.01)*Training_Hours
○ Mech_EX_Fact = 1.05
DOCUMENT: Mechanic Experience Cost Factor
(unitless)

A Multiplier which MGT can use to hire more experienced mechanics for more money.

○ modified_learning_curve_FO = -LOGN(1-learning_curve_FO)/LOGN(2)
DOCUMENT: Modified Learning Curve Fraction

Modifies the learning curve fraction for use in the learning curve eqautions.

○ modified_learning_curve_frac = -LOGN(1-learning_curve_fracwork)/LOGN(2)
DOCUMENT: Modified Learning Curve Fraction

Modifies the learning curve fraction for use in the learning curve eqautions.

○ modified_learning_curve_frac_2 = -LOGN(1-learning_curve_frac)/LOGN(2)
DOCUMENT: Modified Learning Curve Fraction

Modifies the learning curve fraction for use in the learning curve eqautions.

○ modified_learning_curve_frac_5 = -LOGN(1-learning_curve_frac_5)/LOGN(2)
DOCUMENT: Modified Learning Curve Fraction

Modifies the learning curve fraction for use in the learning curve eqautions.

○ modified_learning_curve_frac_ops = -LOGN(1-LC_frac_Ops)/LOGN(2)
DOCUMENT: Modified Learning Curve Fraction

Modifies the learning curve fraction for use in the learning curve eqautions.

○ modified_learning_curve_frac_ops_2 = -LOGN(1-LC_frac_Ops_2)/LOGN(2)
DOCUMENT: Modified Learning Curve Fraction

Modifies the learning curve fraction for use in the learning curve eqautions.

○ program_start = 0
DOCUMENT: Program starting date

⊘ EFFLREX = GRAPH(Mech_EX_Fact)
(0.00, 0.904), (10.0, 0.904), (20.0, 0.907), (30.0, 0.917), (40.0, 0.942), (50.0, 0.981), (60.0, 1.02), (70.0, 1.03), (80.0, 1.04), (90.0, 1.04), (100, 1.04)

Plant: Capacity Calculation

○ Bought_Power = IF(cust_demand-capacity_Online)<0 THEN 0 ELSE (cust_demand-capacity_Online)
DOCUMENT: Bought Power
Units: {%}
This is the power that must be bought by the utility to make up for power not generated.

○ capacity_bdown = frac_equip_bdown
DOCUMENT: Capacity Brokendown
[Fraction production capacity brokendown]

Capacity down due to equipment breakdown. Assume S shaped curve due to online spares for common breakdowns but no spares for infrequent breakdown items. This data should be gotten from a sage model analysis of the facilities involved. The current curve is assumed to be the same as for takedowns. However if the plant has a brakedown, forced outage due to a scram there is a time delay until the cause is found and corrected and the plant can be legally started up. During this time the capacity is zero.

○ capacity_dwn = MIN(((capacity_bdown+capacity_tdown)*100),100)
DOCUMENT: Capacity Down
[percent production capacity down]

Total capacity down from both breakdowns and takedowns

○ capacity_Online = MAX((1-capacity_bdown-capacity_tdown)*100,0)*(1-Per_Outage)
DOCUMENT: Capacity Online
[percent production capacity up and running]

○ cust_demand = 80
○ equip_w_schd_WIP = Schd_WIP*equip_per_wo
DOCUMENT: Equipment with Scheduled Work in Progress
[equipment]

○ frac_equip_bdown = Equip_Brokendown/Total_Equipment_in_Plant
DOCUMENT: Fraction Equipment Brokendown
[fraction: equipment brokendown/total equipment]

Fraction of equipment that is broken down

○ frac_equip_tag_pm = Equip_Tagged_for_PM/Total_Equipment_in_Plant
DOCUMENT: Fraction Equipment Tagged Preventative Maintenance
[fraction: equipment with schd WO/total plant equipment]

Fraction of plant equipment in the preventive or predictive maintenance system.

○ frac_equip_tdown = (equip_w_schd_WIP/Total_Equipment_in_Plant)+EFFForcOut
DOCUMENT: Fraction Equipment TakenDown
[fraction: equipment tdwn/total equipment]

Fraction of equipment that has been removed from service due to scheduled maintenance.

○ production_pressure = IF(Per_Outage=0)THEN(Plant_Demand/(capacity_Online*.89+10))ELSE(0)
DOCUMENT: Production Pressure
[unitless]

○ total_equip_percvd_avail_for_ops = Equip_Perceived_Fully_Funct+Equip_Tagged_for_PM-equip_w_schd_WIP
DOCUMENT: Total Equipment Perceived Available for Operations
[equipment]

Total equipment perceived as either on-line and operating or quickly available for such (equipment takedown for pm work but not considered broken).

⊘ capacity_tdown = GRAPH(frac_equip_tdown)
(0.00, 0.00), (0.1, 0.04), (0.2, 0.096), (0.3, 0.17), (0.4, 0.26), (0.5, 0.4), (0.6, 0.585), (0.7, 0.725), (0.8, 0.845), (0.9, 0.945), (1.00, 1.00)
DOCUMENT: Capacity Takendown
[fraction production capacity Takendown]

Capacity down due to equipment takedown. Assume S shaped curve due to the intelligence of people to take things down that have the least effect on capacity. This data should be gotten from a sage model analysis of the facilities involved. The current curve is assumed to be the same as for breakdowns

Plant: Defect Sources

○ Base_dfcts_ops_per_wk = .115*(1-Frac_New_Eq)
DOCUMENT: Base Defects Operations per Week
[defects/equipment/week]

Base level of defects which result from wear and tear of normal operations. Exogenous constant.

○ Base_dfct_f_wmanship = .35
DOCUMENT: Base Defect from Workmanship
[defects/equipment]

Base level of defects resulting from worker error or mishap. Base value does not account for effects of experience or training. It will now-MGT 8/4/94

○ base_dfct_per_bdwn = .48
DOCUMENT: Base Defects Per Breakdown
[defect/breakdown]

Base level of defects per breakdown of another or the same piece of equipment. Not influenced by experience or improvement of plant systems and procedures.

○ defect_reduction = DEF_RED
DOCUMENT: Defect Reduction
[unitless multiplier]

Test parameter to reduce defects by an arbitrary percentage. If it is .7, defects are reduced by 30%

○ Frac_New_Eq = New_Equipment/Total_Equipment_in_Plant

○ new_defects_ops = IF(TIME>52)THEN(total_equip_percvd_avail_for_ops*defect_reduction*Def_Rate_Ops*(1-Frac_New_Eq))ELSE (4800)
DOCUMENT: New Defects Operations
[defects/week]

New defects resulting from simply operating plant equipment.

○ new_dfcts_bdwn = IF TIME>52 THEN total_bdwns*new_dfct_per_bdwn ELSE 2200
DOCUMENT: New Defects Breakdown
[defects /week]

New defects caused by the breakdown of other or same piece of plant equipment.

○ new_dfcts_from_wmanship = IF TIME >25 THEN(Total_maintd_equip*Defect_Occ_Rate_wkmanshp*smth_effotdg*defect_reduction*EFFeng_wo_rt_def*EFFuwErtdef*EFFuwoMrtdef*Eff_Mt_wo_rt_def) ELSE (1500)
DOCUMENT: New Defects from Workmanship
[defects/week]

New defects introduced from poor workmanship.

○ new_dfct_per_bdwn = base_dfct_per_bdwn*defect_reduction
DOCUMENT: New Defects per Breakdown
[defect/breakdown of equipment]

New defects resulting from a breakdown of another or same piece of plant equipment.

○ smth_effotdg = SMTH1(EffFotDG,8,1)

○ total_bdwns = online_brkdwns+Tagged_PM_equip_brkdwn
DOCUMENT: Total Breakdowns
[equipment breakdowns/week]

Total breakdowns of all plant equipment, both equipment online and operating and equipment offline under inspection or maintenance.

○ Total_maintd_equip = total_WO_completed*equip_per_wo
DOCUMENT: Total Maintained Equipment
[equipment/week]

All equipment worked on as a result of a scheduled or unscheduled work orders.

Plant: Engineering Staff

□ ave_E_overtime(t) = ave_E_overtime(t - dt) + (change_in_ave_E_OT) * dt
INIT ave_E_overtime = eng_standard_hours*target_frac_eng_overtime

DOCUMENT: Average Overtime
[hours/week/person]

Average number of overtime hours worked. The averaging represents the process through which excessive overtime gradually causes fatigue and reduces productivity. The process of recovering from excessive overtime is also gradual.

INFLOWS:

- change_in_ave_E_OT = (Indicated_E_overtime-ave_E_overtime)/time_to_change_ave_E_OT
  DOCUMENT: Change in Average Overtime
  [hours/week/person/week]

□ Pro_Engineering_Staff(t) = Pro_Engineering_Staff(t - dt) + (Estaff_up_to_speed - pro_Estaff_loss - promotions) * dt
INIT Pro_Engineering_Staff = .40*Initial_Mechanics_Staff

INFLOWS:

- Estaff_up_to_speed = Rookie_Engineering_Staff/time_to_train_engs
  DOCUMENT: Maintenance Staff Loss
  [people/week]

OUTFLOWS:

- pro_Estaff_loss = Engineerlayoffs/time_to_layoff_engs+eng_attrition+bud_layoff_eng/time_to_layoff_engs+Add_layoff_Comp
- promotions = 0

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Rookie_Engineering_Staff(t) = Rookie_Engineering_Staff(t - dt) + (Eng_hiring - Estaff_up_to_speed) * dt
INIT Rookie_Engineering_Staff = 5

DOCUMENT: Maintenance Staff
[people]

Total Maintenance personnel, including planners.

INFLOWS:

Eng_hiring = eng_attrition+(New_Eng_Hiring_from_OT*New_hiring_Switch_Eng/Eng_hiring_delay)+promotions
DOCUMENT: Maintenance Hiring
[people/week]

hiring of new mechanics

(if time = 10 then 0/dt else 0

OUTFLOWS:

Estaff_up_to_speed = Rookie_Engineering_Staff/time_to_train_engs
DOCUMENT: Maintenance Staff Loss
[people/week]

Add_layoff_Comp = PULSE(Layoff_Switch*total_Estaff*Layoff_Fraction,200,1000)
bud_layoff_eng = IF(total_Estaff>MAX_Eng)THEN(total_Estaff-MAX_Eng)ELSE(0)
cost_of_Eng_OT = (ave_E_overtime*Cost_per_OT_Hr)/1E6
DOCUMENT: Cost of Engineers overtime
(Dollars/week)
Cost of each engineer to work overtime

Cost_per_OT_Hr = 50
Engineerlayoffs = Eng_Layoffs_from_OT+layoff_frac*total_Estaff
DOCUMENT: Maintenance layoffs
[%]

This is a policy variable that is an exogenous function of time.

Engineers_info = frac_Eng_info*total_Estaff
Engineer_Maint = frac_Eng_Maint*total_Estaff*EFFNRCInvMGTENG
Engineer_Plans = frac_Eng_plans*total_Estaff
eng_attrition = .001*Pro_Engineering_Staff
DOCUMENT: Attrition
[fraction: people/week]

staff lost per week due to retirement, death, quiting, etc.

eng_exp_ratio = (total_Estaff-Rookie_Engineering_Staff)/total_Estaff
Eng_hiring_delay = 4
DOCUMENT: Time to hire new mechanics

Units weeks

eng_info_rev_comp =
eng_saf_info_rev_avail*Human_Effs_on_Work_Comp_Eng*EFF_Estaff_exp*(1+target_frac_eng_overtime*eff_info_wld_OT)*eff_prod_pr
s_on_E_OT
eng_info_workload = Eng_info_WTB/(Engineers_info+1)
Eng_info_WTB = info_eng_WTB/info_rep_per_eng_per_week
eng_maint_workload = Eng_maint_WTB/(Engineer_Maint+1)
Eng_maint_WTB = (Sch_wo_wait_eng_Rev+Unschd_WO_wait_eng)/Maint_rev_per_eng_per_week
eng_ot_frac_ratio = frac_E_overtime/target_frac_eng_overtime
eng_plan_rev_avail = Engineer_Plans*plans_rev_per_eng_per_week
eng_plan_rev_comp =
eng_plan_rev_avail*Human_Effs_on_Work_Comp_Eng*EFF_Estaff_exp*(1+target_frac_eng_overtime*eff_plan_wld_OT)*eff_prod_pres_
n_E_OT
eng_plan_workload = Eng_plan_WTB/(Engineer_Plans+1)

Eng_plan_WTB = Plans_wait_eng_rev/plans_rev_per_eng_per_week

eng_saf_info_rev_avail = Engineers_info*info_rep_per_eng_per_week

eng_schd_wo_rev_comp =
eng_wo_rev_avail*Human_Effs_on_Work_Comp_Eng*ratio_eng_schd_to_unschd_wo*EFF_Estaff_exp*(1+target_frac_eng_overtime*eff_aint_wld_OT)*eff_prod_pres_on_E_OT

eng_standard_hours = 40
DOCUMENT: Standard Hours
[hours/week/person]

The standard number of hours worked per week per maintenance staff (mechanic, electrician, pipefitter, machinist, etc.)

eng_tot_work_hours = ave_E_overtime+eng_standard_hours
DOCUMENT: Total Work Hours
[hours/week/person]

eng_unscd_wo_rev_comp = 2*eng_schd_wo_rev_comp*(1-ratio_eng_schd_to_unschd_wo)/ratio_eng_schd_to_unschd_wo

eng_workload =
(eng_info_workload*Engineers_info+eng_plan_workload*Engineer_Plans+Engineer_Maint*eng_maint_workload)/(total_Estaff+1)

eng_wo_rev_avail = Engineer_Maint*Maint_rev_per_eng_per_week

E_OT_Frac = eng_tot_work_hours/eng_standard_hours

frac_Eng_info = .3

frac_Eng_Maint = .5+.714*(.3-frac_Eng_info)

frac_Eng_plans = .2+.286*(.3-frac_Eng_info)

frac_E_overtime =
target_frac_eng_overtime*eff_prod_pres_on_E_OT*((eff_info_wld_OT*Engineers_info+eff_maint_wld_OT*Engineer_Maint+eff_plan_wld_OT*Engineer_Plans)/total_Estaff)
DOCUMENT: Actual fraction overtime
[fraction: hours/hours]

Overtime for maintenance staff in terms of percent of standard work week.

Human_Effs_on_Work_Comp_Eng = eff_motivation_eng_WO_comp*SMTH1(eff_OT_fatigue_eng,4,1)*eff_wload_eng_wo_comp
DOCUMENT: Human Effects on Work Order Completion
[unitless multiplier]

Product of motivation, fatigue and workload effects on worker performance.

Indicated_E_overtime = eng_standard_hours*frac_E_overtime
DOCUMENT: Indicated Overtime
[hours]

Indicated Maintenance overtime that is worked (actual week by week value). As of 8/4 it includes the training hours.

info_rep_per_eng_per_week = 16

layoff_frac = 0

Maint_rev_per_eng_per_week = 8

New_hiring_Switch_Eng = IF(total_Estaff>MAX_Eng)THEN(0)ELSE(1)
DOCUMENT: New Hiring Switch
[0 or 1 logic variable]

1 allows new maintenance staff to be hired when average overtime becomes excessive.
0 disallows any new hiring because of increased workloads.

plans_rev_per_eng_per_week = 16

ratio_eng_schd_to_unschd_wo = MAX(Sch_wo_wait_eng_Rev/(Unschd_WO_wait_eng+Sch_wo_wait_eng_Rev+.0001),.2)

target_frac_eng_overtime = .125
DOCUMENT: Target Fraction Overtime
[hours/hours]

time_to_change_ave_E_OT = 2
DOCUMENT: Time to Change Average Overtime
[weeks]

This is the time to adjust average overtime. It determines how quickly average overtime adjusts to actual overtime.

time_to_layoff_engs = 12

time_to_train_engs = 26

total_Estaff = (Pro_Engineering_Staff+Rookie_Engineering_Staff)*EFF_reg_aband_tot_eng_and_man

EFF_Estaff_exp = GRAPH(eng_exp_ratio)
(0.6, 0.75), (0.65, 0.773), (0.7, 0.804), (0.75, 0.853), (0.8, 0.897), (0.85, 0.953), (0.9, 1.00), (0.95, 1.05), (1.00, 1.10)

eff_info_wld_OT = GRAPH(eng_info_workload)
(0.00, 0.00), (0.333, 0.14), (0.667, 0.42), (1.00, 0.84), (1.33, 1.16), (1.67, 1.42), (2.00, 1.70), (2.33, 2.04), (2.67, 2.34), (3.00, 2.80), (3.33, 3.20), (3.67, 3.62), (4.00, 4.00)

eff_maint_wld_OT = GRAPH(eng_maint_workload)
(0.00, 0.00), (0.333, 0.18), (0.667, 0.4), (1.00, 0.72), (1.33, 1.02), (1.67, 1.34), (2.00, 1.70), (2.33, 2.18), (2.67, 2.44), (3.00, 2.78), (3.33, 3.12), (3.67, 3.60), (4.00, 4.00)

eff_motivation_eng_WO_comp = GRAPH(SALP)
(1.00, 1.15), (1.25, 1.09), (1.50, 1.07), (1.75, 1.05), (2.00, 1.04), (2.25, 1.03), (2.50, 1.02), (2.75, 1.02), (3.00, 1.02), (3.25, 1.01), (3.50, 1.01), (3.75, 1.00), (4.00, 1.00)
DOCUMENT: Effect Motivation Work Order Completion
[unitless multiplier]

This is the motivation factor on productivity based on good leadership. 1.0 is none 1.15 if full

eff_OT_fatigue_eng = GRAPH(ave_E_overtime)
(0.00, 1.00), (2.22, 0.982), (4.44, 0.958), (6.67, 0.917), (8.89, 0.87), (11.1, 0.844), (13.3, 0.827), (15.6, 0.814), (17.8, 0.804), (20.0, 0.802)
DOCUMENT: Effect Overtime Fatigue Work Order Completion
[unitless multiplier]

The effect of overtime on productivity.

eff_plan_wld_OT = GRAPH(eng_plan_workload)
(0.00, 0.00), (0.333, 0.14), (0.667, 0.36), (1.00, 0.66), (1.33, 0.86), (1.67, 1.14), (2.00, 1.36), (2.33, 1.74), (2.67, 2.14), (3.00, 2.44), (3.33, 2.80), (3.67, 3.12), (4.00, 4.00)

eff_prod_pres_on_E_OT = GRAPH(IF (Per_Outage=1) THEN (1.5) ELSE production_pressure)
(1.00, 1.02), (1.04, 1.18), (1.08, 1.31), (1.13, 1.43), (1.17, 1.52), (1.21, 1.62), (1.25, 1.70), (1.29, 1.77), (1.33, 1.83), (1.38, 1.89), (1.42, 1.93), (1.46, 1.97), (1.50, 2.00)
DOCUMENT: Effect Production Pressure on Overtime
[unitless multiplier]

The effect of production pressure on overtime. If product demand is very high, there is pressure for maintenance to work overtime to get the equipment back on-line.

eff_wload_eng_wo_comp = GRAPH(eng_workload)
(0.00, 0.751), (0.125, 0.767), (0.25, 0.8), (0.375, 0.862), (0.5, 0.906), (0.625, 0.938), (0.75, 0.96), (0.875, 0.977), (1.00, 1.00)
DOCUMENT: Effect of Workload on Work Order Completion
[unitless multiplier]

As work slows down, the staff's desire to complete work orders decreases. It represents peoples desire to make the available work fit the available time.

