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DEFINING A DECISION SUPPORT SYSTEM TO MODEL A CONFLICT SCENARIO

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Project Submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

SYSTEMS ENGINEERING

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March, 1991
Blacksburg, Virginia

DEFINING A BATTLE MANAGER DECISION SUPPORT SYSTEM IN A HOSTILE ENVIRONMENT

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(ABSTRACT)

With the constantly changing world situation we live in today, the traditional method of military planning must evolve into a more dynamic form. Traditional methods can be time consuming and are applicable in less integrated methodologies. Recent occurrences in the world political state shows the need for a model for dynamic planning of the approach for warfighting, procurement and long range planning.

The Battle Management tool is developed to include a top level structure of the scenario of interest. An approach is taken to aggregately model many of the changes that can occur before, during and after some military conflict. The format of the model is aggregate and describes major elements including military, political, economic and support elements systems with resource levels.

The system is in the form of a causal diagram includes methods to model and evaluate the transient values of elements of the system and provide insight into the dynamics of these elements.

The application of data to the model in some exemplar analysis with many potential relationships of the integrated military scenario, the effects of a economic investment decisions in a crisis state can dramatically effect other sometimes unconsidered elements of the overall system. Elements of the more broadly defined system show some effects to the capabilities of forces and decision maker's options that were not previously expected.

ACKNOWLEDGEMENTS

Acknowledge the support and

advise for the project from

my Shelly and support

from coworkers at SAIC

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I. INTRODUCTION

A Battle Management decision support system may on the surface sound like a less than desirable system to be developed in today's political environment. However, the present environment which includes reduced budgets[1] and fewer resources available to military research, also creates the opportunity for the application of more efficient systems in this area.

In a crisis preceding a conflict or in an actual conflict state, more efficiency means that fewer resources, equipment and operations could be expected to achieve certain goals. The model structure that will be considered will allow "What-if" evaluations of decisions made in an interrelated system to allow for a proper approach to the allocation of resources.

In particular, the analysis model which is intended to be developed in this project is one which uses some traditional modeling of conflict states, an approach to model the supporting national structure behind one side's resources and characteristics and the interconnections. These are to be incorporated into a dynamic systems model to evaluate the effects of one perturbation of a system element on the overall system state. The term, decision support system is used since a likely product from this project would be the development of a tool for a decision maker either in a practical or analytical environment.

Elements of the expected design of such an integrated military and economic model would take existing parts or types of models and add unique system requirements and interfaces. There are existing tools that presently include mathematical models for multiple sided military exchange analysis, various battlefield decision support tools as well as detailed simulations to account for various unexpected characteristics of conflict states[2]. There are fewer models available that try to incorporate more intangible types of measures such as economic and political states and their relationships to physical systems[3]. These intangible elements however often become the major contributors to the results of actual conflicts. How many times over the last 50 years has the outcome of a war or crisis been attributed to the, at the time current political environment. Figure 1.1 gives a pictorial description of a general scenario under consideration.

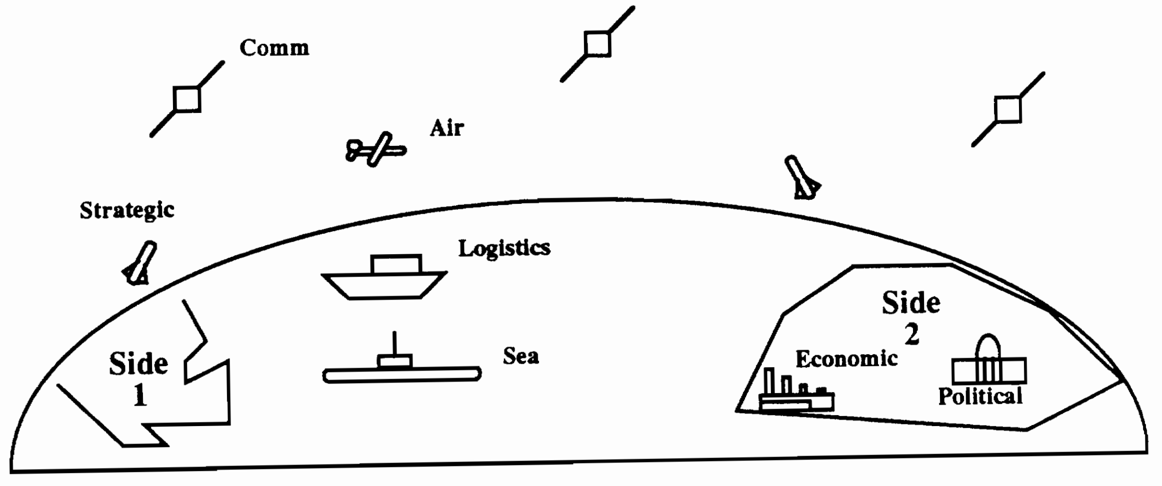


Figure 1.1: Scenario under Consideration

In previous analysis in the field, there are also many other types of representations available. Many of the models are in the form of computer based mathematical programs, some simulations, game theory based tools, games with players acting out the scenarios and analytical solutions. This project will approach the modeling of the system by first using some existing methods in the military modeling area. The general process to develop the model was considered in the systems approach which is shown in general in Figure 1.2.

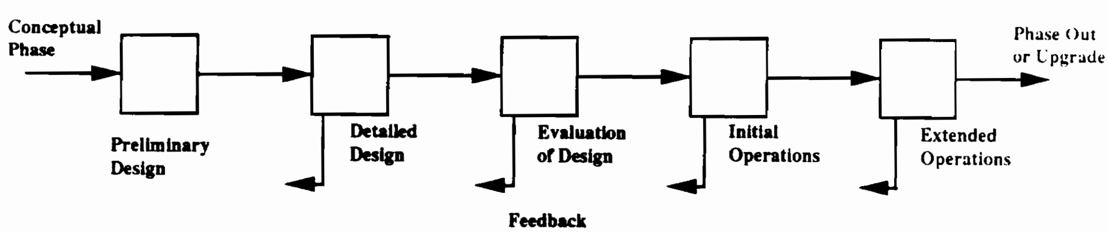


Figure 1.2: Approach to Model Development

The modeling approach chosen to be used was that of systems dynamics. The physical systems were suited to be modeled using systems dynamics approaches. The development of the structure was performed starting with several versions of causal diagrams. The final version of the causal diagram for the entire system that was developed and is shown later in this project. Figure 1.3 shows a top level description of the type of causal diagram that was used for describing the conflict state. The figure shows how the causal structure is broken down into major sections describing military, economic, political and support function element sections.

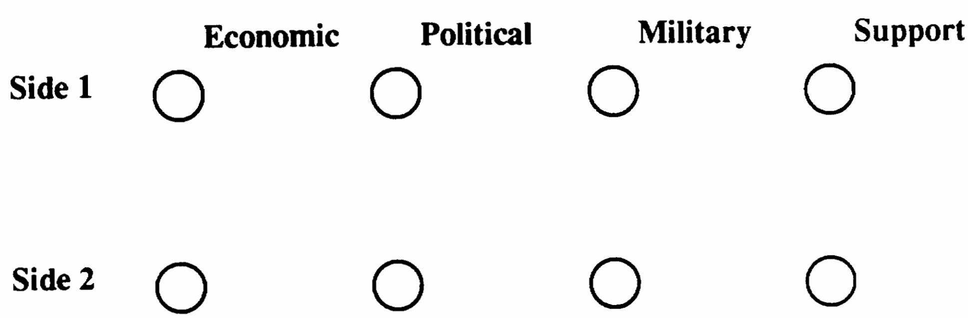


Figure 1.3: Top Level Causal Diagram Structure

The use of the systems dynamics approach seemed appropriate when modeling crisis and conflict states. A more static modeling approach might not fully utilize the capabilities of a dynamic system approach in modeling.

The completion of the project includes a version of a model with some interface to allow the user to explore the results of changes in his immediate system of interest with other related elements of the overall systems environment. The analysis behind the tool was used to produce the basis and data source to describe the world state. Any major change in the way elements are expected to act related to each other would require at a minimum a change in the database and at a maximum a change in the formulation of the various element's relationships. If there were to be an effort that would go one step further and dynamically change the relationships and rules used to describe the system, this would be closer to describing an Expert System[4]. In the design process, the existence of a decision maker and need for interaction with the system makes the need for an Expert system less desirable at this time.

Some of the intended benefits of the system would be its ability to reduce the need for some of the guesswork involved in much of the decision making and integrated battle management required by many users of the elements modeled in the project's system.

1.1 Purpose: As stated in the introduction, the development of a model to describe the dynamic interactions that occur in a global scenario with interrelated elements especially in a crisis or conflict stage could be valuable for many needs. The intention is that the tool could be supported and operated to allow the user to find a solution to a problem both quickly and more accurately.

By more quickly, the project uses a computer based model which integrates elements previously considered individually. The speed at which the analysis is performed is increased by allowing the user to see effects of one or more changes to the overall system.

By more accurately, this can be a function of the speed, such that with more time to perform a larger number of analysis runs, the user can be more confident that he has looked at more of the solution space. With the integration of many elements, the decision maker can acquire knowledge of the broader environment in which his particular element of interest may lie in. Also by laying out the various sections of the system such as the economic levels, to a level of detail required for proper analysis, the user can have more confidence in his results.

The immediate goals of the decision maker in a crisis state is the availability of resources that he requires to perform his operation. In a conflict state, the measure is the effectiveness of his resources as well as the resulting attrition of his resources due to the conflict.

Table 1.1 shows some more specific measures of effectiveness that are used to describe the elements. The needs of the user could be one or more of those shown in the table.

Table 1.1: Measures of Effectiveness

Measure	Description	Application
Accuracy	Level of Accuracy	Analyst
Speed	Return Results	Real-Time use of Data
Completeness	Cover Solution Space	Policy Analyst

One might wonder why the user or analyst would need to know information pertaining to elements not under his immediate control. The reasoning appears more clear when the causal diagram was developed. Any action or change in an element is not in isolation. For instance, the supply of equipment comes from resources that can be eliminated depending on the location, supply and operation of the type of equipment it supplies. In the military arena, it is rare to have battles of the type where armies clash on the battlefield and then withdraw to safe areas[5]. It can be expected that the supplies to the armies are targets and the factories and resources that feed the army's needs are also potentially affected by the enemy actions. So in this example, it is important to the decision maker who would send an army into battle and precipitate the unleashing his opponent's nuclear arsenal on the cities of the attacking army. The consequences of any action of this type must be realized and considered before a potentially unacceptable set of consequences is presented.

Another goal of this project and the intended product will be a model to describe the battle management decision process in an interactive mode both during and before a potential crisis or actual conflict.

To describe the system, the boundaries and scope of the model and data is shown in general in Table 1.2. The systems approach was implemented in describing the depth and boundary of the system desired. The level of detail shown in the Table 1.2 requires a system describing the elements at the minimum as aggregate resources.

Table 1.2 Scope of System Development

Level	System Consideration	Notes
Global	Bound Problem	Initial Step
Top Level	Define Sides	Bound Problem
Detail Level	Elements of Sides	Defines Structure
User Product	Analysis Details	Research and Analysis

The data used in the project is categorized primarily by which function in which it is relevant. The requirements of a user would be that he possess enough data to describe a functional capability of an element describing a state of that element in a given scenario. For example, in power generation, oil is a critical resource that often dictates policy and decision making. Thus, this rather basic element is important enough to be a consideration in defining a national level model. On the other hand, from the conflict and military viewpoint, a basic element which goes into the production of a less critical consumer item would not need to be tracked as closely and given as much consideration when decisions for action are required. Figure 1.4 provides a idea of where the system and model lie in terms of level of aggregation within the design space available. Using this approach to the development of the model in which aggregation is used to attempt to model all the sections of a global conflict is intended to be fulfill some general and specific needs. In general, the problem of quantifying global systems which have included elements such as the economic and political status of a nation as well as more military elements is applicable to users such as Arms Control planners, organizations which are interested in the proper sizing and structuring of total forces and political analysts interested in the effects of allocating national resources to defensive forces. The level of aggregation presented in this model is intended to suit these types of users with potential future growth of some or all of the model to include more detail as the user desires.