Eng_Layoffs_from_OT = GRAPH(eng_ot_frac_ratio)
(0.00, 1.49), (0.111, 0.517), (0.222, 0.307), (0.333, 0.21), (0.444, 0.12), (0.556, 0.0825), (0.667, 0.0375), (0.778, 0.03), (0.889, 0.00), (1.00, 0.0075)

New_Eng_Hiring_from_OT = GRAPH(frac_E_overtime/target_frac_eng_overtime+.00001)
(1.00, 0.05), (1.33, 0.08), (1.67, 0.13), (2.00, 0.25), (2.33, 0.42), (2.67, 0.86), (3.00, 1.31), (3.33, 1.72), (3.67, 1.90), (4.00, 1.97)

Plant: Equipment Flows

Equip_Brokendown(t) = Equip_Brokendown(t - dt) + (Equip_broke_to_on_line + Tagged_PM_equip_bdwn) * dt
INIT Equip_Brokendown = Init_Eq_Bdwn

DOCUMENT: Equipment Brokendown
[Equipment]

Equipment broken down and in the process of being repaired. Unscheduled work is done on broken equipment.

INFLOWS:

Equip_broke_to_on_line = online_brkdwns-unschd_WO_completed*equip_per_wo
DOCUMENT: Equipment Broken to On-Line
[equipment/week]

In the positive direction, the flow is equipment that breakdown. In the negative direction, the flow is equipment that is repaired.

Tagged_PM_equip_bdwn = Tagged_PM_equip_brkdwn
DOCUMENT: Tagged PM Equipment Breakdown
[equipment/week]

Equipment in the predictive and preventive system that breaks down while it is waiting to be inspected or repaired.

Equip_Perceived_Fully_Funct(t) = Equip_Perceived_Fully_Funct(t - dt) + (- Equip_broke_to_on_line - Equip_PM_to_on_line) * dt
INIT Equip_Perceived_Fully_Funct = Init_Eq_PFF

DOCUMENT: Equipment Perceived Fully Functional
[equipment]

The value 13,400 is the number of pieces on equipment in Sabine ADN.
Equipment that is perceived to be fully functional

OUTFLOWS:

Equip_broke_to_on_line = online_brkdwns-unschd_WO_completed*equip_per_wo
DOCUMENT: Equipment Broken to On-Line
[equipment/week]

In the positive direction, the flow is equipment that breakadown. In the negative direction, the flow is equipment that is repaired.

Equip_PM_to_on_line = equip_req_tdwn_for_insp-schd_WO_completed*equip_per_wo-schd_WO_aw_Eq_Forgotten*equip_per_wo
DOCUMENT: Equipment Preventative Maintenance to On-Line
[equipment/week]

The positive flow is takedowns of equipment. The negative flow is the completion of scheduled work and the process of of losing information that equipment is defective.

Equip_Tagged_for_PM(t) = Equip_Tagged_for_PM(t - dt) + (Equip_PM_to_on_line - Tagged_PM_equip_bdwn) * dt
INIT Equip_Tagged_for_PM = Init_Eq_Tag_PM

DOCUMENT: Equipment Tagged for Preventative Maintenance
[equipment]

{The number of pieces of equipment identified as defective by the predictive or preventive program including all casual noticing of defects. Always set the initial condition to be greater than 0.}

? in pm program for routine maintenance or only those things that are broken. defective or potentially defective without pm.

INFLOWS:

Equip_PM_to_on_line = equip_req_tdwn_for_insp-schd_WO_completed*equip_per_wo-schd_WO_aw_Eq_Forgotten*equip_per_wo
DOCUMENT: Equipment Preventative Maintenance to On-Line
[equipment/week]

The positive flow is takedowns of equipment. The negative flow is the completion of scheduled work and the process of of losing information that equipment is defective.

OUTFLOWS:

Tagged_PM_equip_bdwn = Tagged_PM_equip_brkdwn
DOCUMENT: Tagged PM Equipment Breakdown
[equipment/week]

Equipment in the predictive and preventive system that breaks down while it is waiting to be inspected or repaired.

WO_for_bdwn_pm_equip = SMTH1(Tagged_PM_equip_bdwn/equip_per_wo,5)
DOCUMENT: Work Orders for Broken Down PM Equipment
[work orders/week]

(currently applies to pm equipment under inspection, which requires a WO, and not pm equipment operating in plant. This may present a flaw in logic, CHECK)

Plant: Flows of Sched. Work Orders.

☐ Schd_WIP(t) = Schd_WIP(t - dt) + (schd_takedowns - schd_WO_completed) * dt
INIT Schd_WIP = 7.03*5

DOCUMENT: Scheduled Work Orders in Progress
[work orders]

Scheduled work orders that are currently being worked on. In this state, the equipment is off-line.
(does equipment have to be off-line? Yes)

INFLOWS:

schd_takedowns = SMTH1(schd_WO_avail_tdown,.5)/time_to_tdwn
DOCUMENT: This flows takedowns into Sch WIP to equal the amount of work getting done plus an inventory adjustment for getting WIP to one half the target weeks work.

OUTFLOWS:

schd_WO_completed = normal_schd_wo_comp*Human_Effs_on_WO_Comp
DOCUMENT: Scheduled Work Orders Completed
[work orders/week]

The number of scheduled work orders that are completed based on the number of mechanics assigned to perform scheduled work and their productivity in doing scheduled work.

☐ Schd_Work_Plns_Available(t) = Schd_Work_Plns_Available(t - dt) + (Schd_Work_Plng_Completed - schd_work_plns_expended) * dt
INIT Schd_Work_Plns_Available = 100

DOCUMENT: Scheduled Work Plans Available
[Work Orders]

The number of plans that have been completed for scheduled work and are awaiting execution.

[.14]

INFLOWS:

Schd_Work_Plng_Completed = plns_available*frac_plng_is_for_schd_work
DOCUMENT: Scheduled Work Planning Completed
[work orders/week]

The rate at which plans are completed for scheduled work orders: i.e. the rate at which work orders are planned and developed.

OUTFLOWS:

schd_work_plns_expended = schd_work_plans_used+schd_work_plns_bdwn_drop+
schd_work_plns_forgotten
DOCUMENT: Scheduled Work Plans Expended
[work orders/week]

The flow of job plans that are used in completing scheduled work orders or become obsolete because the equipment breaks down before the scheduled work can be completed.

☐ Schd_Work_Reqiring_Mat(t) = Schd_Work_Reqiring_Mat(t - dt) + (new_plnd_wo_req_mat - Schd_work_mats_acqrd) * dt
INIT Schd_Work_Reqiring_Mat = .06*5

DOCUMENT: Scheduled Work Requiring Materials
[work orders]

The number of scheduled and planned work orders that are awaiting materials for completion of work. (These materials were unforeseen in the planning process and were not recognized as being required until work was under way (or at least until after planning). I think this sentence is wrong)

INFLOWS:

new_plnd_wo_req_mat = Schd_Work_Plng_Completed*frac_schd_pln_wo_req_mat
DOCUMENT: New Planned Work Orders Requiring Materials
[work orders/week]

The flow (build up) of scheduled and planned work orders that require additional materials (unforeseen material requirements). The additional material requirements are unexpected and may require expediting.

OUTFLOWS:

Schd_work_mats_acqrd = (Schd_Work_Reqiring_Mat/mat_acq_delay) +WO_bdwn_pm_equip_req_mat
DOCUMENT: Scheduled Work Materials Acquired
[work orders/week]

The rate of reduction of scheduled planned work orders that require materials. The outflow is determined by the number of work orders that receive the necessary materials and work orders that become obsolete because the equipment breaks down before the scheduled work can be completed.

Schd_WO_awaiting_Eq(t) = Schd_WO_awaiting_Eq(t - dt) + (wo_mgt_to_eq - schd_WO_aw_eq_not_done - new_schd_WO_avail) * dt
INIT Schd_WO_awaiting_Eq = 62.74*5

DOCUMENT: Scheduled Work Orders Awaiting Equipment
[work orders]

Work orders waiting for equipment to become available before work may proceed.

INFLOWS:

wo_mgt_to_eq = mgr_schd_wo_rev_comp

OUTFLOWS:

schd_WO_aw_eq_not_done = schd_WO_aw_Eq_Forgotten+(WO_for_bdwn_pm_equip) *(1-frac_schd_WO_WTBD_avail)*EFF_schd_work
DOCUMENT: Scheduled Work Orders Awaiting Equipment Not Done
[work orders/week]

The work orders not initiated because either the work is forgotten or the equipment breakdown, requiring unscheduled work which supercedes schd wo.

new_schd_WO_avail = (Schd_WO_awaiting_Eq/schd_wait_time_by_prod)-(Schd_WO_w_Eq_Avail/schd_recycle_time)
DOCUMENT: New Scheduled Work Orders Available
[work orders/week]

Flow of work orders back and forth between Schd WO Awaiting Equipment and Schd WO with Eq Available based on the production needs.

Schd_WO_Unplnd_Mat_req(t) = Schd_WO_Unplnd_Mat_req(t - dt) + (new_schd_wo_unplnd_mat_req - schd_wo_unplnd_mat_acq) * dt
INIT Schd_WO_Unplnd_Mat_req = 3.08*5

DOCUMENT: Scheduled Work Orders Unplanned Material Requirements
[work orders]

Scheduled work orders that have unforeseen material requirements.

INFLOWS:

new_schd_wo_unplnd_mat_req = schd_takedowns* (1-frac_schd_WO_eq_avail_w_plan)*frc_schd_wo_unpln_mat_req
DOCUMENT: New Scheduled Work Orders Unplanned Material Requirements
[work orders/week]

(Flow of work orders without plans that require additional models.)

OUTFLOWS:

schd_wo_unplnd_mat_acq = Schd_WO_Unplnd_Mat_req/mat_acq_delay
DOCUMENT: Scheduled Work Orders Unplanned Material Acquisition
[work orders/week]

Schd_WO_w_Eq_Avail(t) = Schd_WO_w_Eq_Avail(t - dt) + (new_schd_WO_avail - schd_takedowns - schd_WO_w_eq_av_not_done) * dt
INIT Schd_WO_w_Eq_Avail = 8.5*5

DOCUMENT: Scheduled Work Orders with Equipment Available
[work orders]

This is scheduled work where the equipment is available to work on if plant wants to take it off-line for work.

INFLOWS:

new_schd_WO_avail = (Schd_WO_awaiting_Eq/schd_wait_time_by_prod)-(Schd_WO_w_Eq_Avail/schd_recycle_time)
DOCUMENT: New Scheduled Work Orders Available
[work orders/week]

Flow of work orders back and forth between Schd WO Awaiting Equipment and Schd WO with Eq Available based on the production needs.

OUTFLOWS:

schd_takedowns = SMTH1(schd_WO_avail_tdown,5)/time_to_tdwn
DOCUMENT: This flows takedowns into Sch WIP to equal the amount of work getting done plus an inventory adjustment for getting WIP to one half the target weeks work.

schd_WO_w_eq_av_not_done = EFF_schd_work*SMTH1(((WO_for_bdwn_pm_equip)*frac_schd_WO_WTBD_avail),10)
DOCUMENT: Scheduled Work Orders with Equipment Available Not Done
[work orders/week]

This is the flow of work orders which breakdown while in the Sch Work with Eq. Avail. Stock

Sch_wo_wait_eng_Rev(t) = Sch_wo_wait_eng_Rev(t - dt) + (new_schd_wo_await_equip - wo_eng_to_mgt - schd_eng_wo_forget) * dt
INIT Sch_wo_wait_eng_Rev = 62.74*5
INFLOWS:

new_schd_wo_await_equip = def_eq_req_tdwn/equip_per_wo+mod_CA_planned*schd_wo_per_mod_CA
DOCUMENT: New Scheduled Work Orders Awaiting Equipment
[work orders/week]

The flow of new scheduled work orders that are waiting for equipment to become available.

OUTFLOWS:

wo_eng_to_mgt = eng_schd_wo_rev_comp
schd_eng_wo_forget = IF Sch_wo_wait_eng_Rev>2*wo_eng_to_mgt THEN Sch_wo_wait_eng_Rev/eng_and_man_forget_time ELSE 0

Sch_wo_wait_Mgt_Rev(t) = Sch_wo_wait_Mgt_Rev(t - dt) + (wo_eng_to_mgt - wo_mgt_to_eq - schd_wo_mgr_forget) * dt
INIT Sch_wo_wait_Mgt_Rev = 100
INFLOWS:

wo_eng_to_mgt = eng_schd_wo_rev_comp

OUTFLOWS:

wo_mgt_to_eq = mgr_schd_wo_rev_comp
schd_wo_mgr_forget = IF Sch_wo_wait_Mgt_Rev>2*wo_mgt_to_eq THEN Sch_wo_wait_Mgt_Rev/eng_and_man_forget_time ELSE 0

EFF_schd_work = Sch_Total_worked/Defects_id

frac_schd_pln_wo_req_mat = 1-(Service_Level*utilization)
DOCUMENT: Fraction Scheduled Planned Work Orders Requiring Materials
[fraction: work orders/work orders]

Fraction of scheduled and planned work orders requiring materials to be ordered. (Using 30% based on planning Focus reports for SABINE.)

frac_schd_wip_w_plan = schd_pln_wip/(Schd_WIP+.1)
DOCUMENT: Fraction Scheduled Work In Progress with Plan
[fraction: work orders/work orders]

Fraction of scheduled work orders that is currently being worked on and has been planned.

frac_schd_WO_eq_avail_w_plan = schd_pln_WO_equip_avail/(Schd_WO_w_Eq_Avail+10)
DOCUMENT: Fraction Scheduled Work Orders Equipment Available with Plan
[fraction: work orders/work orders]

Fraction of scheduled work orders in the category of equipment available and having been planned.

frac_schd_WO_TBD_w_plan = (schd_pln_WO_equip_avail+schd_pln_WO_await_equip)/(total_schd_WO_Waiting_TBD+10)
DOCUMENT: Fraction Scheduled Work Orders To Be Done with Plan
[fraction: work orders/work orders]

The fraction of scheduled work orders awaiting to be done that have been planned.

{frac schd await avail w plan}

frac_schd_WO_WTBD_avail = SMTH1(Schd_WO_w_Eq_Avail/(total_schd_WO_Waiting_TBD+10),5)
DOCUMENT: Fraction Scheduled Work Orders Available
[fraction: work orders/work orders]

Fraction of scheduled work orders waiting to be done where the equipment is available.

frac_WO_await_equip_w_plan = schd_pln_WO_await_equip/(Schd_WO_awaiting_Eq+10)

○ frc_schd_wo_unpln_mat_req = 1-(Service_Level*utilization)
DOCUMENT: Fraction Scheduled Work Orders Unplanned Material Requirement
[fraction:]

(This is the fraction of unplanned scheduled work orders which will require material which is not immediately avialable (need to be ordered).)

○ mat_acq_delay = .5
DOCUMENT: Material Acquisition Delay
[weeks]

Time it takes to get extra material.

○ schd_pln_wip = MIN(Schd_Work_Plns_Available,Schd_WIP*targ_frac_plan)
DOCUMENT: Scheduled Planned Work In Progress
[work orders]

Scheduled Work Orders currently being worked that also has been planned.

○ schd_pln_WO_await_equip = Schd_Work_Plns_Available-schd_pln_wip-schd_pln_WO_equip_avail
DOCUMENT: Scheduled Planned Work Orders Awaiting Equipment
[work orders]

Scheduled work that have been planned and are awaiting equipment (to be taken out of service or put into service) for work to proceed.

○ schd_pln_WO_equip_avail = MIN(Schd_WO_w_Eq_Avail*targ_frac_plan,Schd_Work_Plns_Available-schd_pln_wip)
DOCUMENT: Scheduled Planned Work Orders Equipment Available
[work orders]

Scheduled Work Orders with equipment available and having been planned.

○ schd_work_plans_used = schd_WO_completed*frac_schd_wip_w_plan
DOCUMENT: Scheduled Work Plans Used
[work orders/week]

The use of plans in completing scheduled work.

○ schd_work_plns_bdwn_drop = WO_for_bdwn_pm_equip*frac_schd_WO_TBD_w_pln
DOCUMENT: Scheduled Work Plans Breakdown Drop
[work orders/week]

Scheduled work that has been planned but is dropped from the backlog of scheduled work to be done,because a breakdown requiring unscheduled work supercedes the previously planned work.

○ schd_work_plns_forgotten = schd_WO_aw_Eq_Forgotten*frac_WO_await_equip_w_plan
DOCUMENT: Scheduled Work Plans Forgotten
[work orders/week]

Scheduled work orders that were planned but never used and are finally discarded from the backlog of available work to be done.

○ schd_WO_avail_tdown = Schd_WO_w_Eq_Avail-(Schd_Work_Reqiring_Mat*(Schd_WO_w_Eq_Avail/(total_schd_WO_Waiting_TBD+10)))
DOCUMENT: Scheduled Work Orders Available Takedown
[work orders]

The number of scheduled work orders that are available to work on.
This is equal to the number of work orders for which the equipment is available less the work orders that are awaiting materials.

○ schd_WO_aw_Eq_Forgotten = Schd_WO_awaiting_Eq/schd_WO_Memory
DOCUMENT: Scheduled Work Orders Awaiting Equipment Forgotten
[work orders/week]

The number of work orders in the scheduled available to work which is forgotten each week.

○ schd_WO_Memory = 26
DOCUMENT: Scheduled Work Order Memory
[weeks]

(Fraction of work orders forgotten each week. This will depend on how good a system you have for setting priorities and keeping track equipment that is identified as being defective. was .5 and multiplied with schd wo await equip)

○ schd_wo_per_mod_CA = 4

schd_WO_RTBD&BD = Schd_WIP+schd_WO_avail_tdown
DOCUMENT: Scheduled Work Orders Ready To Be Done and Being Done.
[work orders]

All work that either in progress or available to be worked.

Sch_Total_worked = Sch_wo_wait_eng_Rev+Sch_wo_wait_Mgt_Rev+total_schd_WO_in_sys

targ_frac_plan = .5
DOCUMENT: Target Fraction Planned
[planned work orders/work orders]

The target fraction of work that is to be planned.

time_to_tdwn = .5
DOCUMENT: Target Weeks Work In Progress
[weeks]

The target number of weeks worth of work orders that maintenance want to be working on. Exogenous variable

total_schd_WO_in_sys = Schd_WIP+total_schd_WO_Waiting_TBD
DOCUMENT: Total Scheduled Work Orders In System
[work orders]

The total number of work orders that are in some way scheduled.

total_schd_WO_Waiting_TBD = Schd_WO_awaiting_Eq+Schd_WO_w_Eq_Avail
DOCUMENT: Total Scheduled Work Orders Waiting To Be Done
[work orders]

Total scheduled work that is waiting to be done, includes wo with equipment available and wo awaiting equipment.

WO_bdwn_pm_equip_req_mat = (Schd_Work_Reqiring_Mat/total_schd_WO_Waiting_TBD)*WO_for_bdwn_pm_equip
DOCUMENT: Work Orders for Brokendown PM Equipment Requiring Materials
[work orders/week]

EFFeng_wo_rt_def = GRAPH(wo_eng_to_mgt/INIT(wo_eng_to_mgt))
(0.5, 0.903), (0.95, 0.929), (1.40, 0.961), (1.85, 0.982), (2.30, 1.00), (2.75, 1.03), (3.20, 1.06), (3.65, 1.08), (4.10, 1.09), (4.55, 1.10), (5.00, 1.10)

Eff_Mt_wo_rt_def = GRAPH(wo_mgt_to_eq/INIT(wo_mgt_to_eq))
(0.5, 0.9), (0.95, 0.932), (1.40, 0.963), (1.85, 0.987), (2.30, 1.00), (2.75, 1.03), (3.20, 1.06), (3.65, 1.08), (4.10, 1.09), (4.55, 1.10), (5.00, 1.10)

schd_recycle_time = GRAPH(production_pressure)
(0.00, 4.00), (0.167, 3.54), (0.333, 3.06), (0.5, 2.54), (0.667, 2.04), (0.833, 1.60), (1.00, 1.25), (1.17, 1.02), (1.33, 0.88), (1.50, 0.76), (1.67, 0.68), (1.83, 0.58), (2.00, 0.5)
DOCUMENT: Scheduled Recycle Time
[weeks]

This is the time equipment will be available before operations takes it back and it returns to the awaiting equipment availability state

schd_wait_time_by_prod = GRAPH(production_pressure)
(0.00, 0.25), (0.2, 0.31), (0.4, 0.6), (0.6, 0.95), (0.8, 1.35), (1.00, 2.00), (1.20, 2.70), (1.40, 3.70), (1.60, 4.40), (1.80, 4.80), (2.00, 5.00)
DOCUMENT: Scheduled Wait Time
[weeks]

This is the time a work order has to wait to be scheduled based on the demand for production versus the actual production being achieved. This graph is based on having a 2 week wait at 100% of desired production.

Plant: Inspections

av_time_btwn_mand_insp = (25.5/EFFNRCminsp)*Social_to_plant_switch+(30*(1-Social_to_plant_switch))
DOCUMENT: Average time between mandantory inspections for each piece of equipment.
[weeks]

Changed from 30/ to 20/ +10/

def_eq_req_tdwn = equip_ID_dfct_dinspwouttdwn+equip_ID_dfct_minspwouttdwn

○ desired_discretionary_inspects = (Equip_Perceived_Fully_Funct*frac_equip_inspectable /av_time_btwn_dsc_insp)*EFFNRCrepmi*EFFNRCRDDIMI
DOCUMENT: Desired Discretionary inspections
[equipment inspections/week]

○ desired_Staff_for_dsc_insp = (desired_discretionary_inspects*av_time_for_dsc_insp) /standard_hours
DOCUMENT: Desired mechanics for discretionary inspections
[staff persons]

○ dfcts_ID_frm_insp = dfct_equip_ID_insp*dfcts_per_dfct_equip_pff
DOCUMENT: Defects Identified from Inspections
[defects/week]

Total defects identified by inspections both discretionary and mandatory.

○ dfct_equip_dinspwouttdwn = dsc_insp_wout_tdwn*frac_equip_dfct_dsc_insp
DOCUMENT: Defective Equipment in Discretionary Inspection without Takedown
[equipment/week]

The number of discretionary inspections, where the inspection does not require a takedown, that do have defects.

disc inspects no tdown defective

○ dfct_equip_ID_dfct_dinsp = dfct_equip_ID_dfct_dinspwouttdwn+dfct_equip_ID_dfct_dinspwtdwn
DOCUMENT: Defective Equipment Identified as Defective during Discretionary Inspections
[equipment/week]

○ dfct_equip_ID_dfct_dinspwouttdwn = dfct_equip_dinspwouttdwn*(1-prob_miss_dfct_dsc_insp)
DOCUMENT: Defective Equipment Identified Defective during Discretionary Inspections without takedown
[equipment/week]

The number of discretionary inspections, where the inspection does not require a takedown, that do have defects and result in a takedown to fix the equipment.

disc inspect nid defect to inspect

○ dfct_equip_ID_dfct_dinspwtdwn = dsc_insp_w_tdwn*frac_equip_dfct_dsc_insp
DOCUMENT: Defective Equipment Identified Defective during Discretionary Inspection with Takedown
[equipment/week]

disc inspect req tdown defective

○ dfct_equip_ID_dfct_minsp = dfct_equip_ID_dfct_minspwouttdwn+dfct_equip_ID_dfct_minspwtdwn
DOCUMENT: Defective Equipment Identified as Defective during Mandatory Inspection
[equipment/week]

○ dfct_equip_ID_dfct_minspwouttdwn = dfct_equip_minspwouttdwn*(1-prob_miss_dfct_mand_insp)
DOCUMENT: Defective Equipment Identified as Defective during mandatory inspections without takedown
[equipment/week]

Mandatory inspections, not requiring a takedown, which find a defect and result in a takedown to repair the equipment

mand inspect nid defect to inspect

○ dfct_equip_ID_dfct_minspwtdwn = mand_insp_w_tdwn*frac_equip_dfct_mand_insp
DOCUMENT: Defective Equipment Identified Defective during Mandatory Inspections with Takedown
[equipment/week]

Mandatory inspections of equipment that require a takedown for the inspections that are defective

Mand inspect req tdown defective

○ dfct_equip_ID_insp = dfct_equip_ID_dfct_dinsp+dfct_equip_ID_dfct_minsp
DOCUMENT: Defective Equipment Identified Inspections
[equipment/week]

Total takedowns of equipment that is actually defective

○ dfct_equip_minspwouttdwn = mand_insp_wout_tdwn*frac_equip_dfct_mand_insp
DOCUMENT: Defective Equipment Mandatory Inspections without Takedown
[equipment/week]

The number of mandatory inspections, not requiring a takedown, that are done on defective equipment

○ dsc_insp_wout_tdwn = Staff_dsc_insp_wouttd*standard_hours/av_time_for_dsc_insp
DOCUMENT: Discretionary Inspections Without Takedown
[equipment inspections/week]

The number of discretionary inspections performed that don't require a takedown for the inspection. Calculated by taking manpower available times average manhours per week divided by manhours necessary .

○ dsc_insp_w_tdwn = (Staff_dsc_insp_wtdwn*standard_hours)/av_time_for_dsc_insp
DOCUMENT: Discretionary Inspections with Takedown
[equipment/week]

Discretionary inspections that require a takedown for the inspection

○ equip_ID_dfct_dinspwouttdwn = dfct_equip_ID_dfct_dinspwouttdwn+non_dfct_equip_ID_dfct_dinspwouttdwn
DOCUMENT: Equipment Identified Defective during Discretionary Inspections without Takedowns
[equipment/week]

All equipment that was identified as being defective during discretionary online inspection routine (includes actually defect equipment and misidentified equip).

○ equip_ID_dfct_minspwouttdwn = dfct_equip_ID_dfct_minspwouttdwn+non_dfct_equip_ID_dfct_minspwouttdwn
DOCUMENT: Equipment Identified Defective during Mandatory Inspection without Takedown
[equipment/week]

All equipment that is identified as being defective during mandatory online inspections (includes equipment that is actually defective and equipment that was incorrectly identified as defective).

○ equip_req_tdwn_for_insp = equip_ID_dfct_dinspwouttdwn+equip_ID_dfct_minspwouttdwn+mand_insp_w_tdwn+dsc_insp_w_tdwn
DOCUMENT: Equipment Requiring Takedown for Inspection
[equipment/week]

Total takedowns that are required from mandatory and discretionary inspections.

○ frac_dsc_insp_req_tdwn = .15
DOCUMENT: Fraction Discretionary Inspections Requiring Takedown
[fraction: discretionary insp wtdwn/discret insp]

Fraction of discretionary inspections that require a takedown to do the inspection

○ frac_equip_inspectable = .6
DOCUMENT: Fraction Equipment Inspectable
[fraction: inspectable equip/equip]

The fraction of total equipment that can be inspected with the current technology used in the area and deemed justifiable.

○ frac_equip_req_mand_inspect =
MIN((.2*EFFNRCminsp)*(.6*EFFNRCinvminsp)*(EFFNRCRDDIMI)*Social_to_plant_switch+(.1*(1-Social_to_plant_switch)),1)
DOCUMENT: Fraction Equipment Requiring Mandatory Inpection.
[fraction: equipment req insp/equipment]

○ frac_mand_insp_req_tdwn = .36
DOCUMENT: Fraction Mandatory Inspection Requiring Takedown
[fraction: equip insp req tdwn/equip insp]

The fraction of mandatory inspections that require a takedown for the inspection

○ mand_insp = Equip_Perceived_Fully_Funct*frac_equip_req_mand_inspect/av_time_btwn_mand_insp
DOCUMENT: Mandatory Equipment Inspections
[equipment inspections/week]

Pieces of plant equipment requiring mandatory inspections.

○ mand_insp_Staff = (mand_insp*av_time_mand_inspect)/
standard_hours
DOCUMENT: Mandatory Inspection Staff
[people]

Mechanics allocated to mandatory inspections

○ mand_insp_wout_tdwn = mand_insp-mand_insp_w_tdwn
DOCUMENT: Mandatory Equipment Inspections without Takedown
[equipment inspections/week]

Equipment inspections that are mandatory but where the inspection does not require a takedown.

○ mand_insp_w_tdwn = mand_insp*frac_mand_insp_req_tdwn
DOCUMENT: Mandatory Inspection with Takedown
[equipment/week]

Mandatory inspections that require a takedown for the inspection

○ non_dfct_equip_ID_dfct_dinspwouttdwn = dsc_insp_wout_tdwn*(1-frac_equip_dfct_dsc_insp)*
prob_false_pos
DOCUMENT: Non-Defective Equipment Identified Defective during Discretionary Inspections without Takedowns
[equipment/week]

Takedowns for discretionary inspections, not requiring a takedown for the inspection, which have no defects but you think they do.

disc inspect ntd no defect to inspect

○ non_dfct_equip_ID_dfct_minspwouttdwn = mand_insp_wout_tdwn*
(1-frac_equip_dfct_mand_insp)*prob_false_pos
DOCUMENT: Non-Defective Equipment Identified Defective during Mandatory Inspections without Takedowns
[equipment/week]

equipment Takedowns resulting from mandatory inspections (the inspection doesn't require a takedown) that have no defects.

mandatory inspect ntd no defect to inspect

○ prob_false_pos = .05
DOCUMENT: Probability of finding a false positive when doing an inspection.

○ prob_miss_dfct_dsc_insp = .15
DOCUMENT: Probability of missing a defect in a discretionary inspection.

○ prob_miss_dfct_mand_insp = .03
DOCUMENT: Probability Miss Defect during Mandatory Inspection
[fraction]

The probability that a mandatory inspection misses a defective piece of equipment

○ Social_to_plant_switch = 1

DOCUMENT: Social to Plant Switch
[0 or 1 logic switch]

1 connects social pressure/safety regulation section to plant model.
0 disconnects social pressure/safety regulations section from plant model.

○ Staff_dsc_insp_wouttd = dsc_insp_Staff-Staff_dsc_insp_wtdwn
DOCUMENT: Staff Discretionary Inspection without Takedown
[people]

Mechanics allocated to discretionary inspections where the inspection does not require a takedown

○ Staff_dsc_insp_wtdwn = dsc_insp_Staff*frac_dsc_insp_req_tdwn
DOCUMENT: Staff Discretionary Inspection with TakeDown
[people]

Mechanics allocated to discretionary inspections that require a takedown

mech disc inspect td

frac_equip_dfct_dsc_insp = GRAPH(frac_equip_pff_dfct)
(0.00, 0.00), (0.1, 0.15), (0.2, 0.3), (0.3, 0.435), (0.4, 0.55), (0.5, 0.65), (0.6, 0.745), (0.7, 0.83), (0.8, 0.91), (0.9, 0.965), (1.00, 1.00)
DOCUMENT: This calibrates the expected fraction of finding a defect when you inspect a piece of equipment for discreationary inspections.

frac disc inspects defective

frac_equip_dfct_mand_insp = GRAPH(frac_equip_pff_dfct)
(0.00, 0.00), (0.1, 0.15), (0.2, 0.3), (0.3, 0.435), (0.4, 0.55), (0.5, 0.65), (0.6, 0.745), (0.7, 0.83), (0.8, 0.91), (0.9, 0.965), (1.00, 1.00)
DOCUMENT: Fraction Mandatory Inspections Defective
[fraction: equipment defective/equipment inspected]

The fraction of equipment receiving a mandatory inspection that is in fact defective.

Plant: Management Staff

ave_Mgt_OT(t) = ave_Mgt_OT(t - dt) + (chg_in_ave_mgt_OT) * dt
INIT ave_Mgt_OT = mgr_standard_hours*target_frac_eng_overtime

DOCUMENT: Average Overtime
[hours/week/person]

Average number of overtime hours worked. The averaging represents the process through which excessive overtime gradually causes fatigue and reduces productivity. The process of recovering from excessive overtime is also gradual.