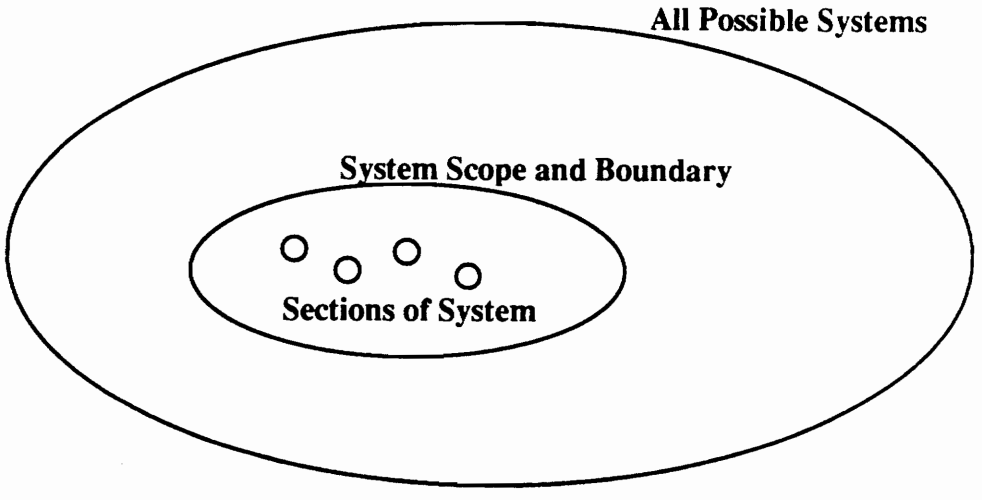


Figure 1.4: System Scope and Development Boundary

II. LITERATURE REVIEW

Early efforts to define the means to evaluate a military conflict scenario led to the recognition that even some of the most studied elements in operations research that are related to military conflicts are those that describe force exchanges. The development of the project tries to identify the conflict dynamics, attempting to resemble the way the real world expectations. The first idea was to model only one of the elements in great detail. In context of the project, this would have been in example, modeling only the strategic force elements of one side. But as the subject matter was reviewed further, it was realized that there were a multitude of other elements of the military and society that depended on or were effected by strategic systems.

After the decision was made to broaden the scope of the project to include other elements into aggregated representations of military systems, it was recognized that some of the details might be lost. To try to justify the structures considered, research was performed in some of the composition of the elements of the military structure, taking into account the complex interfaces that existed[6].

Research was performed using the system definition as a guideline. Preliminary causal diagrams allowed for research on the elements of the system to be performed. As more elements were incorporated into the system, the element's characteristics were identified and the interactions between the elements of the systems were described. The first pass at defining the interactions included simple linear or constant rate types of connections. After more research into the documentation regarding the actual relationships that might exist between defined elements, insight sometimes resulted in identification of more complex interactions which could be incorporated into the system[7]. All along this process, the structure of the defined elements and corresponding causal diagram was improved and updated.

The use of some constant and linear relationships between elements of the systems was not as bad of an estimation into the actual relationships as one might expect. Cause and effect relationships through historical documentation has sometimes been linear[8]. Specifically, some logistical requirements for the supply of military elements follows linear patterns. Certain attrition principles between conflicting sides also act linearly. If one side has a much superior force in terms of numbers or technological advances, constants may exist. A vastly superior Air Force for example may never accept attrition from the opponent, who may never overcome the minimum required threshold of forces to inflict any losses on his opponent.

The research also resulted in the identification of some more complex relationships between elements. Some of these were more complex, but were quantified through some mathematical relationship[9]. For instance, strategic weapons on one side have well defined performance characteristics. Using expected damage and failure rates of systems, a representation of the attack attrition could be computed. For some relationships, finding some mathematical or logical description of the performance was difficult. For instance, trying to describe what happens to the stability of a nation's government when a carrier battle group is lost is a difficult thing to quantify. For these types of problems, typically historical data can offer some of the best actual data to work with along with providing a level of aggregation so that direct detailed relationships that could not be realistically be quantified were not a major issue.

With a potential of modeling the entire world's dynamic interactions in a crisis, some decisions had to be made to create a model in a reasonable scope for the context of the development cycle. The problem is a potential "n" sided scenario. There could be "n" sides in the crisis. For the project, the model is demonstrated as a two sided problem. Also if forecasting the scenario to a future state, one would end up with a almost infinite number of unknowns in the system setup. For the project, the default world structure remains constant, however by changing the values of the elements and their relationships as well and the initial values of the variables, different worlds can be analyzed. Table 2.1 shows some of the major assumptions in the initial definition of the system. The general assumptions of the system under development could change with a new set of relationships so that the information in the table is defined in aggregate terms rather than in specific values that were defined.

Table 2.1: Major Assumptions for the System Definition

Assumption	Source	Note
Aggregation	One Value for Resource	Details Included
Data Source	Research/Estimate	Equal on Both Sides
Time Element	dT = 1 week	Change Data for Other
Relationships	Research	Can Change

The assumptions and choices made in the development of the system were performed in two modes. Some of the key research and development needed to be performed prior to coding, etc. The order of the system development is shown in Table 2.2. This is shown so the reader can see how decisions were made and how at certain key decision points, changes, updates to the relationships of the model were performed. The major steps are identified along with the sequence of performance.

Table 2.2: Chronology of the System Development

Step	Description	Note
Top Level	Sides/Major Elements	Bound the Model
Data	For Major Elements	General Data
Relationships	Interaction of Elements	Simple Relationships
Detailed Level	Of all Elements	More Complex

There were many other possible approaches considered for this problem. One of the most common would have been the method of gaming in the development of scenarios and possible consequences of a global crisis. However, in many gaming activities that occur today, some models and tools are required to evaluate "What If" scenarios. It is considered feasible that a model such as the one represented in this report could also be used for gaming exercises.

Other methods include expert type systems, where one or many experts inputs are used to develop as system to automatically evaluate the possibilities of conflicts and preceding events. Even if an expert system was used, part of the expert's requirements for information might be provided from a model such as this. In an operational sense, the military and supply environments are not in the mode to allow an automated system such as an expert computer system to make decisions and perform activities where the risk is too high.

2.2 Historical Facts: So far much of what has been described has assumed that this type of problem where the integration of military and other elements exists. Describing examples in historical terms as well as the direction the model under consideration will hopefully help to explain the need more clearly.

Throughout history, there has undoubtably been a complex political and military relationship. This is nothing new. The technology involved and modes of battle may have been primitive, but since ancient times, there have always been causes and effects to society and the political structure from the outcomes of wars. However, in retrospect, a potential user of this system in these historical times would have been the field commander or planner located away from the field. The field commander had a job, to win the battles with the resources he was provided. He could most successfully achieve these goals if he were to have more effective forces and would feel less comfortable if he had few effective forces. In those times, the effectiveness of the weapons was almost entirely based on the effectiveness of the men under the command of this leader. Many times in fact, the most effective troops were the most motivated troops. This job was extremely complex to this commander and there might not have been as much gained if he were able to analyze possible perturbations to the system. The commander might not be able to effect changes to elements not under his control. The planner from ancient times, might have been able to use the type of model more, since he would be in charge of acquiring troops, weapons and providing logistics. But again in these times, the planning and supply of the forces were often performed as the needs arose and based on the planner's memory of previous events.

As weaponry became more complex and advances in technology brought the societies of the world closer, the requirement for integration of actions arose. Looking at the US Civil War, one can see that somewhere, decisions were made in military campaigns by those that had some knowledge of the complex interactions of the political and military arms of a society. Sherman's March to destroy the moral, the industrial base and transportation system of the South was a decision with risks, but whose payoff in terms of effecting the warfighting capability of the Confederate Nation directly and indirectly was enormous[10]. This understanding of the direct relationship between the political and industrial bases of a society allowed the military forces of the North to strike non-military targets and directly effect some battlefield outcomes.

In the twentieth century, the advance of media through radio and television as well as the apparent increase in public "awareness" made propaganda and "public image" as important in a conflict as many other elements[11]. These more intangible elements have been the driver for much of modern society's actions and desires.

To demonstrate the potential use of the model structure presented in this project, the Vietnam Conflict can be briefing viewed. Without creating a new subject for the project, i.e. "The Vietnam Era", some generalizations will be made for comparative purposes. The troop and equipment commitments to the Vietnam Conflict were mostly made in response to societal and political changes[12]. When the decision was made not to interfere in many of the actions of the South Vietnamese government led to more unrest and conflict, more troops and resources were committed to the conflict. However it is conceivable that if the proper analysis and investigation tools were available, US action involved the leadership may have been approached differently.

It is not claimed that any mathematical model can completely predict the actions of a culture, but if enough perturbations of the system were performed using the model, then it would probably have shown a worse case scenario could exist, where the required strength to suppress the conflict is more the than the Vietnamese culture could have withtook. Also the analyzing the effects sending of limited numbers of troops as incremental needs required, could have shown that anything less than a full commitment in a conflict of attrition would not have the desired results. Either changes in the nature of the conflict needed to occur or the type of commitment needed to change for a positive outcome to occur.

There presently is much work in the analysis community in defining the probability of events occurring and their consequences to either side[13]. The entire issue of consequences is one that can be incorporated into the dynamic systems approach. A consequence or breakpoint can be set into the causal diagram structure and followed as the system is run through one or many scenarios. Having elements be limited by constraints would allow one to see the consequences of certain actions and at what point these consequences might become a concern.

III. METHODOLOGY

3.1 Approach: The basic approach used to define the model uses systems dynamics. Most of the elements in the causal diagram that has been developed have some sort of dependency upon each other. Some variables are independent such as source supplies and resource levels which are typically uncontrollable, but when it comes to describing most aggregate level elements, for the most part the elements do not act independently.

It was stated in the introduction that the systems engineering development approach was used in the development of the model. Table 3.1 shows a more specific description of the system development steps for the model. Of the system approach to development of the model, some of the operational aspects of the system were emphasized less than the earlier development stages of the system. The operational aspects of the system life cycle were considered to be not as well defined as one would desire, but if the project were to continue towards the development of a marketable system, these aspects would have to be looked at more closely.

Table 3.1: Detailed Systems Approach to Model Development

Step	Detail
Conceptual	General Causal Diagram
Design	Detail Data, Relationships
Operations	Design for User
Phase-Out	Expected in form of Upgrade

As shown in Table 3.1 the system approach to this model development includes multiple steps. This structured method represents the approach used for most of the system, but what is not shown is that much of the important feedback within steps is many times a very important development aspect of the system.

The initial step was the conceptual development of the system. Much of the description at the start of the report through the background and the history of the system provides the basis for the conceptual development of the system. This included the definition of the scope of the system, the environment at issue and the breadth of what is going to be attempted to be quantified. Once this was completed, the more detailed aspects of the system were identified. These included preliminary requirements for data, relationships and confidence of the sources.

The second step is the preliminary design, including development, research and data acquisition. In this step, the causal diagram approach was put into the process. In these preliminary stages of development, most of the top level structure was able to be put into this format.

Detailed design is the next major step in the system development. The causal diagram approach helped this step in the development to assume a more structured flavor. In this step, the top level system that was described was formulated in a more detailed fashion with all of the data and relationships that were identified in research and analysis being incorporated into the system.