INFLOWS:

chg_in_ave_mgt_OT = (indicated_mgt_OT-ave_Mgt_OT)/time_to_change_mgt_OT
DOCUMENT: Change in Average Overtime
[hours/week/person/week]

Pro_Management_Staff(t) = Pro_Management_Staff(t - dt) + (Mgt_up_to_speed - Mgt_loss) * dt
INIT Pro_Management_Staff = (1/11)*(total_Estaff+initial_Mechanics_Staff)
INFLOWS:

Mgt_up_to_speed = Rookie_Management_Staff/mgt_time_to_up_to_speed
DOCUMENT: Maintenance Staff Loss
[people/week]

OUTFLOWS:

Mgt_loss = (attrition_MGT+MGTlayoff/time_to_layoff_mgrs)+Sud_layoff_mgt/time_to_layoff_mgrs

Rookie_Management_Staff(t) = Rookie_Management_Staff(t - dt) + (MGT_hiring - Mgt_up_to_speed) * dt
INIT Rookie_Management_Staff = 0

DOCUMENT: Maintenance Staff
[people]

Total Maintenance personnel, including planners.

INFLOWS:

MGT_hiring = attrition_MGT+((New_Mgt_Hiring_from_OT)*New_hiring_Switch_2/MGT_hiring_delay)
DOCUMENT: Maintenance Hiring
[people/week]

hiring of new mechanics

(if time = 10 then 0/4 else 0

OUTFLOWS:

Mgt_up_to_speed = Rookie_Management_Staff/mgt_time_to_up_to_speed
DOCUMENT: Maintenance Staff Loss
[people/week]

○ attrition_MGT = .001*Pro_Management_Staff
DOCUMENT: Attrition
[fraction: people/week]

staff lost per week due to retirement, death, quiting, etc.

○ Bud_layoff_mgt = IF(total_Mgt_staff>Max_MGT)THEN(total_Mgt_staff-Max_MGT)ELSE(0)
○ des_frac_Mgt_OT =
target_frac_Mgt_OT*eff_prod_pres_on_Mgt_OT/eff_prod_pres_on_Mgt_OT*((eff_mgr_inf_wld_OT*Managers_info+eff_mgr_mnt_wld_O
Managers_maint)/mgt_staff_no_fin)
DOCUMENT: Actual fraction overtime
[fraction: hours/hours]

Overtime for maintenance staff in terms of percent of standard work week.

○ frac_Mgt_fin = .20
○ frac_Mgt_info = frac_Eng_info/2
○ frac_mgt_layoff = 0
○ frac_Mgt_maint = 1-frac_Mgt_info-.2
○ Human_Effs_on_Work_Comp_Mgr = eff_motivation_mgr_WO_comp*SMTH1(eff_OT_fatigue_mgr,4,1)*eff_wload_mgr_work_wo_comp
DOCUMENT: Human Effects on Work Order Completion
[unitless multiplier]

Product of motivation, fatigue and workload effects on worker performance.

○ indicated_mgt_OT = mgr_standard_hours*des_frac_Mgt_OT
DOCUMENT: Indicated Overtime
[hours]

Indicated Maintenance overtime that is worked (actual week by week value). As of 8/4 it includes the training hours.

○ info_rep_per_mgr_per_week = 9
○ maint_rev_per_mgr_per_week = 20
○ Managers_fin = frac_Mgt_fin*total_Mgt_staff
○ Managers_info = frac_Mgt_info*total_Mgt_staff
○ Managers_maint = frac_Mgt_maint*total_Mgt_staff*EFFNRCInvMGTENG
○ mgr_info_rev_avail = Managers_info*info_rep_per_mgr_per_week
○ mgr_info_rev_comp =
mgr_info_rev_avail*Human_Effs_on_Work_Comp_Mgr*Eff_Mgt_staff_exp*(1+target_frac_Mgt_OT*eff_mgr_mnt_wld_OT)*eff_prod_pr
s_on_Mgt_OT
○ mgr_info_workload = mgr_info_WTB/(Managers_info+1)
○ mgr_info_WTB = SMTH1(info_mgr_WTB/info_rep_per_mgr_per_week,1)
○ mgr_maint_rev_avail = Managers_maint*maint_rev_per_mgr_per_week
○ mgr_maint_workload = mgr_maint_WTB/Managers_maint
○ mgr_maint_WTB = SMTH1((Sch_wo_wait_Mgt_Rev+Unschd_wo_wait_mgr/2)/maint_rev_per_mgr_per_week,2)
○ mgr_ot_ratio = des_frac_Mgt_OT/target_frac_Mgt_OT
○ mgr_schd_wo_rev_comp =
mgr_maint_rev_avail*Human_Effs_on_Work_Comp_Mgr*mgt_ratio_sched_to_unsched_wo*Eff_Mgt_staff_exp*(1+target_frac_Mgt_OT*
_mgr_inf_wld_OT)*eff_pred_pres_on_Mgt_OT
○ mgr_standard_hours = 40
DOCUMENT: Standard Hours
[hours/week/person]

The standard number of hours worked per week per maintenance staff (mechanic, electrician, pipefitter, machinist, etc.)

○ mgr_tot_work_hours = ave_Mgt_OT+mgr_standard_hours
DOCUMENT: Total Work Hours
[hours/week/person]

○ mgr_unsch_wo_rev_comp = 2*mgr_schd_wo_rev_comp*(1-mgt_ratio_sched_to_unsched_wo)/mgt_ratio_sched_to_unsched_wo
○ mgr_workload = (Managers_info*mgr_info_workload+Managers_maint*mgr_maint_workload)/(mgt_staff_no_fin+1)

MGTlayoff = Mgr_Layoffs_from_Workload+frac_mgt_layoff*total_Mgt_staff
DOCUMENT: Maintenance layoffs
[%]

This is a policy variable that is an exogenous function of time.

MGT_hiring_delay = 4
DOCUMENT: Time to hire new mechanics

Units weeks

mgt_OT_frac = mgr_tot_work_hours/mgr_standard_hours
mgt_ratio_sched_to_unsched_wo = MAX ((Sch_wo_wait_Mgt_Rev/(Sch_wo_wait_Mgt_Rev+Unschd_wo_wait_mgr+1)),.2)
mgt_staff_no_fin = total_Mgt_staff-Managers_fin
mgt_time_to_up_to_speed = 26
New_hiring_Switch_2 = IF Max_MGT>total_Mgt_staff THEN 0 ELSE 1
DOCUMENT: New Hiring Switch
[0 or 1 logic variable]

1 allows new maintenance staff to be hired when average overtime becomes excessive.
0 disallows any new hiring because of increased workloads.

target_frac_Mgt_OT = .125
DOCUMENT: Target Fraction Overtime
[hours/hours]

time_to_change_mgt_OT = 2
DOCUMENT: Time to Change Average Overtime
[weeks]

This is the time to adjust average overtime. It determines how quickly average overtime adjusts to actual overtime.

time_to_layoff_mgrs = 8
total_Mgt_staff = (Pro_Management_Staff+Rookie_Management_Staff)*EFF_reg_aband_tot_eng_and_man
eff_mgr_inf_wld_OT = GRAPH(mgr_info_workload)
(0.00, 0.00), (0.333, 0.16), (0.667, 0.48), (1.00, 0.72), (1.33, 0.98), (1.67, 1.32), (2.00, 1.68), (2.33, 2.06), (2.67, 2.40), (3.00, 2.70), (3.33, 3.14), (3.67, 3.40), (4.00, 4.00)
eff_mgr_mnt_wld_OT = GRAPH(mgr_maint_workload)
(0.00, 0.00), (0.333, 0.12), (0.667, 0.36), (1.00, 0.66), (1.33, 0.96), (1.67, 1.22), (2.00, 1.62), (2.33, 1.92), (2.67, 2.16), (3.00, 2.56), (3.33, 2.98), (3.67, 3.34), (4.00, 4.00)
Eff_Mgt_staff_exp = GRAPH((total_Mgt_staff-Rookie_Management_Staff)/total_Mgt_staff)
(0.7, 0.7), (0.73, 0.835), (0.76, 0.872), (0.79, 0.89), (0.82, 0.905), (0.85, 0.925), (0.88, 0.957), (0.91, 1.00), (0.94, 1.06), (0.97, 1.14), (1.00, 1.20)
eff_motivation_mgr_WO_comp = GRAPH(SALF)
(1.00, 1.15), (1.25, 1.08), (1.50, 1.07), (1.75, 1.05), (2.00, 1.04), (2.25, 1.03), (2.50, 1.02), (2.75, 1.02), (3.00, 1.02), (3.25, 1.01), (3.50, 1.01), (3.75, 1.00), (4.00, 1.00)
DOCUMENT: Effect Motivation Work Order Completion
[unitless multiplier]

This is the motivation factor on productivity based on good leadership. 1.0 is none 1.15 if full

eff_OT_fatigue_mgr = GRAPH(ave_Mgt_OT)
(0.00, 1.00), (2.22, 0.98), (4.44, 0.971), (6.67, 0.968), (8.89, 0.924), (11.1, 0.896), (13.3, 0.838), (15.6, 0.781), (17.8, 0.755), (20.0, 0.752)
DOCUMENT: Effect Overtime Fatigue Work Order Completion
[unitless multiplier]

The effect of overtime on productivity.

eff_prod_pres_on_Mgt_OT = GRAPH(IF (Per_Outage=1) THEN (1.5) ELSE production_pressure)
(1.00, 1.02), (1.04, 1.18), (1.08, 1.31), (1.13, 1.43), (1.17, 1.52), (1.21, 1.62), (1.25, 1.70), (1.29, 1.77), (1.33, 1.83), (1.38, 1.89), (1.42, 1.93), (1.46, 1.97), (1.50, 2.00)
DOCUMENT: Effect Production Pressure on Overtime
[unitless multiplier]

The effect of production pressure on overtime. If product demand is very high, there is pressure for maintenance to work overtime to get the equipment back on-line.

eff_wload_mgr_work_wo_comp = GRAPH(mgr_workload)
(0.00, 0.752), (0.125, 0.766), (0.25, 0.814), (0.375, 0.852), (0.5, 0.883), (0.625, 0.916), (0.75, 0.944), (0.875, 0.975), (1.00, 1.00)
DOCUMENT: Effect of Workload on Work Order Completion
[unitless multiplier]

As work slows down, the staff's desire to complete work orders decreases. It represents peoples desire to make the available work fit the available time.

Mgr_Layoffs_from_Workload = GRAPH(mgr_ot_ratio)
(0.00, 0.403), (0.0714, 0.242), (0.143, 0.115), (0.214, 0.0775), (0.286, 0.06), (0.357, 0.0375), (0.429, 0.02), (0.5, 0.00)

New_Mgt_Hiring_from_OT = GRAPH(des_frac_Mgt_OT/target_frac_Mgt_OT)
(1.00, 0.00), (1.33, 0.217), (1.67, 0.405), (2.00, 0.585), (2.33, 0.787), (2.67, 0.998), (3.00, 1.16), (3.33, 1.31), (3.67, 1.43), (4.00, 1.49)

Plant: Materials

Dfctv_Inventory(t) = Dfctv_Inventory(t - dt) + (dfct_accptd - new_dfcts_parts) * dt
INIT Dfctv_Inventory = stores_inventory*frac_parts_dfct_at_delvry*(1-frac_rtrnd_given_dfct)

DOCUMENT: Defective Inventory
[defective parts]

Defective parts that are in the parts inventory.

INFLOWS:

dfct_accptd = Parts_accptd*frac_dfct_parts_accptd
DOCUMENT: Defects Accepted
[defective parts/week]

New defective parts that are accidently accepted

OUTFLOWS:

new_dfcts_parts = IF (TIME>25) THEN (parts_consumed*pct_inventory_dfctv/100) ELSE (1400)
DOCUMENT: New Defects Stores
[defective parts/week]

New defects resulting from defective parts that are installed in equipment.

New_Equipment(t) = New_Equipment(t - dt) + (Bought_Equip - Aging_Equip) * dt
INIT New_Equipment = Total_Equipment_in_Plant*.2
INFLOWS:

Bought_Equip = (Bought_Eq_Cap_Inv$/$_per_New_Eq)/Buy_Time

OUTFLOWS:

Aging_Equip = New_Equipment/Age_Time

Quality_of_Specs(t) = Quality_of_Specs(t - dt) + (Quality_Imp_by_Design + Quality_upgrades) * dt
INIT Quality_of_Specs = Spec*initial_quality_spec
INFLOWS:

Quality_Imp_by_Design = specs_created*initial_quality_spec*Spec_upgrade_per_part
DOCUMENT: The increase in spec quality from creating new specs

Quality_upgrades = specs_upgraded*ave_imp_Qual_Spec
DOCUMENT: Quality Upgrades
[quality specs/week]

The improvement in spec quality from upgrading parts requirements.

Spec(t) = Spec(t - dt) + (specs_created) * dt
INIT Spec = Initial_Spec_Input
INFLOWS:

specs_created = new_parts+CA_per_reg*new_reg_evals_completed+mod_CA_planned*schd_wo_per_mod_CA
DOCUMENT: New specs created

stores_dollars(t) = stores_dollars(t - dt) + (dollar_deliveries - maint_materials_cost) * dt
INIT stores_dollars = stores_inventory*dollars_per_part

DOCUMENT: Parts inventory measured in dollars

INFLOWS:

dollar_deliveries = Parts_accptd*dollars_per_part
DOCUMENT: Parts delivenes measured in dollars

OUTFLOWS:

maint_materials_cost = parts_consumed*av_dollars_per_part
DOCUMENT: Parts consumptions measured in dollars

stores_inventory(t) = stores_inventory(t - dt) + (Parts_accptd - parts_consumed) * dt
INIT stores_inventory = Initial_Stores_Inv_Input

DOCUMENT: Stores Inventory
[parts]

The number of total parts in the storeroom.

INFLOWS:

Parts_accptd = deliveries*(1-frac_dfct_parts_rtrnd)
DOCUMENT: Parts Accepted
[parts/week]

OUTFLOWS:

parts_consumed = total_WO_completed*av_parts_per_wo
DOCUMENT: Parts Consumed
[parts/week]

Parts used in completing work orders

$_per_New_Eq = .1
DOCUMENT: Dollars per new Capital Equipment
(Millions of Dollars/Equipment)

This is the cost for each piece of new equipment. New eqipment effect is felt under defects from ops. The assumption is that new equipment breaks down at a lower rate than old equipment. This cost assumes that the cost for new cap equipment is high because the small equipment can be assumed to come under the PMS program. Whole new equipment is assumed here to be complex and affect the chance of breakdown not to completey fix a machine.

Age_Time = 26
DOCUMENT: Age Time
(weeks)

Time for equipment to go from new to old just like the rest of the equipment on average. A guess on MGT's part.

ave_imp_Qual_Spec = (100-av_qual_specs)*Ave_Qual_Spec_Switch*.8
DOCUMENT: Average Improvement Quality Specification
[?]

The average improvement per upgraded specification. It says that for each reject for which the specs were upgraded the increase in spec quality will be 80% of the difference between the old spec quality and 100% quality spec since each spec upgrade will not be perfect.

Ave_Qual_Spec_Switch = 1
DOCUMENT: Average Quality Specification Switch
[0 or 1 logic variable]

1 leads to automatic improvement in parts quality
0 holds quality at initial value.

av_dollars_per_part = stores_dollars/stores_inventory
DOCUMENT: AVerage cost per part in inventory

av_qual_specs = Quality_of_Specs/Spec
DOCUMENT: AVerage quality of specs

Buy_Time = 2
DOCUMENT: Buy Time
(weeks)

Time to install new equipment

○ Cost_New_Cap_Part = 2.5
DOCUMENT: Cost of New Capital Expensed Parts
{Millions of Dollars/Part}

This is the cost of purchasing a new capital equipment and adding the resulting new spec for that epipment to the total. New capital equipment will have less wear and tear and have less of a chance of breaking down.

○ Cost_Per_Part_Des = .025
DOCUMENT: Cost Per Part Design Upgrade
{Millions of Dollars/part}

Cost of improving a specification of part. It represents the cost of investing in improving gaskets to MCPs. Since the utility buys millions of gaskets and only one or two MCPs this number averages out. It also represents the cost of investing in a program to improve competitiveness between suppliers and testing and researching better products.

○ deliveries = MIN(parts_consumed/(1-frac_dfct_parts_rtrnd),Bud_Maint_parts/dollars_per_part)
DOCUMENT: Raw material deliveries

○ frac_dfct_parts_accptd = frac_parts_dfct_at_delvry*(1-frac_rtrnd_given_dfct)
○ frac_dfct_parts_rtrnd = frac_rtrnd_given_dfct*frac_parts_dfct_at_delvry
DOCUMENT: Fraction Defective Parts Returned
{fraction: }

The fraction of incoming parts that are returned.

○ frac_parts_dfct_at_delvry = Frac_parts_def
DOCUMENT: Fraction parts Defective at Delivery
{defective parts/delivered parts}

Fraction of parts delivered that are defective.

○ initial_quality_spec = 60
DOCUMENT: Quality of the initial spec for a new part.

○ new_parts = New_Part_Cap_Inv$/Cost_New_Cap_Part
DOCUMENT: new designed parts
{parts}
This represents the number of parts which are new, thus representing new specifications required.

○ New_Part_Des_Inv = 1.5*5
DOCUMENT: New Part Design Investment
{millions of dollars}

Investment in new part design in order to reduce defect generation rate. This discretionary parameter will provide a delayed improvement in quality. Management can improve parts in general. Assumed to be 1.5 million dollars as a reasonable investment in parts quality.

○ pct_inventory_dfctv = 100*Dfctv_Inventory/stores_inventory
DOCUMENT: Percent Inventory Defective
{%}

Pct of parts that are defective

○ rejects = deliveries*frac_dfct_parts_rtrnd
DOCUMENT: Materials that are delivered and rejected.

○ replacement_investment = 444
DOCUMENT: Replacement Investment
{million dollars}

○ specs_upgraded = rejects*.2

DOCUMENT: Upgrading of materials specifications

This represents the percentage of rejects which will have their specs upgraded, 20% because the large majority of defects will be returned without any increase in specs believing that they are one time defects.

○ stores_inv_per_ERV = 100* stores_dollars/replacement_investment
DOCUMENT: Stores Inventory per Estimated Replacement Investment
[]

stores inventory per estimated replacement investment

○ stores_ratio = stores_inv_per_ERV/target_inventory_as_%ERV
○ target_inventory_as_%ERV = 1.09
DOCUMENT: Target Inventory as Percent of Estimated Replacement Investment
[]

This is the target for stores investment as a percent of estimated replacement investment that creates the proper service level in stores.

⊘ frac_rtrnd_given_dfct = GRAPH(av_qual_specs)
(0.00, 0.00), (10.0, 0.0175), (20.0, 0.04), (30.0, 0.065), (40.0, 0.105), (50.0, 0.17), (60.0, 0.225), (70.0, 0.27), (80.0, 0.3), (90.0, 0.315), (100, 0.32)
DOCUMENT: Fraction Returned Given a Defect
[fraction: parts with defect returned/parts with defect]

The fraction of materials that are returned given that they have a defect.

⊘ Service_Level = GRAPH(stores_ratio)
(0.00, 0.00), (0.111, 0.06), (0.222, 0.195), (0.333, 0.6), (0.444, 0.805), (0.555, 0.88), (0.666, 0.91), (0.777, 0.935), (0.888, 0.965), (0.999, 0.985), (1.11, 0.99), (1.22, 0.99), (1.33, 0.99), (1.44, 0.99), (1.55, 0.99), (1.67, 0.99), (1.78, 0.99), (1.89, 0.99), (2.00, 0.99), (2.11, 0.99), (2.22, 0.99)
DOCUMENT: Stores Ratio
[fraction]

Probability of normally stocked part currently being in inventory.

?

⊘ Spec_upgrade_per_part = GRAPH(New_Part_Des_Inv/Cost_Per_Part_Des)
(0.00, 0.016), (10.0, 0.048), (20.0, 0.064), (30.0, 0.16), (40.0, 0.392), (50.0, 0.632), (60.0, 0.976), (70.0, 1.24), (80.0, 1.38), (90.0, 1.47), (100, 1.52)
DOCUMENT: This represent the multiplication on initial spec requirements that investment in new and better part designs by the utility will have. It could also represent money invested in more competitive operations such as seeking out better products since this costs money also. The output is an S shaped curve which will represent and increase or decrease in percentage defects from the initial defect % of 60%.

Plant: Mechanics

□ ave_overtime(t) = ave_overtime(t - dt) + (change_in_ave_OT) * dt
INIT ave_overtime = 5

DOCUMENT: Average Overtime
[hours/week/person]

Average number of overtime hours worked. The averaging represents the process through which excessive overtime gradually causes fatigue and reduces productivity. The process of recovering from excessive overtime is also gradual.

INFLOWS:

change_in_ave_OT = (indicated_overtime-ave_overtime)/time_to_change_ave_OT
DOCUMENT: Change in Average Overtime
[hours/week/person/week]

□ Maintenance_Staff(t) = Maintenance_Staff(t - dt) + (maint_hiring - mstaff_loss) * dt
INIT Maintenance_Staff = Initial_Mechanics_Staff

DOCUMENT: Maintenance Staff
[people]

Total Maintenance personnel, including planners.

INFLOWS:

maint_hiring = attrition+(New_Staff_Hiring*New_hiring_Switch/maint_hiring_delay)+Contractor_Pulse
DOCUMENT: Maintenance Hiring
[people/week]

hiring of new mechanics

(if time = 10 then 0/dt else 0

OUTFLOWS:

mstaff_loss =
attrition+PULSE(maintenlayoffs*Maintenance_Staff,200,1000)+SMTH1(Outage_Finish*Cont_Hiring*.5,2,0)+(Budget_layloffs_mechs/bud_layoff_time)
DOCUMENT: Maintenance Staff Loss
[people/week]

○ attrition = .05*Maintenance_Staff
DOCUMENT: Attrition
[fraction: people/week]

staff lost per week due to retirement, death, quiting, etc.

○ Budget_layloffs_mechs = IF(Maintenance_Staff>Max_Mech_Staff)THEN(Maintenance_Staff-Max_Mech_Staff)ELSE(0)

○ bud_layoff_time = 6

○ Contractor_Pulse = SMTH1(Cont_Hiring*Outage_Start,1,0)

○ Cont_Hiring = 150
DOCUMENT: Number of contractors hired

○ dsc_insp_Staff = MIN(maint_staff_avail_maint_work*max_frac_avl_mstaff_alloc_dsc_insp,desired_Staff_for_dsc_insp)
DOCUMENT: Discretionary Inspection Staff
[people]

Mechanics allocated to doing discretionary inspections

○ frac_overtime = target_frac_overtime*eff_wload_OT*eff_prod_pres_on_OT
DOCUMENT: Actual fraction overtime
[fraction: hours/hours]

Overtime for maintenance staff in terms of percent of standard work week.

○ Human_Effs_on_WO_Comp = eff_motivation_WO_comp*(SMTH1(eff_OT_fatigue_wo_comp,6,1))*eff_wload_wo_comp
DOCUMENT: Human Effects on Work Order Completion
[unitless multiplier]

Product of motivation, fatigue and workload effects on worker performance.

○ Indicated_overtime = standard_hours*frac_overtime
DOCUMENT: Indicated Overtime
[hours]

Indicated Maintenance overtime that is worked (actual week by week value). As of 8/4 it includes the training hours.

○ Layoff_Fraction = 0
DOCUMENT: Layoff Fraction
unitless
Percentage of the mechanics that will be layed off for the test.

○ Layoff_Switch = 0
DOCUMENT: This switch layoff 25% of workers at week 100

○ maintenlayoffs = Layoff_Fraction*Layoff_Switch
DOCUMENT: Maintenance layoffs
[%]

This is a policy variable that is an exogenous function of time.

○ maint_hiring_delay = 8
DOCUMENT: Time to hire new mechanics

Units weeks

○ maint_staff_avail_maint_work = Maintenance_Staff-Plnrs_Maint

○ maint_staff_avail_mech_work = maint_staff_avail_maint_work-total_insp_manpower
DOCUMENT: Maintenance Staff Available for Mechanical Work
[people]

Maintenance staff available for actual work on machinery, whether mechanical, electrical, instrumentation, etc.

○ max_frac_avl_mstaff_alloc_dsc_insp = Fr_Lab_bud_All_Disc_insp
DOCUMENT: Maximum Fraction Available Maintenance Staff Allocated Discretionary Inspections
[fraction: allocated people/avail people]

Every week a certain number of discretionary inspections come due. These inspections require mechanics, for example 10. This variable represents the fraction of the ten mechanics the plant is willing to give up for the inspections. For example, if the fraction is .8, 8 mechanics would be allocated to discretionary inspections.

○ New_hiring_Switch = IF(Maintenance_Staff>Max_Mech_Staff) THEN (0) ELSE (1)
DOCUMENT: New Hiring Switch
[0 or 1 logic variable]

1 allows new maintenance staff to be hired when average overtime becomes excessive.
0 disallows any new hiring because of increased workloads.

○ Plnrs_Maint = Maintenance_Staff*Frac_Maint_staff_Planners
DOCUMENT: Planners Maintenance
Units: (workers)
This is the number of maintenance workers allocated to planning.

○ standard_hours = 40 (Hours)
DOCUMENT: Standard Hours
[hours/week/person]

The standard number of hours worked per week per maintenance staff (mechanic, electrician, pipefitter, machinist, etc.)

○ target_frac_overtime = .10
DOCUMENT: Target Fraction Overtime
[hours/hours]

○ target_wks_work = 2
DOCUMENT: Target Weeks Work
[weeks]

The desired or target backlog, in time, of work to be maintained.

○ time_to_change_ave_OT = 1
DOCUMENT: Time to Change Average Overtime
[weeks]

This is the time to adjust average overtime. It determines how quickly average overtime adjusts to actual overtime.

○ total_insp_manpower = dsc_insp_Staff+mand_insp_Staff
DOCUMENT: Total Inspection Manpower
[people]

Total maintenance manpower allocated to inspections

○ total_work_hrs = ave_overtime+standard_hours
DOCUMENT: Total Work Hours
[hours/week/person]

○ Training_Hours = Frac_Bud_Trng*standard_hours
DOCUMENT: Training Hours
(Hours/Week/Mech)
This is the number of hours per week that mechanic spend in training. It increases their learning curve but also costs money and takes them off jobs. The benefits should be long term then. IT also increases experience faster.Its effect is on the learning curves of other areas.

○ workload = weeks_work_TBD/target_wks_work
DOCUMENT: workload
[fraction: weeks/weeks]

EffFotDG = GRAPH(ave_overtime)
(0.00, 1.00), (2.00, 1.00), (4.00, 1.00), (6.00, 1.05), (8.00, 1.10), (10.0, 1.15), (12.0, 1.20), (14.0, 1.25), (16.0, 1.30), (18.0, 1.35), (20.0, 1.50)

EFF_mainOT_info = GRAPH(ave_overtime)
(0.00, 0.998), (2.00, 0.994), (4.00, 0.983), (6.00, 0.963), (8.00, 0.944), (10.0, 0.914), (12.0, 0.868), (14.0, 0.829), (16.0, 0.799), (18.0, 0.77), (20.0, 0.751)

Ø eff_motivation_WO_comp = GRAPH(TIME)
(0.00, 1.00), (1.00, 1.00), (2.00, 1.00), (3.00, 1.00), (4.00, 1.00), (5.00, 1.00), (6.00, 1.00), (7.00, 1.00), (8.00, 1.00), (9.00, 1.00), (10.0, 1.00), (11.0, 1.00), (12.0, 1.00)
DOCUMENT: Effect Motivation Work Order Completion
[unitless multiplier]

This is the motivation factor on productivity based on good leadership. 1.0 is none 1.15 if full

Ø Eff_OT_fatigue_OA = GRAPH(ave_overtime)
(0.00, 0.995), (2.00, 0.97), (4.00, 0.95), (6.00, 0.925), (8.00, 0.88), (10.0, 0.825), (12.0, 0.795), (14.0, 0.765), (16.0, 0.755), (18.0, 0.74), (20.0, 0.72)

Ø eff_OT_fatigue_wo_comp = GRAPH(ave_overtime)
(0.00, 1.00), (1.05, 0.98), (2.11, 0.955), (3.16, 0.945), (4.21, 0.93), (5.26, 0.915), (6.32, 0.905), (7.37, 0.865), (8.42, 0.845), (9.47, 0.82), (10.5, 0.79), (11.6, 0.785), (12.6, 0.775), (13.7, 0.76), (14.7, 0.755), (15.8, 0.735), (16.8, 0.72), (17.9, 0.705), (18.9, 0.695), (20.0, 0.68)
DOCUMENT: Effect Overtime Fatigue Work Order Completion
[unitless multiplier]

The effect of overtime on productivity.

Ø eff_prod_pres_on_OT = GRAPH(production_pressure)
(1.00, 0.00), (1.04, 0.408), (1.08, 0.732), (1.13, 0.948), (1.17, 1.10), (1.21, 1.26), (1.25, 1.42), (1.29, 1.56), (1.33, 1.68), (1.38, 1.77), (1.42, 1.85), (1.46, 1.94), (1.50, 2.00)
DOCUMENT: Effect Production Pressure on Overtime
[unitless multiplier]

The effect of production pressure on overtime. If product demand is very high, there is pressure for maintenance to work overtime to get the equipment back on-line.

Ø eff_wload_OT = GRAPH(workload)
(0.00, 0.00), (0.4, 0.28), (0.8, 0.42), (1.20, 0.52), (1.60, 0.72), (2.00, 1.08), (2.40, 1.38), (2.80, 1.82), (3.20, 2.46), (3.60, 3.30), (4.00, 4.00)
DOCUMENT: Effect Workload Overtime
[unitless multiplier]

If the number of weeks of maintenance work is high, there is pressure to work over time to get the work done.

Ø eff_wload_wo_comp = GRAPH(workload)
(0.00, 0.00), (0.125, 0.025), (0.25, 0.08), (0.375, 0.17), (0.5, 0.32), (0.625, 0.435), (0.75, 0.595), (0.875, 0.83), (1.00, 1.00)
DOCUMENT: Effect of Workload on Work Order Completion
[unitless multiplier]

As work slows down, the staff's desire to complete work orders decreases. It represents peoples desire to make the available work fit the available time.

Ø New_Staff_Hiring = GRAPH(ave_overtime)
(0.00, -0.5), (1.00, -0.14), (2.00, 0.05), (3.00, 0.1), (4.00, 0.2), (5.00, 0.35), (6.00, 0.463), (7.00, 0.613), (8.00, 0.913), (9.00, 1.40), (10.0, 2.00)

Plant: Mechanics Time Allocation

○ base_frac_schd_WO_hrs_maint_hrs = .27
DOCUMENT: Base Fraction Scheduled Work Order Hours Maintenance Hours
[fraction: wrench hours/maintenance hours]

Per cent of mechanics hours allocated top wrench time if none of the work is planned

○ base_frac_unschd_WO_hrs_maint_hrs = .25
DOCUMENT: Base Fraction Unscheduled Work Order Hours Maintenance Hours
[fraction: wrench hours/maintenance hours]

For unscheduled work orders, the percent of mechanic time that goes to wrench hours if none of the work is planned

○ frac_manweeks_work_TBD_schd = manweeks_schd_work/(total_manweeks_work_TBD+.1)
DOCUMENT: Fraction Work To Be Done Scheduled
[fraction: weeks/weeks]

The fraction of the maintenance staff that is allocated to scheduled work.

○ frac_schd_WO_hrs_maint_hrs = MAX(base_frac_schd_WO_hrs_maint_hrs*eff_schd_planning_on_maint_hrs,.02)
DOCUMENT: Fraction Scheduled Work Order Hours Maintenance Hours
[fraction: hours/hours]

Per Cent of mechanics going to wrench time for scheduled work

○ frac_unsch_WO_hrs_maint_hrs = MAX(base_frac_unschd_WO_hrs_maint_hrs*
unsch_efct_plan_pct_hr_wtime,.02)
DOCUMENT: The per cent of unscheduled work hours that go to wrench hours

○ Ind_Manweeks_Schd_work = Schd_WO_to_work*WO_hrs_per_schd_WO/total_work_hrs
DOCUMENT: Indicated Manweeks Scheduled Work
[person weeks]

○ Ind_manweeks_unschd_work = Unschd_WO_to_work*WO_hrs_per_unschd_WO/total_work_hrs
DOCUMENT: Indicated Manweeks Unscheduled work
[person weeks]

○ Maint_hrs_per_schd_WO = 1.8
DOCUMENT: Maintenance Hours per Scheduled Work Order
[person hours/work order]

The number of wrench hours required per scheduled work order

○ Maint_hrs_per_unschd_WO = 1.8
DOCUMENT: Maintenance Hours per Unscheduled Work Order
[person hours/work order]

The number wrench hours required to complete an unscheduled work order

○ manweeks_schd_work = Ind_Manweeks_Schd_work/eff_OT_fatigue_wo_comp
DOCUMENT: Manweeks Scheduled Work
[person weeks]

The number of weeks worth of scheduled work

○ manweeks_unsch_work = Ind_manweeks_unschd_work/eff_OT_fatigue_wo_comp
DOCUMENT: Manweeks Unscheduled Work
[person weeks]

Manweeks of unscheduled work.

○ normal_schd_wo_compr = SMTH1(schd_maint_time/Maint_hrs_per_schd_WO,8)
DOCUMENT: Normal Scheduled Work Order Completion
[work orders/week]

Normal completion of workorders given the number of mechanics, wrench hours per work order, and hours worked

○ schd_maint_time = schd_mech*(standard_hours+indicated_overtime-Training_Hours)*
frac_schd_WO_hrs_maint_hrs
DOCUMENT: Scheduled Maintenance Time
[hours/week]

Wrench hours allocated to scheduled work.

○ schd_mech = maint_staff_avail_mech_work*frac_manweeks_work_TBD_schd
DOCUMENT: Scheduled Mechanics
[people]

The number of mechanics allocated to perform scheduled work.

○ Schd_WO_to_work = MAX((schd_WO_RTBD&BD-Schd_WO_Unplnd_Mat_req),10)
DOCUMENT: Scheduled Work Orders to Work
[work orders]

Work orders in progress or ready to work having no equipment or material delays.