For this system, the preliminary use and testing of the system is important. When the first useable form of this system would be available, it could be allowed to be analyzed by some users or potential users to allow the feedback to be incorporated into the design. Also the incorporation of some real more accurate data would allow for more capable testing of the system.

The operational aspects are important, but for the scope of this project, this was not dealt with in any major fashion. This section of the system would include any support for the use, incorporation of user's more specific requirements, and working towards the development of improved versions of the system. Improvements along the system life cycle is a definite consideration especially from expected user's comments and more individual requirements.

Phase out is a less important factor since it is considered that the system would be replaced or altered to continue use beyond a traditional expected life as long as the user base is considered into the improvements.

The activities involved in the early development stages included defining a preliminary causal diagram, acquisition of primary data, research for data, and development of relationships between elements. Some of these activities were taking place in a parallel mode, and there were many uncertainties along the way. The uncertainties were identified and researched and some assumptions were made during the model development. The trends shown by running the model. In many of the cases where uncertainties were not resolved, features were added into the model to account for the uncertainty of a value or relationship so some factor or choice can be applied to demonstrate the more realistic aspect of that element's contribution to the system environment.

Another key part of the development of the model was that consideration was taken for a potential user's set of requirements. Although from the onset, no formal request to a user for a description of his needs was acquired to develop the system in particular fashion, nevertheless an expectation of a potential user was considered as an important aspect of the system design. Since no formal definition of a user was identified because in the early stages of the system development it was decided that the more general structure of the system would be a better approach rather than describing only one element (i.e. Strategic Systems). Since some unconventional relationships were being defined, design for a potentially large group of users was considered the best course of action. The general user was determined to be typically a battle manager or military commander who would make decisions at the resource element level of the system, i.e. Land Forces and would like to see the implications of his action. The tool's could more likely be an analyst either working for a decision maker in a crisis or conflict state or an analyst involved in projecting potential scenarios and relationships. The user would more than likely be required to incorporate data for his specific application if more correct analysis were to be performed. Most of the relationships would be acceptable as they would be designed from the expected normal interactions, but if some change in the structure or fundamental relationship were required, then the user would have to identify where his application differed and changes would need to be implemented.

Coding of the model was performed using a MacIntosh Based Application called

STELLA. This software allows the development of complex systems using the systems dynamics structures[14]. Input to the software is performed through a Graphical User Interface which represents elements, system flows and relationships between elements. There are facilities on the software for equation and data definition as well as run time tools to allow for the user to view both graphically and in tabular form, the simulation of the system under consideration. Simulation was chosen to represent the global conflict scenario for reasons including the ability to show dependance of the conflict to the time element of the battle, and the ability to have other elements such as the economic and political status interact with the military elements in a crisis over time.

It was also determined using the software that periodically as well for specific cases of interest, analysis would need to be performed to evaluate the application's integrity. During the development of the system, the model elements were run through the current model configuration to evaluate the data's consistency and the model structure's integrity. This type of development allowed for the feedback of corrections and revised requirements of the system to become more evident.

The approach taken includes many structured steps in development but also includes some less structured development. It was unknown during early development as to what deviations may be discovered in the relationships between elements. Figure 3.1 shows some details of the development approach used.

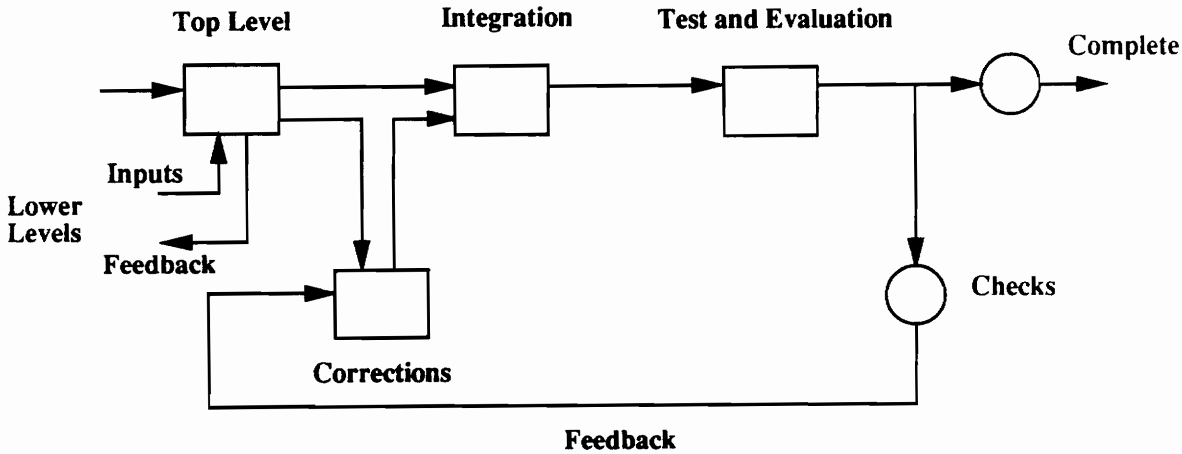


Figure 3.1: Development Approach Description

3.2 Systems Approach/Operational Life: The Systems Development approach as described in the previous section showed how the general approach to the model development was used.

The initial research incorporated much of the previous experiences of the type of models that have been created and used in the field in question. The operational aspects of the system were considered throughout development. One of the first steps of the system development was to try to put the system elements and details into a format that would be coherent as well as sensible in the context of the subject of the model. In this respect, although the project has not gone to the point where it is a fully integrated decision support system with complex graphic interfaces, the basis and foundation for this type of further extension could be supported properly if future development occurs.

The implementation of some of the user interface elements that were not included in this phase of development could occur to respond to specific user needs from those who work with the system as well as from some projected need or requirement that can be expected.

3.3 Choice of System Dynamics: As an important element in the development of the system dynamics approach of the system, the causal diagram should represent the structure defined for the system elements. The causal diagram also represents the particular relationships that were defined in the development of the system.

The specific methodology used in the system development resulted in the choice of the following set of major sections of the model shown in Table 3.2.

Table 3.2: Methodology of System Development

Key Element	Why Chosen	Alternatives
Two Sides	Bound the Project	More than two sides
Economic	Non-Military Interaction	Consider as Support
Political	Non-Military Interaction	Consider as Military C3
Military	Most Emphasis	Pure Military Model
Defense	Different Interactions	Embedded in Military
Support	Across all Elements	Possessed by Elements

One notion followed was that before any element or relationship was included in the system, the choice to include the element was reviewed. These choices were analyzed by asking why it was chosen to see if the reasoning was acceptable for inclusion. As development progressed, if other options presented themselves, the choices made up to that point were revisited and verified. Also at junctures when the system was reviewed, the results of the assumptions and conclusions made from these choices of system structure were reevaluated to see if any discrepancies existed.

The boundary of the system was considered several times and finally "placed" to include all elements which relate to a 2 sided conflict or crisis scenario down to an aggregate level of resources in terms of details. The environment which the boundary of the system was in, includes obviously the earth and its resources. The time frame of the system was also an important aspect of the system environment. This scope of the project may include more detail in some areas than others and potentially some shortfalls in detail in other areas. The remainder of what are called major elements are described in more detail in the annex to this report but were chosen after consideration to how each effects the bounded system.

The particular procedure in creating the causal structure for the key elements is shown in Figure 3.2 below. The development approach has similar steps to that of the general system development methodology. One important aspect in the development of the causal diagram is the ability to use constant feedback in the STELLA software.

The step of the definition of the elements that effect the workings of the causal diagram. In the systems approach to system development, this part of the development approach of the system would be performed in preliminary design phase. The identification of these elements allows the system to be defined to a level where development could occur.

Step by Step Description of Causal Diagram Development

Element Aspects		System Aspects
○	Define Element	
○	Describe Element	
○	Quantify	
○	Define Element Relationships to Other Elements Integrate Element into System	
○	Test Revised System	○
○	Check Flows and Data Integrity	
○	Interim Causal Diagram Structure	
○	Recheck Entire Structure	○
○	Complete Project	○

Figure 3.2: Step by Step Description of Causal Diagram Development

Figure 3.3 shows the general level of data and the scope of the project as it relates to building of the system structure.

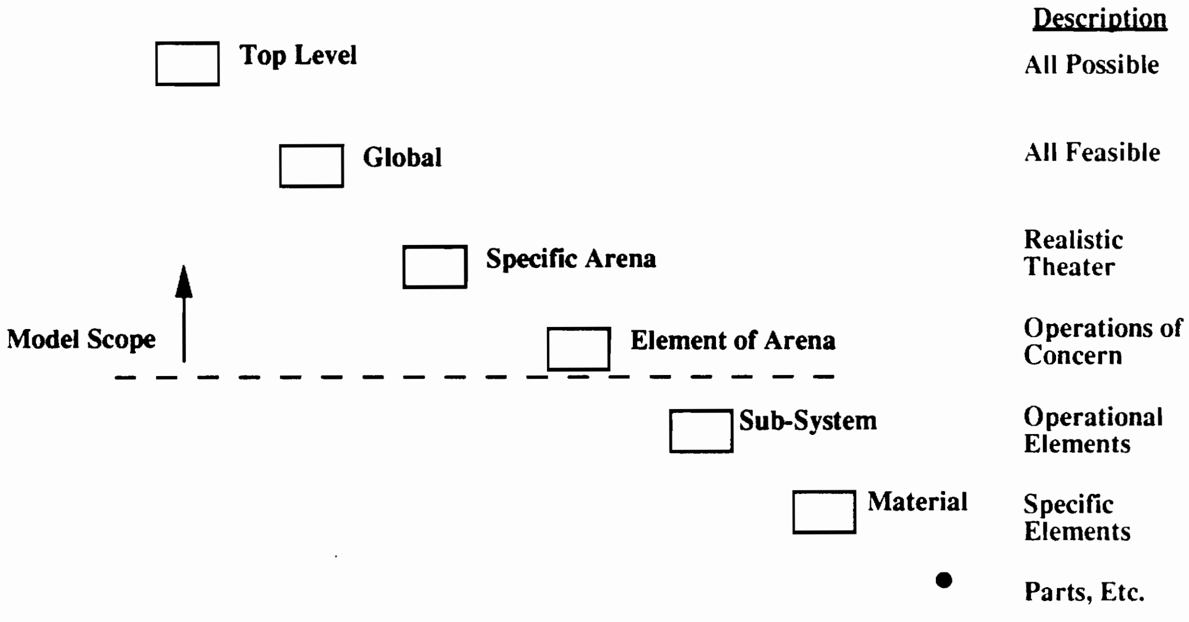


Figure 3.3 Addressing Different Levels of Detail in One System

The second step would be to describe the elements for use in system. In this step it was discovered whether or not any other element in the system is performing the same or part of the same function. Detailed design would take form to allow data and research to be applied to the system. The quantification of the system occurs by use of research and analysis to put a value or function to an element.

Using information gathered by the completion of the previous step, each element was put into the system. The next steps are used to test and verify the application of the elements to the system.

Interactions of the elements of the system were built into the causal diagram. Many of the military interactions took the form of directly affecting the level of the opposing side and attrition through some conflict. Figure 3.4 shows a notional structure that many of these element's relationships followed.

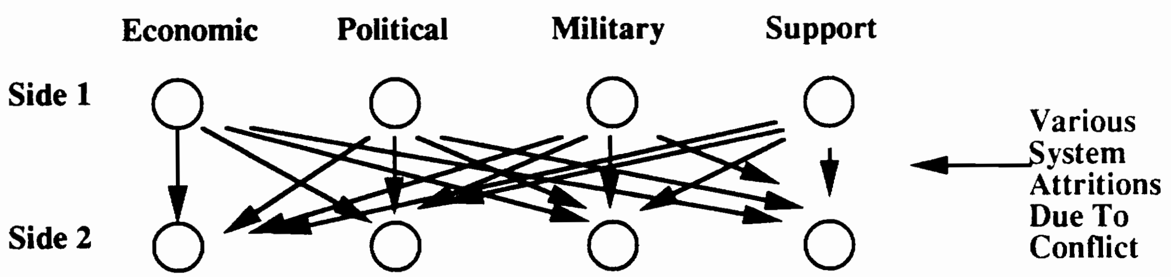


Figure 3.4 Basic Conceptual Model Structure

3.4 Causal Diagram Structure: The causal diagram structure is shown in Figure 3.5. This is not the entire causal diagram which is shown in the report's annex, but is a condensed representation which shows more of a top level type of breakdown of the system.

The top levels of the system are primarily aggregate levels of resources or other measures which comprise various lower level elements of resources as well as effectiveness and conversion factors to relate them into the overall causal diagram structure. For an example of a more detailed portion of the causal diagram see Figure 3.6. In this figure the same generic structure is shown, but the level of functionality of the elements is at a lower level than the top level shown in Figure 3.5.

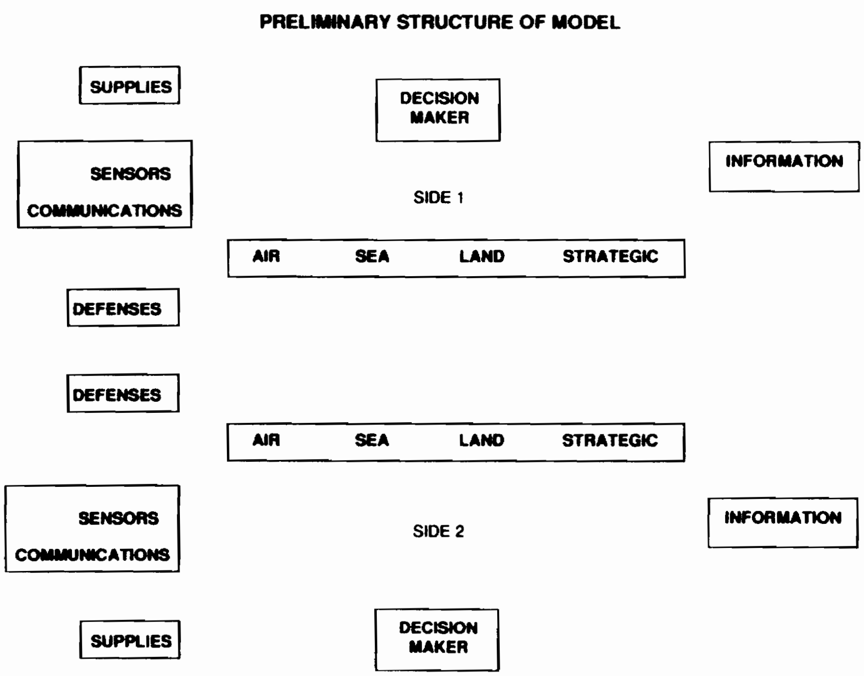


Figure 3.5: Top Level Causal Diagram

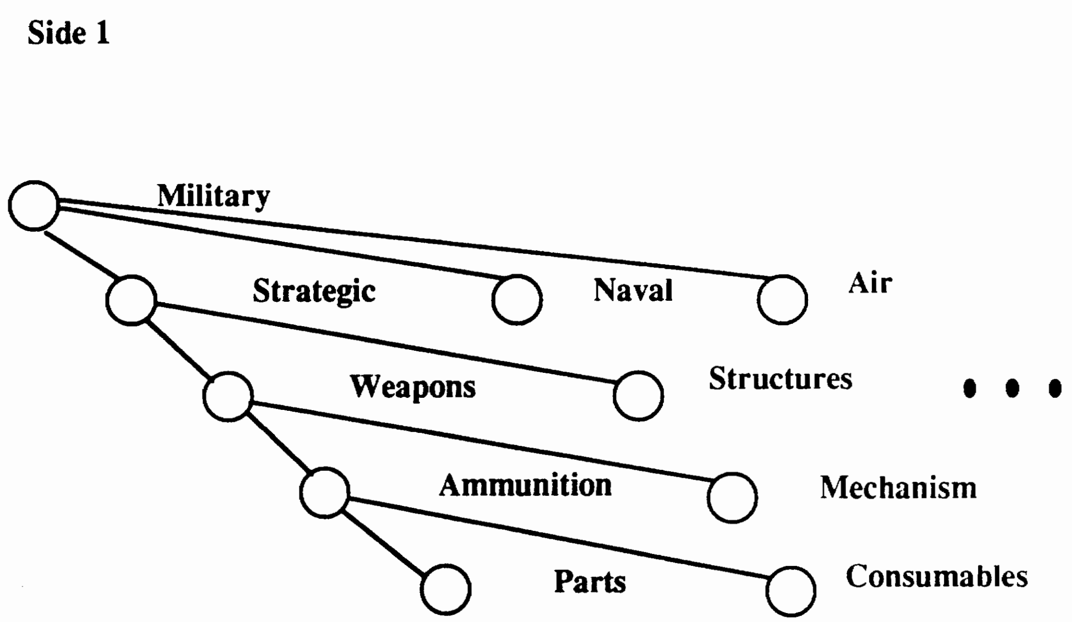


Figure 3.6: Lower Level Causal Diagram Example

The level of detail shown in Figure 3.6 is that which is available through research, testing or other means. The causal diagram structure used to describe the scenario does not model to this level of detail. As will be discussed in the future potential development of the system, extension of the model to include this level of detail would be considered an important improvement if any future upgrades would be considered.

The causal diagram includes many traditional feedback loops as well as some descriptive cause and effect paths. In particular, when the effects of a use of military force is shown on economic levels, the factors shown include inputs from many of the other elements, yet if more than one is influencing the stability of the scenario, research can show that one of the feedback could dominate.

3.5 Basic Equations: Each element shown in the causal diagram has some relationship to the other elements of the system. Except for constants, the variability of the elements within the system can describe any changes of interest. The military attrition structures as well as basic supply and demand relationships are based on some basic mathematical concepts for the system. Figure 3.7 shows the generalized attrition relationship that was used in the development of the system.

NUM = NUMo + dt(INCREASE - DECREASE)

INCREASE = SUM(INCREASE)

DECREASE = SUM(DECREASE)

Figure 3.7: Some Primary Relationships

The first equation simply represents the basis behind many of the conflict scenarios. The level of the element labeled NUM, increases by incoming resources and decreases by outgoing resources. The incoming resources and outgoing resources can be constant or related to other elements of defined system. The "dt" represents the time step considered in the model. The choice of the time step would be left to the user depending on his requirements for run time and accuracy. For the analysis shown in this report, the "dt" used was that of 1 week. This was chosen so that some significant effects on the levels of elements could be seen while running the notional cases.

Implications of this dt are important to understand for each of the major elements of the system. The top level measures and global analysis typically can use a longer "dt" for analysis. With a lower level analysis involved the more basic elements of the system, a smaller "dt" could be used to assure proper modeling and understanding of the detailed flows.

Beyond the basic relationship shown, there are other more complex relationships that exist to describe the attrition relationships. Section 6 of the appendix shows the equations that describe all of the relationships that were used in the system.

Some interesting cases which utilize the alternate mathematical approaches are the damage calculations which are based on expected values of attrition due to the randomness of success and failure of an attacking system. Defensive systems are based on confidence and specific distributions to describe their actions against attacks. For defensive systems the actual distribution or operational effects of the weapons are dependant on the scenario and the employment.

The damage calculations and defensive system effectiveness were systems which were modeled using some analytical approach. Other systems such as the political and economic elements rely on historical data and observable occurrences to model their activities in the real world. In the causal diagram, the major elements are represented as resources who level changes over time. There are also various factors, including effectiveness of the weapons, defense capabilities, allocation of forces and constant factors. The resources are shown to have inputs and outputs.

3.6 Data Flow: One of the most critical parts of creating a system that would model real world scenarios would be to allow some for credibility to be seen in the system structure by using accepted data flow over elements.

The initial steps of defining data requirements and acquiring the data includes the step of converting the data into a format which allows for its placement into the integrated causal diagram system structure. This step allowed for the dimensional structuring of the data and provided a check into the integrity of the system. The list of equations is provided in section 7 of the appendix.

To describe the flow of the data through the model, the causal diagram was found to be the most logical method. The connectors used between elements and resources in the causal diagram worked out to be the descriptors of data flows present through the elements. Conversion factors and dimensional factors were used to place the data of the system into a form so that it can be applied globally.

The initial data was acquired during the research into the system. The baseline case is a notional present day case and deviations dependant on the scenario desired could change it. Some basic element resource data was considered to be the most stable and independent of the case chosen. For the future scenarios under consideration, the model could use projections and other forecasting model runs to define the data. Some forecasting could be used to determine the data in future times, but it was understood that the later in time of the projection, the less confidence of the data integrity.

Figure 3.8 shows a basic top level data flow contained in the model. The general data elements shown in Figure 3.8 are assumed to have under their level of aggregation much of the total data contained in the system.

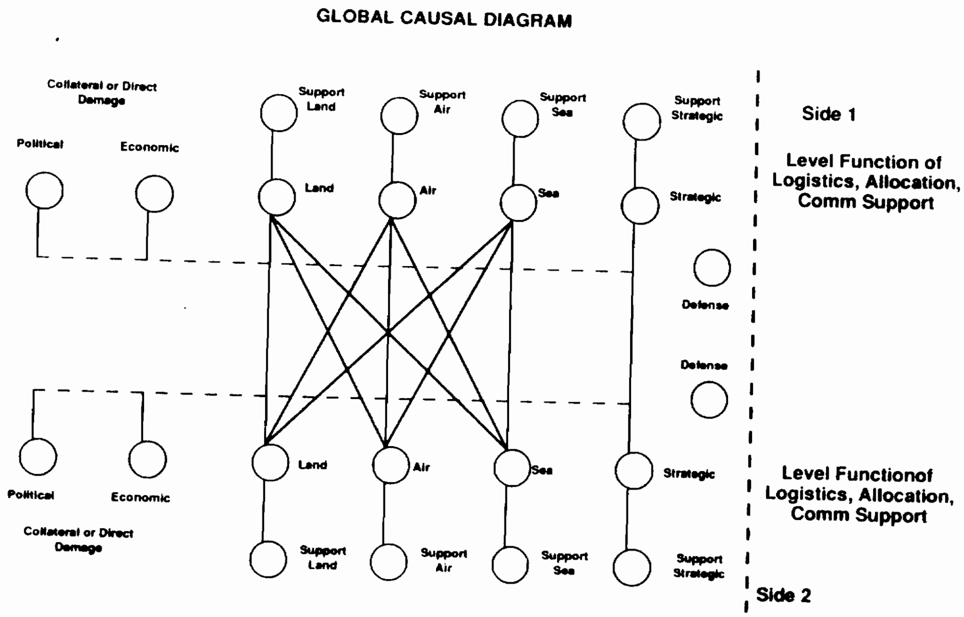


Figure 3.8: Basic Data Structure and Flows

3.7 Sections of System: In the element definition, it should be understood that they must function somehow within the model structure of the system. As explained in the main body of text, the system is broken down into several main sections for purposes of defining the system's variable types of elements as well as facilitating the decision process.

Side 1	**Political**	**Civilian Defense**	**Land Forces**	**Sea Forces**	**Communications**
	Economic	**Military Defense**	**Air Forces**	**Strategic Forces**	**Logistics**
Side 2	**Political**	**Civilian Defense**	**Land Forces**	**Sea Forces**	**Communications**
	Economic	**Military Defense**	**Air Forces**	**Strategic Forces**	**Logistics**

Figure 3.9: Sections of the System

Figure 3.9 shows the breakout of the system into sections. These sections were considered separately as unique aggregate elements of the model that would exist in the causal structure.