○ total_manweeks_work_TBD = manweeks_schd_work+manweeks_unsch_work
DOCUMENT: Total Manweeks Work To Be Done
[man weeks]

Total manweeks of work both scheduled and unscheduled

○ unschd_mech = maint_staff_avail_mech_work*(1-frac_manweeks_work_TBD_schd)
DOCUMENT: Unscheduled Mechanics
[people]

Mechanics allocated to unscheduled work

○ Unschd_WO_to_work = MAX(Unschd_WIP-Uschd_WO_unpln_Mat_req,10)
DOCUMENT: Unschedule Work Orders to Work
[work orders]

○ unsch_maint_time = unschd_mech*(standard_hours+indicated_overtime-Training_Hours)*
frac_unsch_WO_hrs_maint_hrs
DOCUMENT: Unscheduled Maintenance Time
[hours/week]

Wrench time to unscheduled work

○ unsch_wo_norm_completed = unsch_maint_time/Maint_hrs_per_unschd_WO
DOCUMENT: Unscheduled Work Orders Normally Completed
[work orders/week]

The normal number of unsch work orders completed given the number of mechanics, hours worked, and the required number of wrench hours per work order.

○ weeks_work_TBD = total_manweeks_work_TBD/maint_staff_avail_mech_work
DOCUMENT: Weeks Work To Be Done
[weeks]

Total weeks of maintenance work both scheduled and unscheduled.

○ WO_hrs_per_schd_WO = SMTH1(Maint_hrs_per_schd_WO/frac_schd_WO_hrs_maint_hrs,2)
DOCUMENT: Scheduled Work Order Hours
[hours/Work order]

Total staff hours per scheduled work order, includes actual maintenance time, prep work, dress out, breaks, etc. -- everything except planning personnel's time.

○ WO_hrs_per_unschd_WO = Maint_hrs_per_unschd_WO/frac_unsch_WO_hrs_maint_hrs
DOCUMENT: Work Order Hours per Unscheduled Work Orders
[hours/work order]

Total staff hours per unscheduled work order, includes actual maintenance time, prep work, dress out, breaks, etc. -- everything except planning personnel's time.

⊘ eff_schd_planning_on_maint_hrs = GRAPH(frac_schd_wip_w_plan)
(0.00, 1.00), (0.25, 1.38), (0.5, 1.76), (0.75, 2.14), (1.00, 2.52)
DOCUMENT: The effect of planning on the fraction of mechanic time allocated to wrench time in scheduled work.

⊘ unsch_efct_plan_pct_hr_wtime = GRAPH(frac_unsch_wip_w_plan)
(0.00, 1.00), (0.25, 1.17), (0.5, 1.34), (0.75, 1.51), (1.00, 1.68)
DOCUMENT: The effect of planning on the percent of time that goes to wrench time

Plant: Periodic Outage

Per_Outage(t) = Per_Outage(t - dt) + (Outage_Start - Outage_Finish) * dt
INIT Per_Outage = 0

DOCUMENT: Periodic Outage
A function which says 1=periodic outage 0=fully operational.

INFLOWS:
Outage_Start = PULSE(1,Outage_Per,Outage_Per+Outage_length)
OUTFLOWS:
Outage_Finish = PULSE(1,(Outage_length+Outage_Per),(Outage_Per+Outage_length))

Outage_length = 5
DOCUMENT: Outage Length
{week}

Right now this set by the user. Needs to be a function of broken equipment at the beginning of the outage.

Outage_Per = 10000
DOCUMENT: Refueling outage periodicity
{weeks}

This is the time between outages.

Periodic_Outage_Function = 1
DOCUMENT: Refueling Outage Function
{unitless}

=1 if using refueling outages,0 if not.

EFFBEOL = GRAPH(frac_equip_bdown)
(0.00, 0.9), (0.1, 1.11), (0.2, 1.25), (0.3, 1.35), (0.4, 1.48), (0.5, 1.60), (0.6, 1.70), (0.7, 1.76), (0.8, 1.80), (0.9, 1.80), (1, 1.80)

Plant: planners

library_plans(t) = library_plans(t - dt) + (Plans_reviewed - obsolescence_plans) * dt
INIT library_plans = 100

DOCUMENT: Library Plans
[plans]

The library represents the plants memory of previous work. If work has been done before, then planners can reference library for developing new work plans, thus saving time.

INFLOWS:
Plans_reviewed = eng_plan_rev_comp
OUTFLOWS:
obsolescence_plans = library_plans/obsolescence_time
DOCUMENT: Obsolescence Plans
[plans/week]

The obsolescence of plans.

Plans_wait_eng_rev(t) = Plans_wait_eng_rev(t - dt) + (Plan_created - Plans_reviewed) * dt
INIT Plans_wait_eng_rev = 100
INFLOWS:
Plan_created = plns_completed*(1-frac_w_plans)
DOCUMENT: Creation New Plans
[plans/week]

The creation of new plans for the library. (work which has never been done or not done in so long that a totally new plan is required: i.e. no or little historical reference.)

OUTFLOWS:
Plans_reviewed = eng_plan_rev_comp

maximum_plans = 28000*5
DOCUMENT: Maximum Plans
[plans]

The number of plans that constitutes a "full" library. At this number of plans there is a plan in the library for 93% of the work orders. This assumes that there is a finite number of things that could be done in the plant.

○ obsolesence_time = 10*52
DOCUMENT: Obsolesence Time
[weeks]

The average time before a plan becomes obsolete

○ planners_weeks_work = SMTH1(total_wo_req_plans,4,10)/
((base_plnprd_w_pln*frac_w_plans+base_plnprd_wout_pln*
(1-frac_w_plans))*plnrs_avail_pln)
DOCUMENT: Backlog Planner's Work
[weeks]

The number of weeks of work the planners have to do

○ planner_prod = (base_plnprd_w_pln*frac_w_plans+base_plnprd_wout_pln*(1-frac_w_plans))*eff_wload_plnprod
DOCUMENT: Planner Productivity
[plans/planner/week]

Planner productivity in terms of plans per week

○ plan_ratio = (library_plans+Plans_wait_eng_rev)/maximum_plans
DOCUMENT: Plan Ratio
[fraction: plans/plans]

A reference ratio to calculate the odds of having previous experience with the work presently being planned.

○ plnrs_avail_pln = MAX(Plnrs_Maint-plnrs_to_mat_acq,0)
DOCUMENT: Planners Available Plan
[people]

Planners available to create plans

○ plnrs_per_WO_req_Mat = 2.5/40
DOCUMENT: Planners per Work Order Requiring Materials
[planners]

Maintenance staff assigned to planning unplanned WO requiring materials. (2.5 planners per 40 work orders)

○ plnrs_to_mat_acq = total_WO_req_unplnd_mat*plnrs_per_WO_req_Mat
DOCUMENT: Planners to Material Acquisition
[people]

○ plns_available = plns_completed-Plan_created+Plans_reviewed
○ plns_completed = plnrs_avail_pln*planner_prod
DOCUMENT: Plans Completed
[work orders/week]

The number of plans that planners have completed/planned based on available number of planners and planner productivity.

○ total_WO_req_unplnd_mat = Schd_WO_Unplnd_Mat_req+Uschd_WO_unpln_Mat_req
DOCUMENT: Total Work Orders Requiring Unplanned Materials
[work orders]

⊘ eff_wload_plnprod = GRAPH(planners_weeks_work)
(0.00, 0.00), (0.05, 0.455), (0.1, 0.705), (0.15, 0.85), (0.2, 0.92), (0.25, 0.955), (0.3, 0.97), (0.35, 0.985), (0.4, 1.00)
DOCUMENT: The effect of work load on planner productivity. If planners have more work they work more intensely to complete it.

⊘ frac_w_plans = GRAPH(plan_ratio)
(0.00, 0.00), (0.1, 0.18), (0.2, 0.345), (0.3, 0.47), (0.4, 0.585), (0.5, 0.66), (0.6, 0.715), (0.7, 0.78), (0.8, 0.83), (0.9, 0.885), (1.00, 0.935)
DOCUMENT: Fraction With Plans
[fraction: work orders with historical plans/work orders]

The fraction of work orders for which there is an existing plan in the library

Plant: Safety and ALARA Sub-Sector

☐ Sum_Forced_Outages(t) = Sum_Forced_Outages(t - dt) + (DT_Forced_out) * dt
INIT Sum_Forced_Outages = .05
INFLOWS:

DT_Forced_out = EFFForcOut

Total_ManRem(t) = Total_ManRem(t - dt) + (Change_in_ManRem) * dt
INIT Total_ManRem = 9
INFLOWS:

Change_in_ManRem = EFF_ManRem_FO+EFF_ManRem_Isp+EFF_ManRem_Ops+EFF_ManRem_SM+EFF_ManRem_UM

Total_Run_Time(t) = Total_Run_Time(t - dt) + (DT_Cap) * dt
INIT Total_Run_Time = 1
INFLOWS:

DT_Cap = capacity_Online

Yr_ManRem(t) = Yr_ManRem(t - dt) + (Yr_Ch_in_ManRem - Yr_Reset) * dt
INIT Yr_ManRem = .01
INFLOWS:

Yr_Ch_in_ManRem = Change_in_ManRem

OUTFLOWS:

Yr_Reset = PULSE(Yr_ManRem,52,52)

Core_Melt_Frequency_Est = EFFEBCM*EFFFOCM*EFFFORtCMFreq*EFFTDCM*EFFFORtCMFreq*(1/Operator_Astuteness)*1E6
DOCUMENT: Core Melt Frequency Estimated
(melts/week)*1E6
This the crudely estimated measure of core melt frequency. The initial core melt frequency is set at about 6E-6 base on TMI accident's being the only Core Melt in US.

EFFFORtCMFreq = (Ev_Rt_Op_Er_Exp+Ev_Rt_Op_Misinf)/4400
DOCUMENT: Effect of Rate of Operator Errors (Events) on Core Melt Frequency
(Core Melts Per Week)
This effect is based on the baseline of 4400 events per core melt. There has been one core melt in 40 years of Reactor operation with 110 events per year. Or a chance of 1/4400 of an event being a core melt. This is the base core melt frequency.

EFF_ManRem_FO = DT_Forced_out*MRperFO
EFF_ManRem_Isp = (dec_insp_wout_tdwn+dec_insp_w_tdwn+mand_insp)*MRper_Insp
EFF_ManRem_Ops = capacity_Online*MRper%
EFF_ManRem_SM = MR_perWO*schd_WO_completed
EFF_ManRem_UM = MRperUWO*unschd_WO_completed
Forced_out_Frequency = Sum_Forced_Outages/(.05+TIME)
For_Out_Funct = IF(capacity_Online>40) AND(TIME>25) THEN (MONTECARLO(Total_FO__%_prob,153)*FO_DElay)*(1-Per_Outage) ELSE 0
FO_DElay = IF(TIME > 27) THEN 1 ELSE 0
Minor_Event_Funct = MONTECARLO((Ev_Rt_Op_Er_Exp+Ev_Rt_Op_Misinf)*100,3444)
MRper% = .1
MRperFO = .1
MRperUWO = .001
MRperwk = Total_ManRem/(TIME+1)
MRper_Insp = .0001
MR_perWO = .0005
Operator_Astuteness = Eff_OT_fatigue_OA*Morale
Running_Ave_Cap = Total_Run_Time/(.05+TIME)
Site_Alert_Funct = MONTECARLO((Ev_Rt_Op_Er_Exp+Ev_Rt_Op_Misinf)*100/10,677)
Site_Emergency_Funct = MONTECARLO((Ev_Rt_Op_Er_Exp+Ev_Rt_Op_Misinf)*100/50)
Total_FO__%_prob = FO_Occurrence_Rate_Op*100+EffEBFO
EFFEBCM = GRAPH(frac_equip_bdown)
(0.00, 0.595), (10.0, 0.645), (20.0, 0.595), (30.0, 0.595), (40.0, 0.642), (50.0, 0.833), (60.0, 1.17), (70.0, 1.40), (80.0, 2.50), (90.0, 4.78), (100, 5.71)
EffEBFO = GRAPH(frac_equip_bdown)
(0.00, 0.00), (0.025, 0.06), (0.05, 0.125), (0.075, 0.125), (0.1, 0.25), (0.125, 0.35), (0.15, 0.35), (0.175, 0.35), (0.2, 0.4), (0.225, 0.65), (0.25, 1.30), (0.275, 1.85), (0.3, 2.55), (0.325, 3.45), (0.35, 4.45), (0.375, 5.35), (0.4, 6.20), (0.425, 6.90), (0.45, 7.60), (0.475, 8.40), (0.5, 9.80)
DOCUMENT: Effect of Broken Equipment on Forced outages
(%/week)
Percentage Chance of having an outage per week from broken equipment.

EFFFOCM = GRAPH(Forced_out_Frequency/INIT(Forced_out_Frequency))
(0.00, 0.9), (0.5, 0.945), (1.00, 1.01), (1.50, 1.06), (2.00, 1.11), (2.50, 1.19), (3.00, 1.24), (3.50, 1.29), (4.00, 1.33), (4.50, 1.36), (5.00, 1.40)
EFFTDCM = GRAPH(total_defects/INIT(total_defects))
(0.00, 0.96), (0.5, 1.00), (1.00, 1.06), (1.50, 1.09), (2.00, 1.14), (2.50, 1.24), (3.00, 1.40), (3.50, 1.67), (4.00, 1.92), (4.50, 2.18), (5.00, 2.97)

Morale = GRAPH(TIME)
(0.00, 1.00), (52.0, 1.00), (104, 1.00), (156, 1.00), (208, 1.00), (260, 1.00), (312, 1.00), (364, 1.00), (416, 1.00), (468, 1.00), (520, 1.00)

Plant: Unscheduled Work Orders

UnSchd_pln_WO_req_Mat(t) = UnSchd_pln_WO_req_Mat(t - dt) + (new_unschd_pln_WO_req_mat - unschd_pln_WO_mat_acqd) * dt
INIT UnSchd_pln_WO_req_Mat = 2.7

DOCUMENT: Unscheduled Planned Work Orders Requiring Materials
[work orders]

The number of unscheduled, planned work orders that are waiting for additional materials for work to begin.

INFLOWS:

new_unschd_pln_WO_req_mat = unsch_work_plns_completed*frac_unschplan_req_mat
DOCUMENT: New Unscheduled Planned Work Orders Requiring Materials
[work orders/week]

The flow of new unscheduled, planned work orders that require additional materials.

OUTFLOWS:

unschd_pln_WO_mat_acqd = UnSchd_pln_WO_req_Mat/mat_acq_delay
DOCUMENT: Unscheduled Planned Work Orders Materials Acquired
[work orders/week]

The flow of unscheduled, planned workorders that have received the additional materials

Unschd_WIP(t) = Unschd_WIP(t - dt) + (unsch_work_begun - unschd_WO_completed) * dt
INIT Unschd_WIP = 353.83*5

DOCUMENT: Unscheduled Work In Progress
[work orders]

Unscheduled Work Orders Currently being worked on.

INFLOWS:

unsch_work_begun = (unschd_wo_wait_eq-UnSchd_pln_WO_req_Mat)/
unschd_backlog_time
DOCUMENT: Unscheduled Work Begun
[work orders/week]

Work orders flow into the work in progress category when work on the unscheduled work orders is begun.

OUTFLOWS:

unschd_WO_completed = unsch_wo_norm_completed*Human_Effs_on_WO_Comp
DOCUMENT: Unscheduled Work Orders Completed
[work orders/week]

The completion of unscheduled work orders

Unschd_Work_Plns_Avail(t) = Unschd_Work_Plns_Avail(t - dt) + (unsch_work_plns_completed - Unsch_Work_pln_used) * dt
INIT Unschd_Work_Plns_Avail = 10

DOCUMENT: Unscheduled Work Plans Available
[work orders]

Unscheduled work orders with Plans that are available to be worked.
(2.8)

INFLOWS:

unsch_work_plns_completed = plns_available*(1-frac_plng_is_for_schd_work)
DOCUMENT: Unscheduled Work Plans Completed
[work orders/week]

The completion of plans for unscheduled work orders

OUTFLOWS:

Unsch_Work_pln_used = unschd_WO_completed*frac_unsch_wip_w_plan
DOCUMENT: Unscheduled Work Plans Used
[work orders/week]

Planned unscheduled work orders that are consumed in the process of completing unscheduled work.

Unschd_WO_wait_eng(t) = Unschd_WO_wait_eng(t - dt) + (new_unschd_work - u_wo_rev_eng - unschd__wo_eng_forget) * dt
INIT Unschd_WO_wait_eng = 359.13*5

DOCUMENT: Unscheduled work orders waiting for Engineer Review.
[work orders]

INFLOWS:

new_unschd_work = (online_brkdwns+Tagged_PM_equip_brkdwn)/equip_per_wo
DOCUMENT: New Unscheduled Work
[work orders/week]

The flow of new unscheduled work orders

OUTFLOWS:

u_wo_rev_eng = IF TIME>0 THEN eng_unscd_wo_rev_comp ELSE 1250
unschd__wo_eng_forget = IF Unschd_WO_wait_eng>2*u_wo_rev_eng THEN Unschd_WO_wait_eng/eng_and_man_forget_time ELSE (

unschd_wo_wait_eq(t) = unschd_wo_wait_eq(t - dt) + (u_wo_rev_mgt - unsch_work_begun) * dt
INIT unschd_wo_wait_eq = 1500
INFLOWS:

u_wo_rev_mgt = IF TIME>0 THEN mgr_unsch_wo_rev_comp ELSE 1250

OUTFLOWS:

unsch_work_begun = (unschd_wo_wait_eq-UnSchd_pln_WO_req_Mat)/
unschd_backlog_time
DOCUMENT: Unscheduled Work Begun
[work orders/week]

Work orders flow into the work in progress category when work on the unscheduled work orders is begun.