3.8 Variables: The development and definition of variables assumed the structure of the system is that of a defined structured system. This structured approach helped to identify and categorize the variables and constants required for the definition of the system.

An important aspect of the variables in their structure are classified at different levels of importance. These variables are described in Table 3.3 and are shown in general terms. The level or relative importance of the variable is described by the designation number.

Table 3.3: Variable Structure

LEVEL	ELEMENT TYPE	DESCRIPTION
1	SIDE	TWO SIDES
1.1	FUNCTION	(OFFENSIVE...
1.1.1	SUB FUNCTION	(LAND,SEA,AIR...
1.1.1.1	SYSTEM	(ARMORED..
1.1.1.1.1	SUBSYSTEM	(TANK,MEN..
1.1.1.1.1.1	ELEMENT	(AMMO,PARTS,..
1.1.1.1.1.1.1	SUB-ELEMENT	(PART OF ELEMENT
1.1.1.1.1.1.1.1	RESOURCE	(BASIC ELEMENT..

This breakout of variables is categorical, one which can interrelate any level of variable with any other. The causal diagram for the project shows that sometimes any of the variables from any other may follow unexpected paths.

The variables were developed from a functional sense. Most of the top level of the system structure as functionally based. For variables that are in the lower level structure, they are less functionally based and describe more in terms of specific elements which have for the most part been used to identify the top level structure.

From Table 3.3's description of variables, the first level "Side" is easily described to be at a global level. For this system, there are 2 sides used, (the US and USSR). Understandably if the system were to become more complex it could include many more sides, countries, affiliations and other opposing elements.

The variables described as functions are described as the major elements of possessed and controlled by the side as example Military forces, Economic Forces, etc.

Sub Functional variables are elements of military forces that operate in a different format and can be considered to be different in capabilities and relationships.

A description of the System elements are functionally operative elements such as naval offensive forces, tank forces, etc.

Sub-systems in this model are the major elements that define the system. For instance, the individual tanks and weapons are considered at this level.

Elements are the major functional parts of the sub-systems and subelements are the parts of the elements that may be controlled by some decision maker in the chain.

The Basic element is the resource such as fuel, power, etc. that is required for the support of the higher level systems.

IV. MODEL

4.1 Model Description: Up to this point, the emphasis has been on the development aspects and representation of the model. Results from the development of the causal diagram structure will be discussed at this point. For helping the explanation of the goals and scope, Figure 4.1 shows a top level structure.

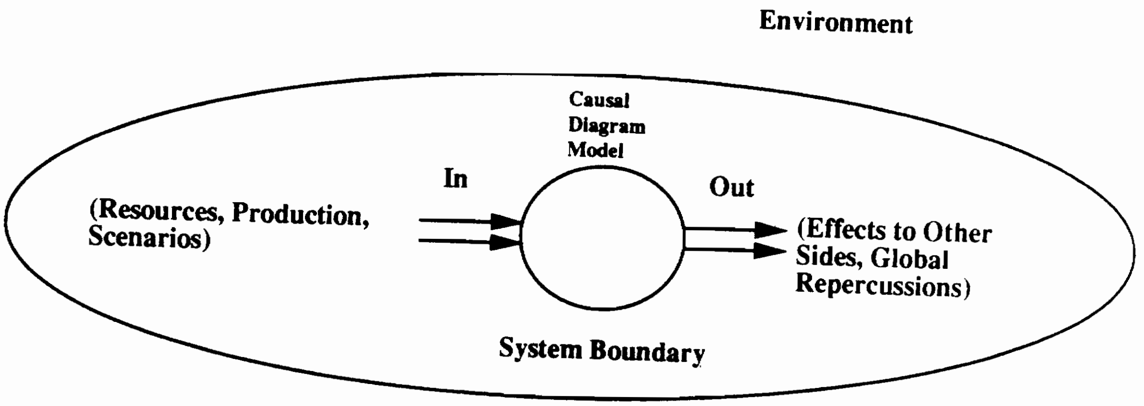


Figure 4.1: Structure of Model

To help to understand the workings of the model, one may consider that the use of the systems dynamics method of model development allows for the model to represent, over time the interrelationships of the elements. The initial state can represent a user desired world state without conflict or preceding a crisis. The state is important in defining the activities and rates of the elements in attrition and in the increase in the level of resources. As time progresses, the elements considered important can be watched to see if their level changes during conflict, due to attrition from the various causes. Critical shortfalls should be seen during the running of the model. These shortfalls can be used to identify the key lessons created from the system.

Each major element of the model can be broken down into a more detailed level. The modular approach to the development and application of parts of the model was used to make the development more manageable and the integration more understandable to a user that might have expertise in only one or two of the model's modules. Each development module has a definite substructure that is used in the development approach. Figure 4.2 shows the somewhat generic application of the element structure to each module of the system.

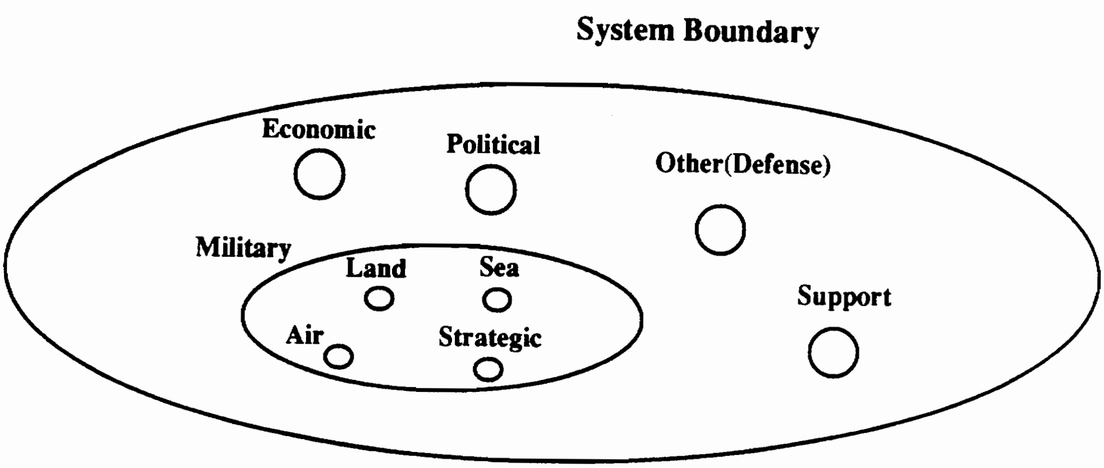


Figure 4.2: Modular Structure of Model Elements

4.2 Key Elements: In defining a system which tries to quantify entire national systems or structures, some aggregation is required. When aggregating complex systems to describe them in simpler terms, some assumptions must be made. These assumptions are in three major forms, actual data, mathematical relationships and projection of system structures. Some of the approximations make possible, good modeling of the real system while others only succeed partially in terms of modeling the actual physical activities and operations. The information in Table 4.1 takes elements of the basic model structure and shows key areas for each and some of the potential implications to the model's accuracy and consistency.

Table 4.1: Key Model Elements

Elements	Aggregation Level	Source
Military	# Effective Divisions	Summation of Forces
Economic	Dollar Value	Current $ and Growth
Political	Stability Level	Historical Levels
Support	# Divisions Supported	Summation of Support

One major form of the assumptions is that of constraints on the system. Through research, some of the relationships have limitations placed on them that define their values. These constraints are important in trying to understand the level of modeling required for modeling. With the use of pure mathematical relationships were used, potentially uncontrollable values for some of the variables could come to exist. As an example, if in the case of attrition of an element, in the real world scenario, the decision maker would most likely withdraw the element if the attrition of that element reached a value below a lowest acceptable threshold[17]. Another example is the uncontrollable growth of elements. Some of the elements are supplied as though they might be attrited at a certain rate due to an opposing force. If the element's attrition was based on probabalistic relationships, there would be some small chance that very few of that element would be attrited while the logistics system of that side would still be supplying the element at an expected rate. For this not to continue unbounded, the levels of this element must be constrained so that it did not exist in such a quantity that would not be realistic.

4.3 Combination of the Model Sections: All of the portions of the system discussed as comprising the project were combined. The following Figure 4.3 shows the various elements of the system structure. In the global structure considered, none of the major sections that comprise the model act completely independent. All of the military, support, economic and political sections that define a global scenario are effected by at least some portion from the rest of the world. In the aggregate model developed, all of the sections were described as being affected by almost all of the other sections of the system. This includes attrition from the opposing side's weapons, and effects of the economic and political status of each side. In the model, interactions between resources within each side, are mostly described as economically driven functions. The limitation of resources due to economic constraints provide for the effects of limiting one type of weapon for the investment in some other weapon or support function.

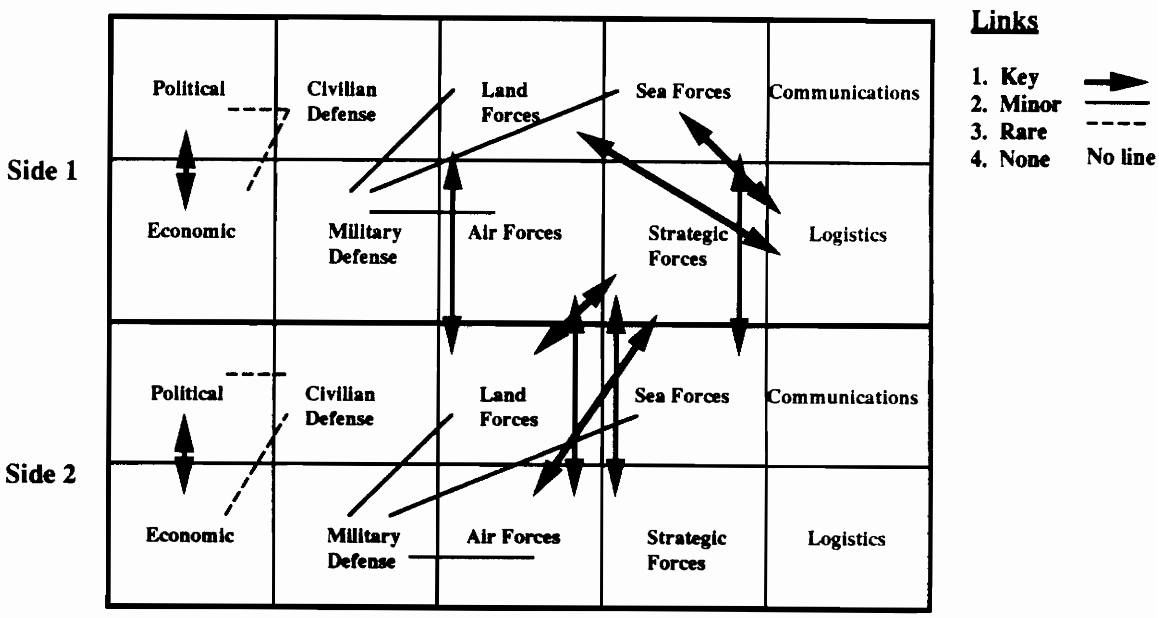


Figure 4.3: Diagram for Modules Interactions of the System

In Figure 4.3, note the "1. Key 2. Minor 3. Rare 4. No" interactions that exist between elements. These values for the interaction representations of the system elements are based on the research and expected interactions based on the scenario in question. Only some of the interactions are shown, the true matrix of interactions as seen in the causal diagram is much more prolific.

4.4 Analysis: This section describes the analysis portion of the project. There was analysis used to build the model. In this, the relationships of the model were analyzed. This took the form of researching and testing the mathematical relationships between elements to check on feasibility and accuracy. As stated earlier, the software model, STELLA allowed for the analysis of the model at preliminary states before completion. This allowed for trials of the various sections of the model as well as corrections along the way.

The reasoning for some of analysis was to demonstrate the use of the model as well as gain insight as to some of the potential capabilities of the structure that was developed. The other aspect would be the ability to find weaknesses and identify any areas that would need to be improved and evaluated further.

For purposes of this project, a few runs were made with the model. These runs ranged from very short top level runs to test the model and sensitivity runs to demonstrate the use of the model to find the behavior of one particular element in a scenario. The runs were performed using a set of notional data input for the system elements. The STELLA model is such that it will not run if any of the elements values and interrelationships are not completely defined so that he model had to include some form of all of the required data. The runs were performed for a total of 26 time steps. The calculations were performed by the model using the Euler[18] method of calculation for each time step. The two major types of runs were the ones with a battle ongoing and one where a non conflict crisis exists. Several runs were performed under the same scenario, but different types of elements and variables were viewed to determine their activity during the run.

Output from the analysis considered shown above is typified by the following set of charts in Figure 4.4 below which show the typical outputs and relationships with the Strategic forces section of the system variables over time.

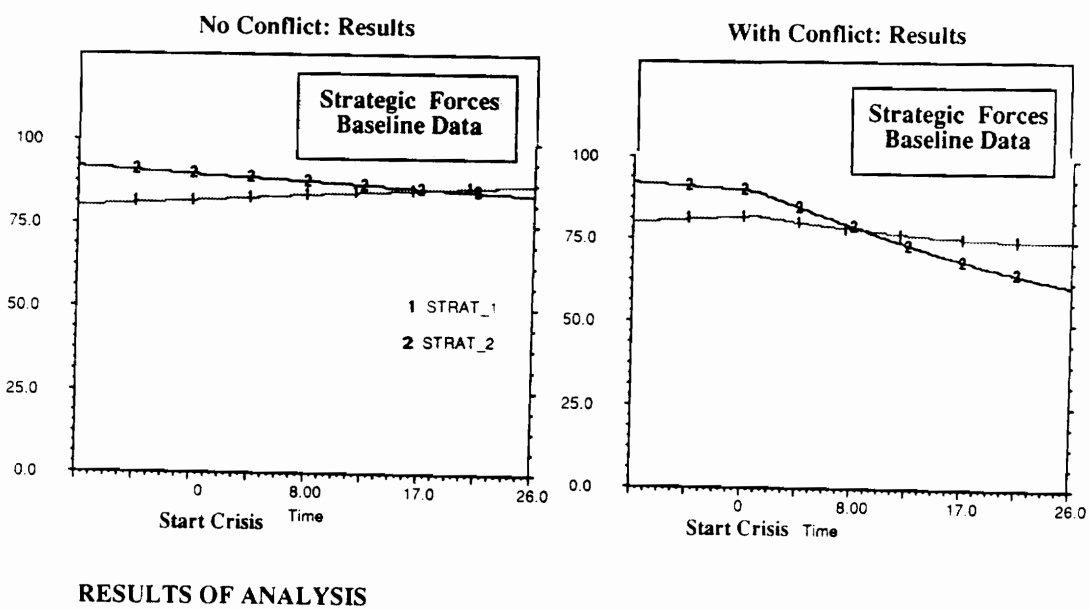


Figure 4.4 Analysis Output From System For Strategic Elements

To demonstrate potential some analysis using the model, the following charts show the characteristics of the Strategic elements of the system, when some perturbations are made to the basic data structure.

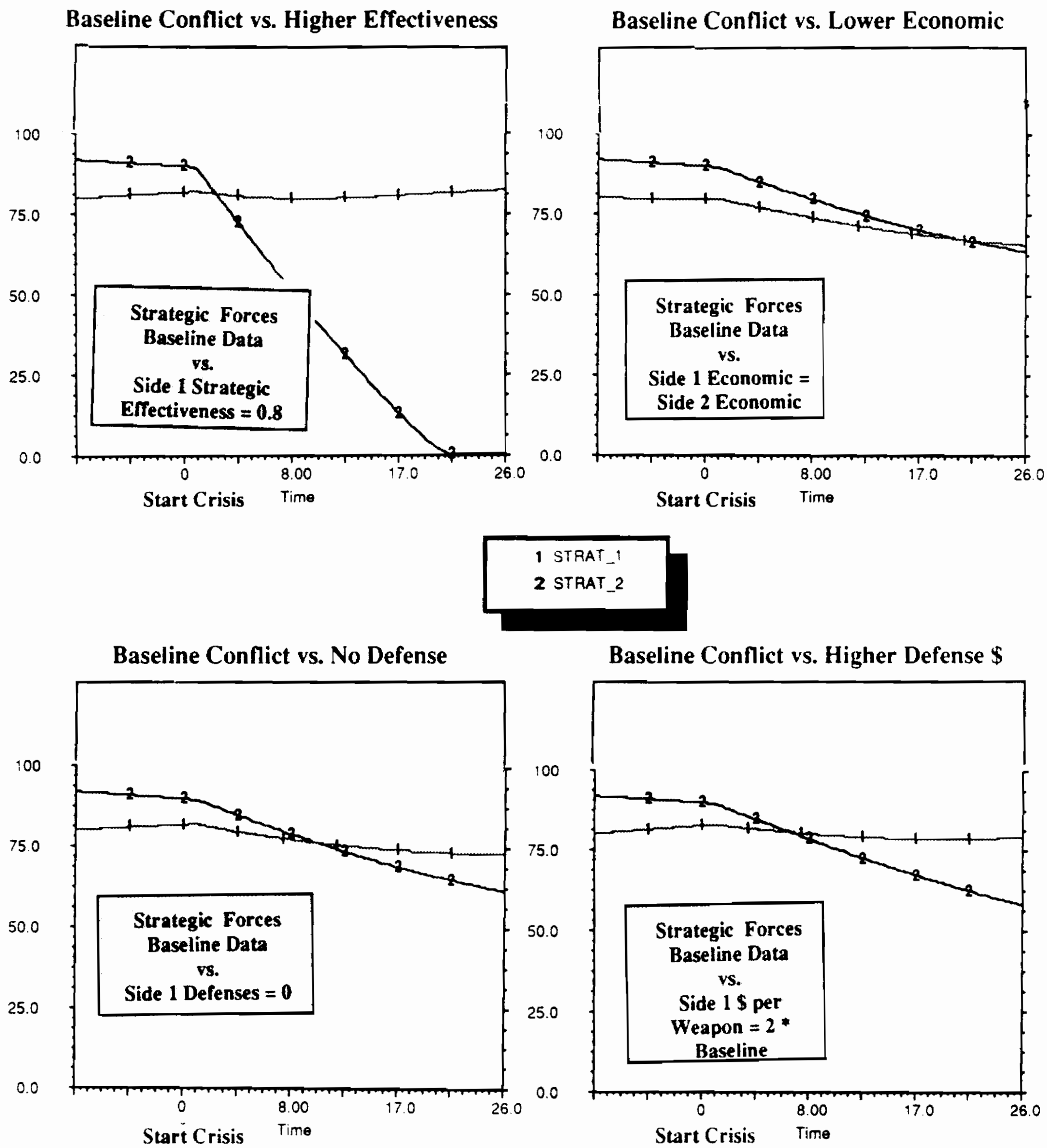


Figure 4.4a: Level of Strategic Elements With Changes in Scenarios

4.5 Economic/Production Section Results: A section of the system under consideration is the economic/production section of a side, including replacement capabilities of the military systems involved. Figure 4.5 shows the general structure of the Economic/Production section of the system used in the causal diagram for both sides.

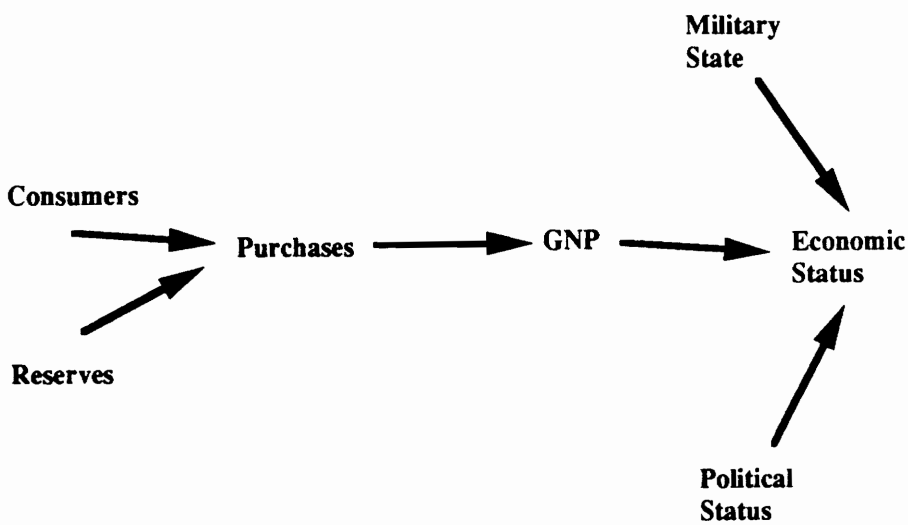


Figure 4.5: Description of the Economic/Production Elements of the System

The complete model was run and some of the results are shown in Figure 4.6. The graphic shown in this figure shows the level of the Economic status of side 1 in the case of a conflict and without a conflict. The levels seen show how the total dollars that represent the economic level act over time. The line shown as a minimum level would be set by a planner who would view a dip below this required level as an undesirable event.

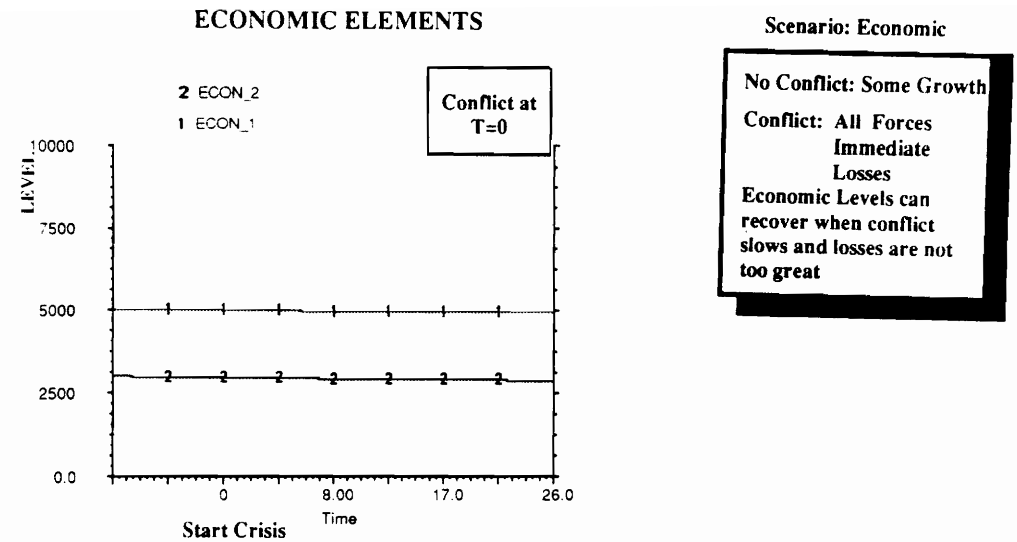


Figure 4.6: Results Describing the Economic Section of the System

Providing very detailed information regarding the economic system for the entire status of a side is beyond the scope of the project. However some parts of the economic status and effects for both sides must be incorporated to model interrelationships of the elements of the system.

4.6 Political Section: Another section of the system under consideration is the political status, especially in the form of a stability level. This structure takes into consideration the interrelations from the other basic elements to show a combined effect on other elements at a higher level. Figure 4.7 shows the general form for this political section.