Unschd_wo_wait_mgr(t) = Unschd_wo_wait_mgr(t - dt) + (u_wo_rev_eng - u_wo_rev_mgt - unschd_wo_mgr_forget) * dt
INIT Unschd_wo_wait_mgr = 1500

DOCUMENT: Unscheduled work orders waiting for manager approval.
[work orders per week]

INFLOWS:

u_wo_rev_eng = IF TIME>0 THEN eng_unscd_wo_rev_comp ELSE 1250

OUTFLOWS:

u_wo_rev_mgt = IF TIME>0 THEN mgr_unsch_wo_rev_comp ELSE 1250
unschd_wo_mgr_forget = IF Unschd_wo_wait_mgr>2*u_wo_rev_mgt THEN Unschd_wo_wait_mgr/eng_and_man_forget_time ELSE (

Uschd_WO_unpln_Mat_req(t) = Uschd_WO_unpln_Mat_req(t - dt) + (new_unsch_wo_unpln_mat_req - uschd_wo_unplan_mat_acq) * dt
INIT Uschd_WO_unpln_Mat_req = 70.80*5

DOCUMENT: Unscheduled Work Orders Unplanned Material Requirements
[work orders]

Unscheduled, unplanned work orders that are waiting for
materials

INFLOWS:

new_unsch_wo_unpln_mat_req = unsch_work_begun*frc_unsch_wo_unpln_mat_req*(1-frac_unschd_WO_pfunc_w_plan)
DOCUMENT: New Unscheduled Work Orders Unplanned Material Requirements
[work orders/week]

OUTFLOWS:

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uschd_wo_unplan_mat_acq = Uschd_WO_unpln_Mat_req/mat_acq_delay
DOCUMENT: Unscheduled Work Orders Unplanned Materials Acquisition
[work orders/week]

unscheduled, unplanned work orders for which the additional materials arrive

eng_and_man_forget_time = 12

frac_plng_is_for_schd_work = schd_wo_req_plns/total_wo_req_plans
DOCUMENT: Fraction Planning is for Scheduled Work
[fraction: plans/plans]

The fraction of planning work the planner performs on scheduled work orders.

(originally: frac req plans sch)

frac_unschd_WO_pfunc_w_plan = unschd_pln_WO_pfunc/(unschd_wo_wait_eq+10)
DOCUMENT: Fraction Unscheduled Work Orders Partially Functional with Plan
[fraction: work orders/work orders]

The fraction of unscheduled work orders on partially functional equipment that have a plan

frac_unschplan_req_mat = 1-(Service_Level*utilization)
DOCUMENT: Fraction Unscheduled Planned Work Orders Requiring Materials
[fraction: work orders/work orders]

The fraction of unscheduled, planned work orders that require additional materials that must be ordered: i.e. not currently in warehouse stock.

frac_unsch_wip_w_plan = unschd_pln_wip/(Unschd_WIP+10)
DOCUMENT: Fraction Unscheduled Work in Progress with Plan
[fraction: work orders/work orders]

The fraction of unscheduled work orders that have a plan

Frac_WO_schd = schd_WO_completed/total_WO_completed
DOCUMENT: Fraction Work Orders Scheduled
[fraction: work orders/work orders]

Fraction of all work orders completed that are scheduled wo.

frc_unsch_wo_unpln_mat_req = 1-(Service_Level*utilization)
DOCUMENT: Fraction Unscheduled Work Orders Unplanned Material Requirements
[fraction: work orders/work orders]

The fraction of unscheduled, unplanned work orders that require additional materials to be ordered: i.e. parts not currently in warehouse stocks.

schd_wo_req_plns = MAX(Sch_Total_worked*targ_frac_plan-Schd_Work_Plns_Available,1)
DOCUMENT: Scheduled Work Orders Requiring Plans
[work orders]

total_unschd_work = Unschd_WO_wait_eng+Unschd_WIP+unschd_wo_wait_eq+ Unschd_wo_wait_mgr
DOCUMENT: Total Unscheduled Work
[work orders]

Total number of unscheduled work orders currently open.

total_WO_completed = schd_WO_completed+unschd_WO_completed
DOCUMENT: Total Work orders completed
[work orders/week]

The total number of work orders completed per week, both scheduled and unscheduled.

total_wo_req_plans = unschd_wo_req_plns+schd_wo_req_plns
DOCUMENT: Total Work Orders Requiring Plans
[work orders]

○ unschd_backlog_time = 1
DOCUMENT: Unscheduled Backlog Time
[weeks]

This is the time between noticing a piece of equipment begins to fail and the time that it is available to work on. Units are weeks.

○ unschd_pln_wip = MIN(Unschd_WIP*targ_frac_plan,Unschd_Work_Plns_Avail)
DOCUMENT: Unscheduled Planned Work in Progress
[work orders]

Unscheduled work orders currently being worked on that have a plan

○ unschd_pln_WO_pfunc = Unschd_Work_Plns_Avail-unschd_pln_wip
DOCUMENT: Unscheduled Planned Work Orders partially Functional
[work orders]

Unscheduled work orders that are partially functional that have a plan

○ unschd_wo_req_plns =
MAX((total_unschd_work-Unschd_WO_wait_eng-Unschd_wo_wait_mgr)*targ_frac_plan-Unschd_Work_Plns_Avail,1)
DOCUMENT: Unscheduled Work Orders Requiring Plans
[work orders]

○ Unsch_wo_part_func_eq = total_unschd_work-Unschd_WIP

○ utilization = .7
DOCUMENT: Utilization
[fraction:]

The fraction of materials that come from plant stores.
Exogenous variable
I believe this variable represents the fraction of parts used in the plant that is carried by the plant warehouse.

⊘ EFFuwErtdef = GRAPH(u_wo_rev_eng/INIT(u_wo_rev_eng))
(0.5, 0.901), (0.95, 0.949), (1.40, 0.986), (1.85, 1.01), (2.30, 1.03), (2.75, 1.05), (3.20, 1.06), (3.65, 1.07), (4.10, 1.08), (4.55, 1.09), (5.00, 1.10)

⊘ EFFuwoMrtdef = GRAPH(u_wo_rev_mgt/INIT(u_wo_rev_mgt))
(0.5, 0.901), (0.95, 0.97), (1.40, 1.02), (1.85, 1.05), (2.30, 1.07), (2.75, 1.08), (3.20, 1.09), (3.65, 1.10), (4.10, 1.10), (4.55, 1.10), (5.00, 1.10)

Report Screen Process

☐ Reps_Waiting_for_Screening(t) = Reps_Waiting_for_Screening(t - dt) + (Incoming_Reps - reports_screened - reps_abandoned) * dt
INIT Reps_Waiting_for_Screening = 70

DOCUMENT: Reports Waiting for Screening
[reports]

Reports waiting to be screened for applicability. May become backlogged if the operating experience program recieves too much information at the same time.

INFLOWS:

Incoming_Reps =
EPRI_res_completion+NRC_IN_comp+SEN_reports++VEN_res_completion+WANO_rep_comp+SER_reports+report__analyses_received
DOCUMENT: Incoming Reports
[reports/week]

Includes all other incoming reports that contain useful information.
Will be screened for applicability.

OUTFLOWS:

reports_screened = Reps_Waiting_for_Screening/adj_time_to_screen_reps
DOCUMENT: Reports Screened
[reports/week]

Reports undergoing screening to determine applicability to the utility.

reps_abandoned = IF (info_eng_unavail_ratio>4) THEN frac_rep_abandoned*Reps_Waiting_for_Screening ELSE 0

☐ SOERs_Waiting_for_Screening(t) = SOERs_Waiting_for_Screening(t - dt) + (Incoming_SOERs - SOER_screened) * dt
INIT SOERs_Waiting_for_Screening = 5

DOCUMENT: SOERs Waiting for Screening
[SOER]

SOER waiting to be screened by an engineer. Screening determined whether the SOER is applicable or non-applicable.

INFLOWS:

Incoming_SOERs = SOER_reports
DOCUMENT: Incoming SOERs
[SOER/week]

SOERs coming into to the utility (usually through SEE-IN) for analysis.

OUTFLOWS:

SOER_screened = SOERs_Waiting_for_Screening/time_to_screen_SOER
DOCUMENT: SOER Screened
[SOER/week]

SOER screening completion.

○ adj_time_to_screen_reps = time_to_screen_reps*info_eng_unavail_ratio
DOCUMENT: Adjusted Time to Screen Reports
[week]

Time to screen reports adjusted for availability of engineers.

○ app_reps = reports_screened*frac_reps_dtmd_app
DOCUMENT: Applicable Reports
[reports/week]

Number of screened reports that are determined applicable.

○ app_reps_prev_anal = reports_screened*frac_reps_prev_analyzed
DOCUMENT: Applicable Reports Previously Analyzed
[reports/week]

Number of screened reports that had been previously analyzed.

○ app_SOER = SOER_screened*frac_SOER_dtmd_app

DOCUMENT: Applicable SOER
[SOER/week]

SOERs determined applicable to our utility.

○ concerns_from_app_SOER = app_SOER*concerns_per_SOER
DOCUMENT: Concerns From Applicable SOER
[concerns/week]

New concerns from SOERs to be analyzed futher.

○ concerns_per_SOER = 5
DOCUMENT: Concerns per SOER
[concerns/SOER]

Average number of utility concerns that come from SOERs.

○ frac_reps_dtmd_app = 1-frac_reps_prev_analyzed
DOCUMENT: Fraction of Reports Determined Applicable
[applicable reports/screened reports]

Fraction of screened reports that are applicable an need futher analysis.

○ frac_reps_prev_analyzed = .3*EFF_DEFRED_repeat_reps
DOCUMENT: Fraction of Reports Previously Analyzed
[previously analyzed reports/screened reports]

Number of screened reports that have problems that had previously been screened by the utility.

○ frac_rep_abandoned = .4

frac_SOER_dtmd_app = .80
DOCUMENT: Fraction of SOER Determined Applicable

Fraction of screened SOERs that are applicable to the utility.

non_app_reps = reports_screened*(1-frac_reps_prev_analyzed-frac_reps_dtmd_app)
DOCUMENT: Non Applicable Reports
[reports/week]

Number of screened reports that are determined non-applicable.

non_app_SOER = SOER_screened*(1-frac_SOER_dtmd_app)

DOCUMENT: Non-Applicable SOER
[SOER/week]

SOERs determined to be non-applicable to out utility.

time_to_screen_reps = 3
DOCUMENT: Time to Screen Reports
[week]

Time for engineers to screen reports for applicability.

time_to_screen_SOER = 1
DOCUMENT: Time to Screen SOER
[weeks]

Time to screen SOER. Not adjusted by the engineer availability because these are always screened as soon as possible.

Social: Media Coverage

EffectiveMediaReports(t) = EffectiveMediaReports(t - dt) + (FollowupRptDissimination + OperationalRptDissimination + EventRptDissimination - EffectRptFading) * dt
INIT EffectiveMediaReports = Init_Eff_Media_Rpts

DOCUMENT: Effective Media Reports
[articles]

INFLOWS:

FollowupRptDissimination = FollowupReports/FwupRptSpreadTime
DOCUMENT: Follow-up Reporting Dissemination
[articles/week]

OperationalRptDissimination = OperatingReports/OpRptSpreadTime
DOCUMENT: Operations Report Dissemination
[articles/week]

EventRptDissimination = EventReports/EvtRptSpreadTime
DOCUMENT: Event Reporting Dissemination
[articles/week]

OUTFLOWS:

EffectRptFading = EffectiveMediaReports/AverageRptEffectLife
DOCUMENT: Effective Reporting Fading
[articles/week]

EventReports(t) = EventReports(t - dt) + (EventRptingRate - EventRptDissimination) * dt
INIT EventReports = Init_EventRep

DOCUMENT: Event Reports
[articles]

The development of background reports for media articles on major plant events.

INFLOWS:

EventRptingRate = Plant_breakdwns_P2+(Plant_Force_Out/200)*0
DOCUMENT: Event Reporting Rate
[articles/week]

OUTFLOWS:

EventRptDissimination = EventReports/EvtRptSpreadTime
DOCUMENT: Event Reporting Dissemination
[articles/week]

FollowupReports(t) = FollowupReports(t - dt) + (FollowReportingRate - FollowupRptDissimination) * dt
INIT FollowupReports = .5

DOCUMENT: Follow-up Reports
[articles]

Media articles written to provide additional information on an earlier article (original article).

INFLOWS:

FollowReportingRate = Social_Multiplier*(EventRptDissimination+OperationalRptDissimination)
DOCUMENT: Follow-up Reporting Rate
[articles/week]

OUTFLOWS:

FollowupRptDissimination = FollowupReports/FwupRptSpreadTime
DOCUMENT: Follow-up Reporting Dissemination
[articles/week]

OperatingReports(t) = OperatingReports(t - dt) + (OperatingReportingRate - OperationalRptDissimination) * dt
INIT OperatingReports = Init_Ops_Rpt

DOCUMENT: Operating Reports
[articles]

Resevoir of articles written on plant performance (not including major events).

INFLOWS:

OperatingReportingRate = (Operating_Conditions+defect__operating_reports)*EffPIM
DOCUMENT: Operating Reporting Rate
[articles/week]

OUTFLOWS:

OperationalRptDissimination = OperatingReports/OpRptSpreadTime
DOCUMENT: Operations Report Dissemination
[articles/week]

AverageRptEffectLife = 4
DOCUMENT: Average Report Effective Life
[weeks]

EvtRptSpreadTime = 2
DOCUMENT: Event Report Spread Time
[weeks]

Time for information in media article to disseminate throughout the country.

FwupRptSpreadTime = 1.5
DOCUMENT: Follow-up Reporting Spread Time
[weeks]

The time for followup reports to disseminate across the country.

OpRptSpreadTime = 3
DOCUMENT: Operations Reporting Spread Time
[weeks]

Time for operations articles to disseminate throughout country.

Plant_Force_Out = PULSE(1,0,DT)*For_Out_Funct
DOCUMENT: Plant Breakdowns
[breakdowns/week]

Social_Multiplier = EFFCLM*EFFPOM*EFFLPOM
DOCUMENT: Social Multiplier
[unitless multiplier]

Combined impact of social concerns on the media's efforts for followup reports.

t_bdwns_P2 = 0+(STEP(10000/13400,156)-STEP(10000/13400,166))*Event_Switch

EFFMLM = GRAPH(EffectiveMediaReports)
(0.00, 0.823), (1.00, 0.997), (2.00, 1.00), (3.00, 1.00), (4.00, 1.01), (5.00, 1.02), (6.00, 1.06), (7.00, 1.11), (8.00, 1.22), (9.00, 1.28), (10.0, 1.30)
DOCUMENT: Effect of Media on Lawmakers
[unitless]

EFFMNRC = GRAPH(EffectiveMediaReports)
(0.00, 0.88), (1.00, 0.949), (2.00, 1.00), (3.00, 1.00), (4.00, 1.00), (5.00, 1.01), (6.00, 1.02), (7.00, 1.04), (8.00, 1.06), (9.00, 1.11), (10.0, 1.20)
DOCUMENT: Effect of Media on NRC Concern
[unitless]

EFFMPO = GRAPH(EffectiveMediaReports/INIT(EffectiveMediaReports))
(0.00, 0.862), (1.03, 1.03), (2.07, 1.03), (3.10, 1.03), (4.14, 1.06), (5.17, 1.07), (6.21, 1.08), (7.24, 1.10), (8.28, 1.13), (9.31, 1.14), (10.3, 1.16), (11.4, 1.17), (12.4, 1.20), (13.4, 1.20), (14.5, 1.22), (15.5, 1.22), (16.6, 1.24), (17.6, 1.25), (18.6, 1.26), (19.7, 1.27), (20.7, 1.27), (21.7, 1.28), (22.8, 1.28), (23.8, 1.28), (24.8, 1.28), (25.9, 1.29), (26.9, 1.29), (27.9, 1.29), (29.0, 1.29), (30.0, 1.30)
DOCUMENT: Effect of Media on Public Concern
[unitless]

The media transmits information deemed to be of public interest to the general public. This variable represents the impact of media articles upon the public's concern over nuclear power.

Operating_Conditions = GRAPH(capacity_Online+(100*Per_Outage))
(0.00, 2.77), (10.0, 2.73), (20.0, 2.52), (30.0, 1.62), (40.0, 0.775), (50.0, 0.475), (60.0, 0.275), (70.0, 0.175), (80.0, 0.1), (90.0, 0.00), (100, 0.00)
DOCUMENT: Operating News
[articles/week]

Represents media attention toward a nuclear plant -- assuming such attention is a function of on-line capacity of plant (performance).