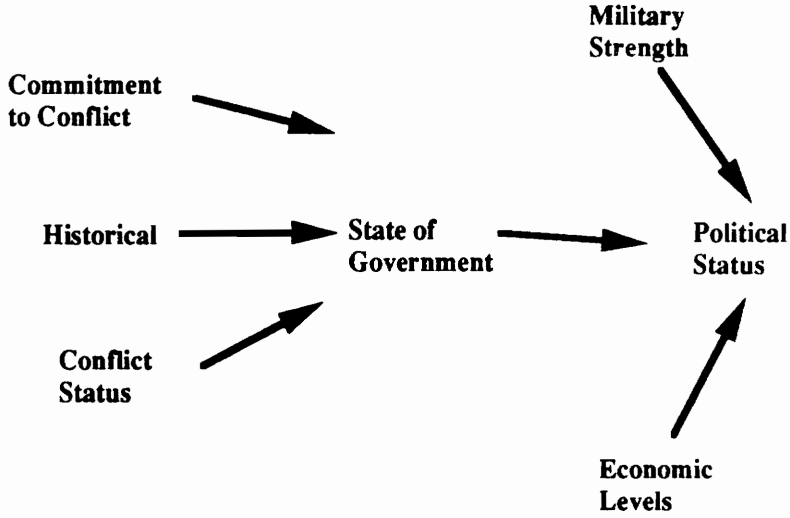
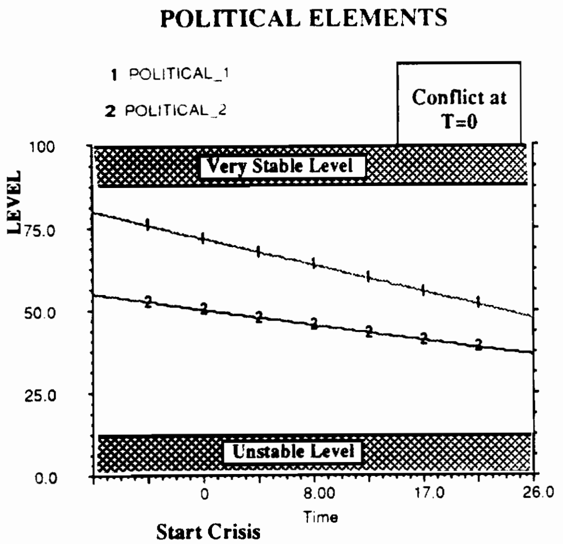


Figure 4.7: Description of the Political Elements of the System

The sample analysis for the system includes only this political portion of the model and how the interactions exist between this element and the rest of the system. Figure 4.8 shows graphically how the political state of the side exists and interacts along with a graphical portrayal of the effects of integration on this section.



Scenario: Political

No Conflict: Remains somewhat constant

Conflict: More Unstable due to conflict

The Stability of Side 1 is secure even with a conflict, Side 2 tend to be closer towards instability

Figure 4.8: Results from the Political Section of System

4.7 Military Forces Section: This section describes the military relationships used to describe the system in the model. It is described by six separate areas that show the major military elements as well as some support elements of the system. These sections as noted previously are the Air Forces, the Land Forces, the Sea Forces, the Strategic Forces, the Defenses and the Support elements.

Air Forces: One major section of the system under consideration is the Air Forces status, as well as support of the military systems involved. The general structure is shown in Figure 4.9.

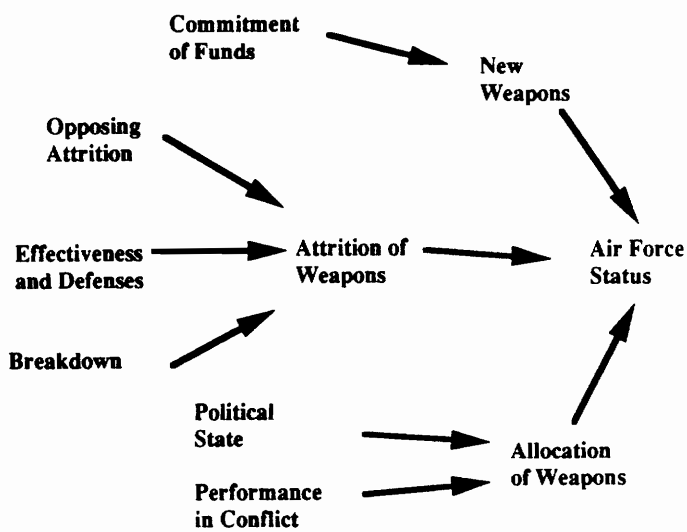


Figure 4.9: Description of the Air Force Elements of the System

Results of some analysis describing the activity of the Air Forces is shown in the following Figure 4.10.

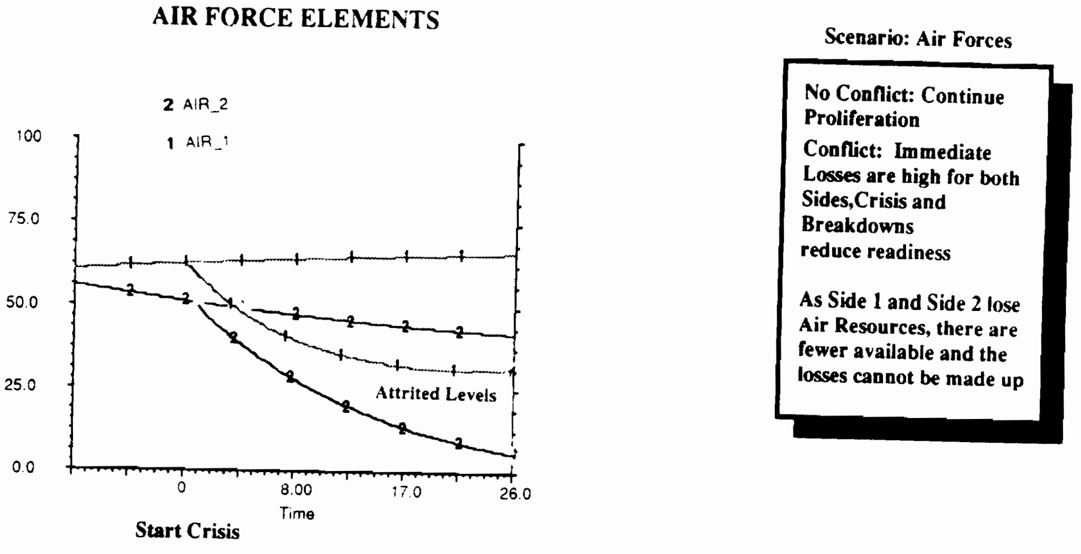


Figure 4.10: Results for the Air Forces Section of System

Land Based Forces: Another military section in the system is the one that describes the Land Based Forces. The Figure 4.11 shows a general structure for the land forces that was used in the model.

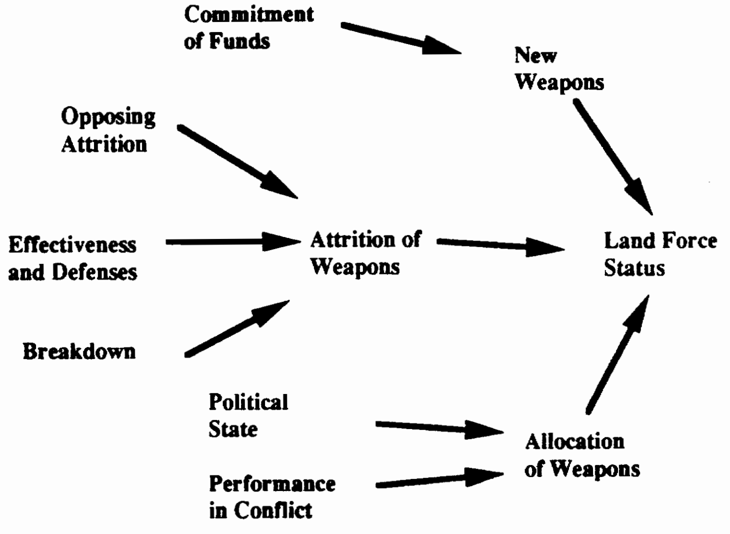


Figure 4.11: Description of the Land Based Forces of the System

Figure 4.12 shows graphically how the land based forces of the side exists and interacts along with a graphical portrayal of the effects of integration on this section.

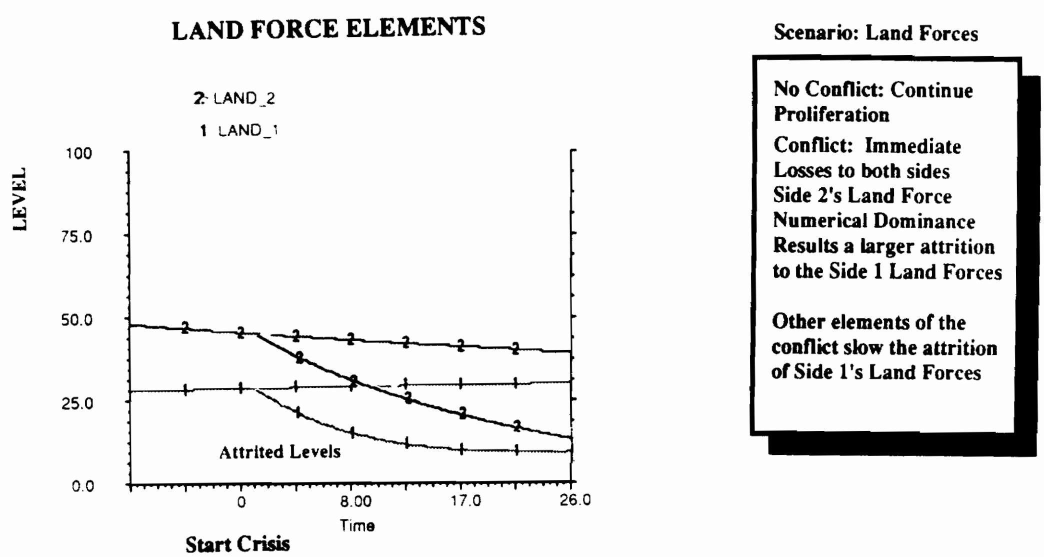


Figure 4.12: Results from the Land Based Forces Section of System

Sea Forces: Figure 4.13 shows the structure of the Sea Forces of the system. Figure 4.14 shows some exemplar results from the model of the Sea Force section of system.

Figure 4.13: Description of the Sea Based Forces Elements of the System

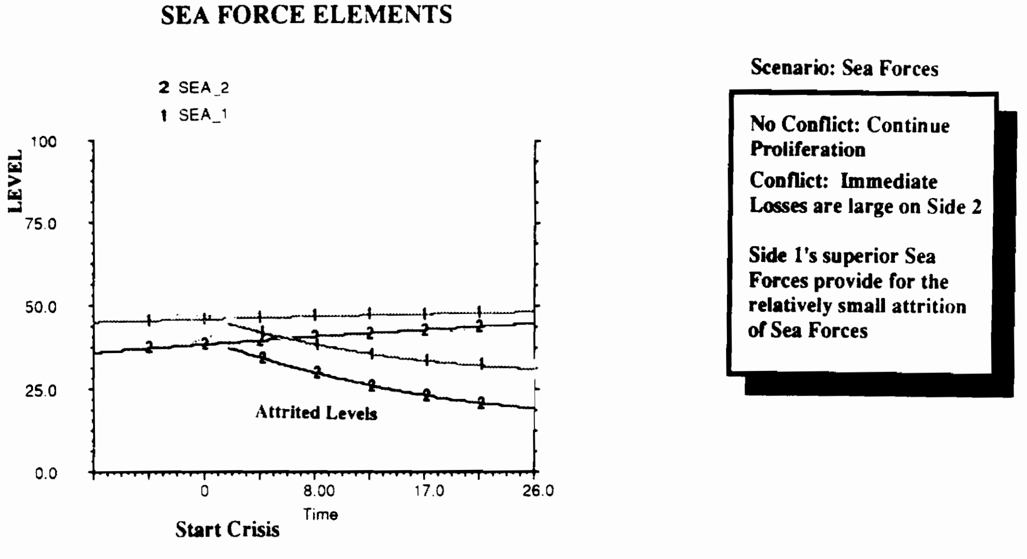


Figure 4.14: Results from the Sea Based Forces Section of System

Strategic Forces: Figure 4.15 shows the structure of the Strategic Forces of the system. Figure 4.16 shows some exemplar results from the model of the Strategic Force section of system.