Plant_breakdwns_P2 = GRAPH(t_bdwns_P2)
(0.00, 0.00), (0.1, 0.1), (0.2, 0.2), (0.3, 0.65), (0.4, 1.25), (0.5, 4.00), (0.6, 6.65), (0.7, 7.95), (0.8, 8.90), (0.9, 9.65), (1, 9.90)
DOCUMENT: Plant Breakdowns
[breakdowns/week]

Social: Interest Groups

AntiNuclear_Campaigns(t) = AntiNuclear_Campaigns(t - dt) + (CampaignInitiationRate - ImplementationRate - FailureRate) * dt
INIT AntiNuclear_Campaigns = Init_Cmpgns

DOCUMENT: Anti-Nuclear Campaigns
[campaigns]

INFLOWS:

CampaignInitiationRate = Social_Concerns*(Eff_Breakdwn_P2+Eff_Ops/20+Eff_Breakdwn/20)
DOCUMENT: Campaign Initiation Rate
[campaigns/week]

OUTFLOWS:

ImplementationRate = AntiNuclear_Campaigns/AveCampaignsDevelopmentTime
DOCUMENT: Implementation Rate
[campaigns/week]

FailureRate = AntiNuclear_Campaigns*FractionCampaignsFailed/AveCampaignsDevelopmentTime
DOCUMENT: Failure Rate
[campaigns/week]

☐ EffectiveAntiNCampaigns(t) = EffectiveAntiNCampaigns(t - dt) + (ImplementationRate - EffectFading) * dt
INIT EffectiveAntiNCampaigns = Init_EffCmpgns

DOCUMENT: Effective Anti-Nuclear Campaigns
[campaigns]

INFLOWS:

- ImplementationRate = AntiNuclear_Campaigns/AveCampaignsDevelopmentTime
  DOCUMENT: Implementation Rate
  [campaigns/week]

OUTFLOWS:

- EffectFading = EffectiveAntiNCampaigns/AveCampEffectLife
  DOCUMENT: Effective Fading
  [campaigns/week]

☐ I_G_Lawsuits(t) = I_G_Lawsuits(t - dt) + (Suit_Filing_Rate - Dismissal_Rate - OutCourtSettleRate - TrialResolutionRate) * dt
INIT I_G_Lawsuits = Init_IG_suits

DOCUMENT: Interest Group Lawsuits
[suits]

INFLOWS:

- Suit_Filing_Rate = Social_Concerns*(Eff_Breakdwn_P2+Eff_Ops+Eff_Breakdwn)
  DOCUMENT: Suit Filing Rate
  [suits/week]

OUTFLOWS:

- Dismissal_Rate = I_G_Lawsuits/AveTimetoDismiss
  DOCUMENT: Dismissal Rate
  [suits/week]

- OutCourtSettleRate = I_G_Lawsuits/AvetimetoSettle
  DOCUMENT: Out of Court Settlement Rate
  [suits/week]

- TrialResolutionRate = I_G_Lawsuits/AveTrialDuration
  DOCUMENT: Trial Resolution Rate
  [suits/week]

○ AveCampaignsDevelopmentTime = 12
DOCUMENT: Average Campaign Development Time
[weeks]

○ AveCampEffectLife = 4
DOCUMENT: Average Campaign Effective Life
[weeks]

○ AveTimetoDismiss = 26
DOCUMENT: Average Time To Dismiss
[weeks]

○ AvetimetoSettle = 2*[illegible]
DOCUMENT: Average Time to Settle
[weeks]

○ AveTrialDuration = 6*[illegible]
DOCUMENT: Average Trial Duration
[weeks]

○ FractionCampaignsFailed = .5
DOCUMENT: Fraction Campaigns Failed
[fraction: campaigns failed/campaigns]

○ Social_Concerns = EffPOPI*EFFCLPI*EFFLPOLPI

⊘ EFFPILM = GRAPH(EffectiveAntiNCampaigns)
(0.00, 0.82), (1.00, 0.997), (2.00, 1.00), (3.00, 1.00), (4.00, 1.01), (5.00, 1.03), (6.00, 1.09), (7.00, 1.17), (8.00, 1.25), (9.00, 1.29), (10.0, 1.30)
DOCUMENT: Effect of Public Interest on Lawmakers
[unitless]

⊘ EffPIM = GRAPH(EffectiveAntiNCampaigns+I_G_Lawsuits)
(0.00, 0.00), (1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.01), (6.00, 0.035), (7.00, 0.1), (8.00, 0.203), (9.00, 0.409), (10.0, 0.728)

⊘ EFFPINRC = GRAPH(EffectiveAntiNCampaigns+I_G_Lawsuits)
(0.00, 0.877), (2.00, 1.00), (4.00, 1.00), (6.00, 1.01), (8.00, 1.01), (10.0, 1.03), (12.0, 1.04), (14.0, 1.06), (16.0, 1.08), (18.0, 1.11), (20.0, 1.14)
DOCUMENT: Effect of Public Interest on NRC Concern
[unitless]

⊘ EFFPIPO = GRAPH(EffectiveAntiNCampaigns/INIT(EffectiveAntiNCampaigns))
(0.00, 0.981), (0.3, 0.981), (0.6, 0.983), (0.9, 0.992), (1.20, 1.00), (1.50, 1.01), (1.80, 1.03), (2.10, 1.04), (2.40, 1.06), (2.70, 1.06), (3.00, 1.07)
DOCUMENT: Effect of Public Interest on Public Concern
[unitless]

⊘ EFFPIPUC = GRAPH(EffectiveAntiNCampaigns)
(0.00, 0.98), (1.00, 0.944), (2.00, 0.898), (3.00, 0.896), (4.00, 0.894), (5.00, 0.892), (6.00, 0.89), (7.00, 0.884), (8.00, 0.792), (9.00, 0.748), (10.0, 0.7)
DOCUMENT: Effect of Public Interest on Lawmakers
[unitless]

⊘ Eff_Breakdwn = GRAPH(frac_equip_bdown+EFFForcOut)
(0.00, 0.00), (0.1, 0.025), (0.2, 0.06), (0.3, 0.2), (0.4, 0.5), (0.5, 1.12), (0.6, 2.42), (0.7, 3.90), (0.8, 4.47), (0.9, 4.88), (1, 4.97)
DOCUMENT: Effect Breakdowns
[actions/week]

⊘ Eff_Breakdwn_P2 = GRAPH(t_bdwns_P2)
(0.00, 0.00), (0.1, 0.025), (0.2, 0.15), (0.3, 0.825), (0.4, 1.65), (0.5, 2.50), (0.6, 3.33), (0.7, 3.98), (0.8, 4.47), (0.9, 4.88), (1, 4.97)
DOCUMENT: Effect Breakdowns
[actions/week]

⊘ Eff_Ops = GRAPH(capacity_Online+(95*Per_Outage))
(0.00, 4.92), (10.0, 3.38), (20.0, 2.23), (30.0, 1.23), (40.0, 0.725), (50.0, 0.475), (60.0, 0.25), (70.0, 0.15), (80.0, 0.1), (90.0, 0.075), (100, 0.025)
DOCUMENT: Effect Operations
[actions/week]

Social: Public Concern

☐ Loc_Public_Opposition(t) = Loc_Public_Opposition(t - dt) + (Change_Loc_Opp - Fading_Loc_Opp) * dt
INIT Loc_Public_Opposition = 15
INFLOWS:
Change_Loc_Opp = (Bound_LPO-Loc_Public_Opposition)/Time_to_ch_Loc_Opp
OUTFLOWS:
Fading_Loc_Opp = Loc_Public_Opposition/Loc_Desensitization

☐ Nat_Public_Opposition(t) = Nat_Public_Opposition(t - dt) + (Pub_Concern_Adjustment - FadingConcern) * dt
INIT Nat_Public_Opposition = 20

DOCUMENT: Public Concern
[Concern Units]

Range 0 to 100

INFLOWS:
Pub_Concern_Adjustment = (Bounded_IPOs-Nat_Public_Opposition)/PC_Adj_Time
DOCUMENT: Public Concern Adjustment
[concern/week]

OUTFLOWS:

FadingConcern = Nat_Public_Opposition/(AvePubDesensitzation)
DOCUMENT: Fading Concern
{concern units/week}

Utility_Goodwill(t) = Utility_Goodwill(t - dt) + (GW_change) * dt
INIT Utility_Goodwill = 1
INFLOWS:

GW_change = (Ind_Goodwill-Utility_Goodwill)/GW_Change_time

$_on_Ed = 02
DOCUMENT: Dollars on Education
Units: {mln $'s/week}
Money spent on public education which translates into goodwill.

AvePubDesensitzation = 520
DOCUMENT: Average Public Desensitizing Time
{weeks}

This is the time it takes even with other factors remaining constant for the public to be desensitized to an issue. Over time people become more and more used to particular number of media reports, interest group action etc. and they care less and less.

Bounded_IPOs = MAX(MIN(Indicated_Public_Opposition,90),20)
Bound_LPO = MAX(MIN(Ind_Loc_Opp,95),5)
GW_Change_time = 52*Ind_Goodwill/Utility_Goodwill
Indicated_Public_Opposition = Nat_Public_Opposition*Net_Effect_on_PC
Ind_Goodwill = EffCussatGW*EffLOCEdGW*EffLPOGW
Ind_Loc_Opp = Loc_Public_Opposition*Net_Ef_on_Loc_Op
Loc_Desensitization = 520
Net_Effect_on_PC = EFFPIPO*EFFMPO*EFFUOpsPO*EFFGAPO*EFFSALPnat_pub_opp
DOCUMENT: Net Effect on Public Concern
{unitless}

Various factors influence the public's concern over nuclear power. This variable calculates the net effect of all variables within this model acting on public concern.

Net_Ef_on_Loc_Op = EFFGAPO*EFFMPO*EffOpsLPO*EFFPIPO*EFFPOLPO*EffUtGoodwillLPO*EFFSALPlocpub_opp
PC_Adj_Time = 6*Nat_Public_Opposition/Indicated_Public_Opposition
DOCUMENT: Public Opposition Adjustment Time
{weeks}

The average time for the public opposition over nuclear power to adjust to a new position given a pressure to do so. It will be about 6 weeks for a small change in opposition.

Time_to_ch_Loc_Opp = 4*Loc_Public_Opposition/Ind_Loc_Opp
EffCussatGW = GRAPH(Cust_Sat)
(0.00, 0.901), (0.1, 0.907), (0.2, 0.912), (0.3, 0.927), (0.4, 0.941), (0.5, 0.953), (0.6, 0.961), (0.7, 1.05), (0.8, 1.08), (0.9, 1.09), (1, 1.10)
EffLOCEdGW = GRAPH($_on_Ed/.06)
(0.00, 0.207), (0.714, 0.518), (1.43, 1.36), (2.14, 2.03), (2.86, 2.37), (3.57, 2.61), (4.29, 2.66), (5.00, 2.73), (5.71, 2.78), (6.43, 2.82), (7.14, 2.87), (7.86, 2.93), (8.57, 2.96), (9.29, 2.96), (10.00, 2.99)
EffLPOGW = GRAPH(Loc_Public_Opposition)
(0.00, 1.20), (10.0, 1.15), (20.0, 1.12), (30.0, 1.08), (40.0, 1.06), (50.0, 1.03), (60.0, 1.00), (70.0, 0.974), (80.0, 0.916), (90.0, 0.846), (100, [illegible])
EFFLPOLPI = GRAPH(Loc_Public_Opposition)
(0.00, 0.96), (10.0, [illegible]), (20.0, [illegible]), (30.0, 1.00), (40.0, 1.02), (50.0, 1.04), (60.0, 1.06), (70.0, 1.09), (80.0, 1.13), (90.0, 1.17), (100, 1.2[illegible])
EFFLPOM = GRAPH(Loc_Public_Opposition)
(0.00, 0.99), (10.0, 0.992), (20.0, 0.988), (30.0, 0.983), (40.0, 0.984), (50.0, 0.983), (60.0, 0.984), (70.0, 0.995), (80.0, 0.996), (90.0, 1.01), (100, 1.08)
EFFLPOPerSaf = GRAPH(Loc_Public_Opposition)
(0.00, 1.10), (10.0, 1.01), (20.0, 0.994), (30.0, 0.988), (40.0, 0.982), (50.0, 0.986), (60.0, 0.989), (70.0, 0.961), (80.0, 0.975), (90.0, 0.945), (100, 0.901)
DOCUMENT: Effect of Local Public Opposition on Perceived Safety
this is the influence public protesters have on the financial community's percieved safety of the reactor.

EFFLPOSRisk = GRAPH(Loc_Public_Opposition)
(0.00, 0.934), (10.0, 0.936), (20.0, 0.941), (30.0, 0.974), (40.0, 0.986), (50.0, 1.02), (60.0, 1.06), (70.0, 1.08), (80.0, 1.09), (90.0, 1.09), (100, 1.10)

EffOpsLPO = GRAPH((capacity_Online+(Per_Outage*80))/(EFFForcOut+1))
(0.00, 1.69), (10.0, 1.49), (20.0, 1.32), (30.0, 1.30), (40.0, 1.09), (50.0, 1.05), (60.0, 1.03), (70.0, 1.01), (80.0, 0.98), (90.0, 0.95), (100, 0.902)

EFFPOCussat = GRAPH(Loc_Public_Opposition)
(0.00, 1.12), (10.0, 1.06), (20.0, 1.00), (30.0, 0.938), (40.0, 0.886), (50.0, 0.864), (60.0, 0.854), (70.0, 0.846), (80.0, 0.842), (90.0, 0.826), (100, 0.802)
DOCUMENT: Effect of Local Public Opposition on Customer Satisfaction

EFFPOLM = GRAPH(Nat_Public_Opposition)
(0.00, 0.7), (5.00, 0.9), (10.0, 1.00), (15.0, 1.03), (20.0, 1.04), (25.0, 1.06), (30.0, 1.12), (35.0, 1.21), (40.0, 1.25), (45.0, 1.28), (50.0, 1.30)
DOCUMENT: Effect of Public Concern on Lawmakers
[unitless multiplier]

EFFPOLPO = GRAPH(Nat_Public_Opposition)
(0.00, 0.9), (10.0, 0.904), (20.0, 0.916), (30.0, 0.933), (40.0, 0.949), (50.0, 0.96), (60.0, 0.982), (70.0, 0.995), (80.0, 1.03), (90.0, 1.08), (100, 1.10)

EFFPOM = GRAPH(Nat_Public_Opposition)
(0.00, 0.8), (5.00, 1.00), (10.0, 1.01), (15.0, 1.03), (20.0, 1.07), (25.0, 1.12), (30.0, 1.18), (35.0, 1.23), (40.0, 1.27), (45.0, 1.29), (50.0, 1.30)
DOCUMENT: Effect of Public Concern on Media
[unitless multiplier]

EFFPOPerSaf = GRAPH(Nat_Public_Opposition/INIT(Nat_Public_Opposition))
(0.00, 1.21), (1.00, 1.00), (2.00, 0.997), (3.00, 0.982), (4.00, 0.967), (5.00, 0.961), (6.00, 0.955), (7.00, 0.946), (8.00, 0.94), (9.00, 0.931), (10.0, 0.925)
DOCUMENT: Effect of National Public Opposition on Perceived Safety
(unitless)

this is the effect Nat Public Opposition has on the perceived safety of nuclear plants by the financial community.

EffPOPI = GRAPH(Nat_Public_Opposition)
(0.00, 1.00), (5.00, 1.04), (10.0, 1.08), (15.0, 1.12), (20.0, 1.15), (25.0, 1.19), (30.0, 1.23), (35.0, 1.27), (40.0, 1.30), (45.0, 1.30), (50.0, 1.30)

EFFPOStRisk = GRAPH(Nat_Public_Opposition)
(0.00, 0.981), (10.0, 0.99), (20.0, 0.999), (30.0, 1.00), (40.0, 1.01), (50.0, 1.02), (60.0, 1.03), (70.0, 1.03), (80.0, 1.05), (90.0, 1.06), (100, 1.07)
DOCUMENT: Effect of Public Concern on Stock Risk
(unitless)
This factor on risk represents the latent fear of individuals to buy the stock thus increasing the risk factor and driving stock price down. It can represent other factors too such as the fact that as public concern grows more stockholders become anti-nuke possible demanding that the company diversify out of the nuclear business.

EFFUOpsPO = GRAPH((capacity_Online/100)+(Per_Outage*.8))
(0.00, 1.02), (0.1, 1.01), (0.2, 1.01), (0.3, 1.01), (0.4, 1.01), (0.5, 1.00), (0.6, 1.00), (0.7, 0.991), (0.8, 0.982), (0.9, 0.976), (1, 0.976)
DOCUMENT: Effect of Utility Public Relation on Public Concern
[unitless]

Utilities spend much time and resources trying to assuage the public fears over nuclear power. This variable represents the impact of those actions on public concern.

EffUtGoodwillLPO = GRAPH(Utility_Goodwill/INIT(Utility_Goodwill))
(0.00, 1.08), (0.103, [illegible]), (0.207, 1.07), (0.31, 1.06), (0.414, 1.05), (0.517, 1.04), (0.621, 1.04), (0.724, 1.02), (0.828, 1.02), (0.931, 1.00), ([illegible], 0.985), (1.14, 0.974), (1.24, 0.966), (1.34, 0.964), (1.45, 0.962), (1.55, 0.961), (1.66, 0.96), (1.76, 0.96), (1.86, [illegible]), (1.97, 0.960), (2.07, 0.960), (2.17, 0.959), (2.28, 0.959), (2.38, 0.958), (2.48, 0.957), (2.59, 0.956), (2.69, [illegible]), (2.79, 0.955), (2.90, 0.952), (3.00, 0.95)