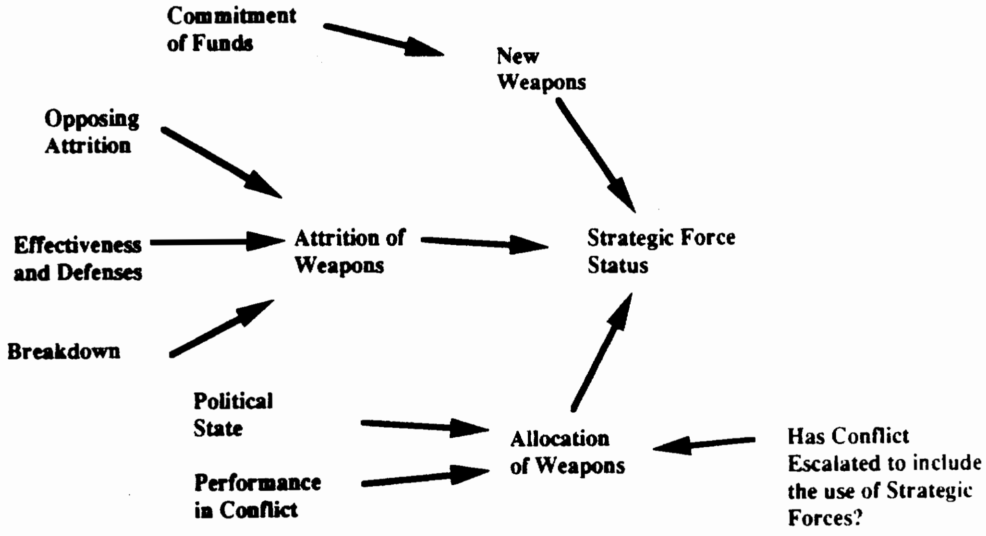
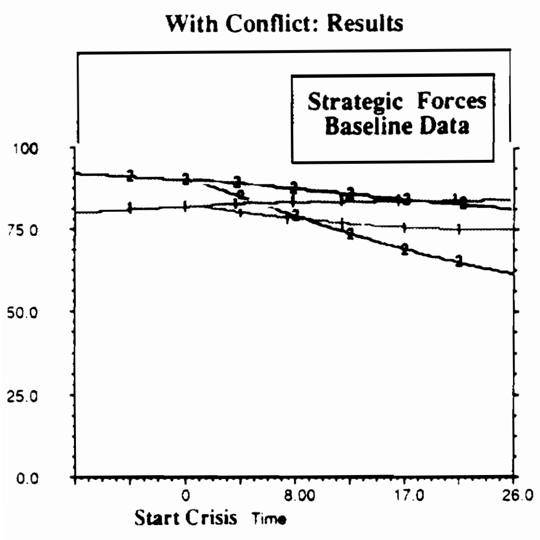


Figure 4.15: Description of the Strategic Force Elements of the System



Scenario: Strategic Forces

No Conflict: Continue Proliferation

Conflict: Immediate Losses far from threshold

The characteristics of the Strategic Forces are such that they are survivable and add to stability of both sides so they are not all expended

There are still enough Strategic Force Elements on each side to deter the other side

Figure 4.16: Results form the Strategic Force Section of System

Support Functions: Each of the military force structures and elements described above have their specific support elements as well as shared ones that can be described by the following two categories.

Communications Functions: The model handles all of the support elements possessed by each side as resources. One key resource as it relates to military conflict is the communication sections. Figure 4.17 shows the basic structure of the C3 elements of a side. Figure 4.18 shows some exemplar results of the level of these elements.

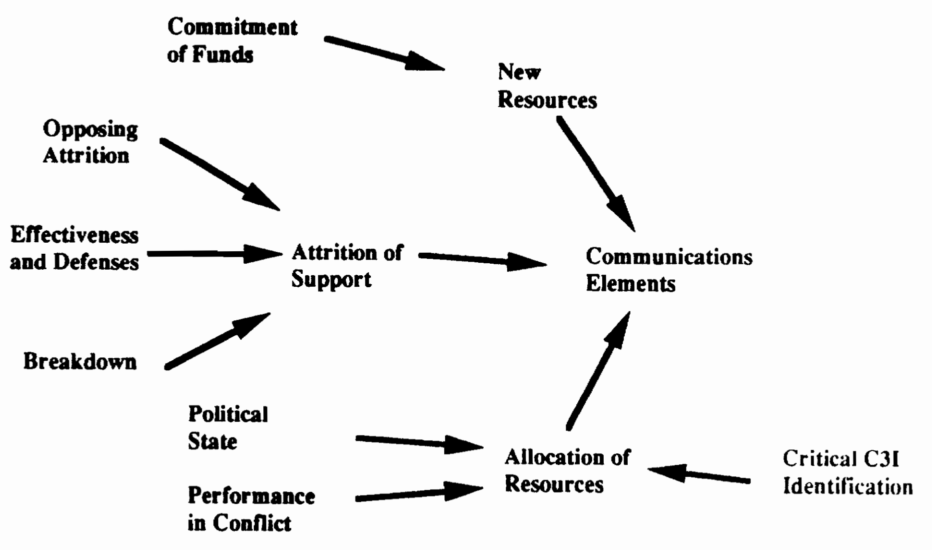


Figure 4.17: Description of the Communications Elements of the System

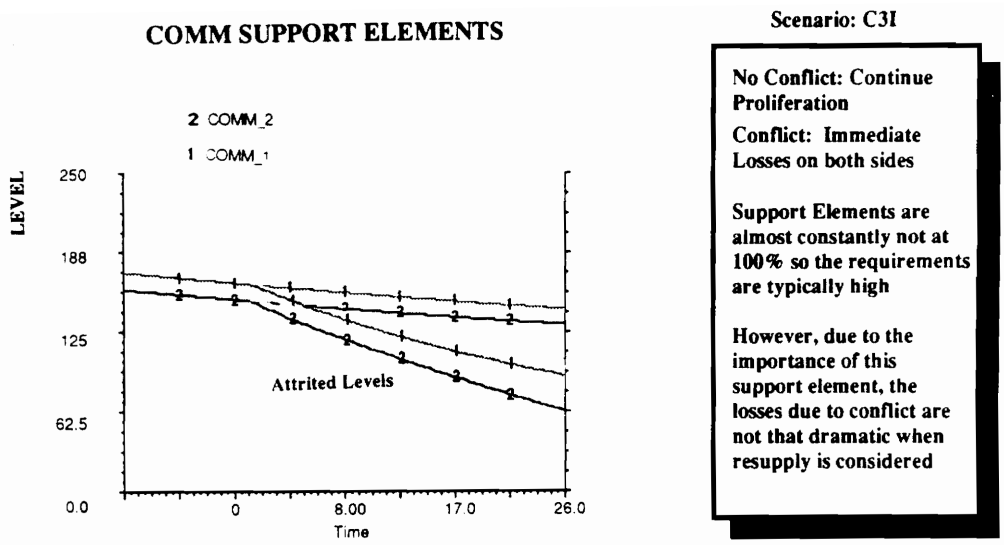


Figure 4.18: Results from the Communications Section of System

Logistics Functions: Another support function considered is the logistics. This section is supposed to represent all of the material supply available to one side. Figure 4.19 shows the general structure of the logistics support elements. Figure 4.20 shows some exemplar results.

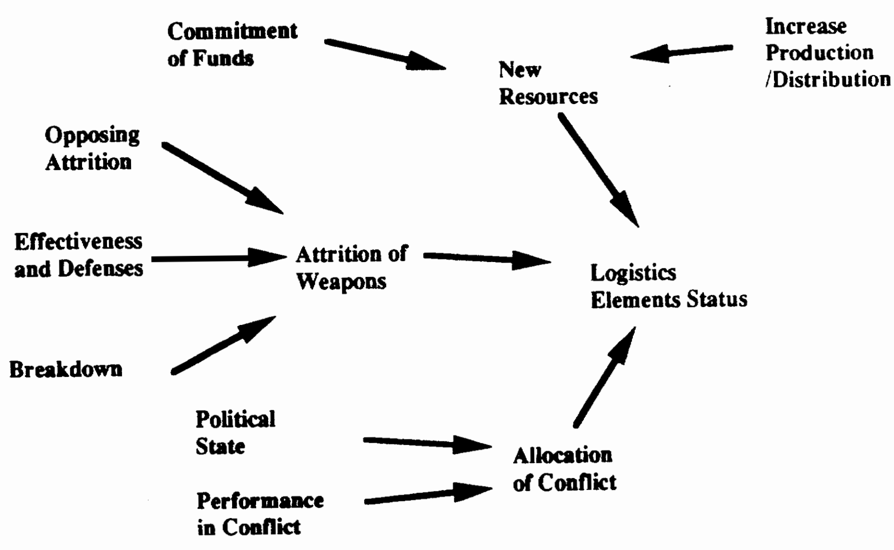


Figure 4.19: Description of the Logistics Elements of the System

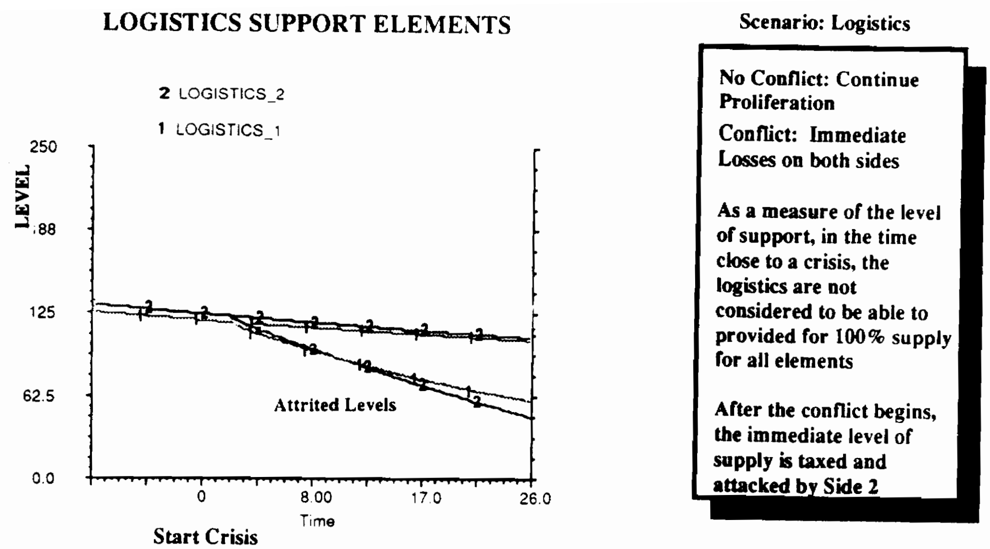


Figure 4.20: Results of Logistics Section of System

Defense Functions: The last section of the model that will be described in this section is that of the defense elements of each side. For the example case provided in the model and analysis performed for this report, defenses were considered to be an integral part of both side's forces. Figure 4.21 shows the general structure of these defense forces. Figure 4.22 shows some sample results describing the level of defenses in the given scenario.

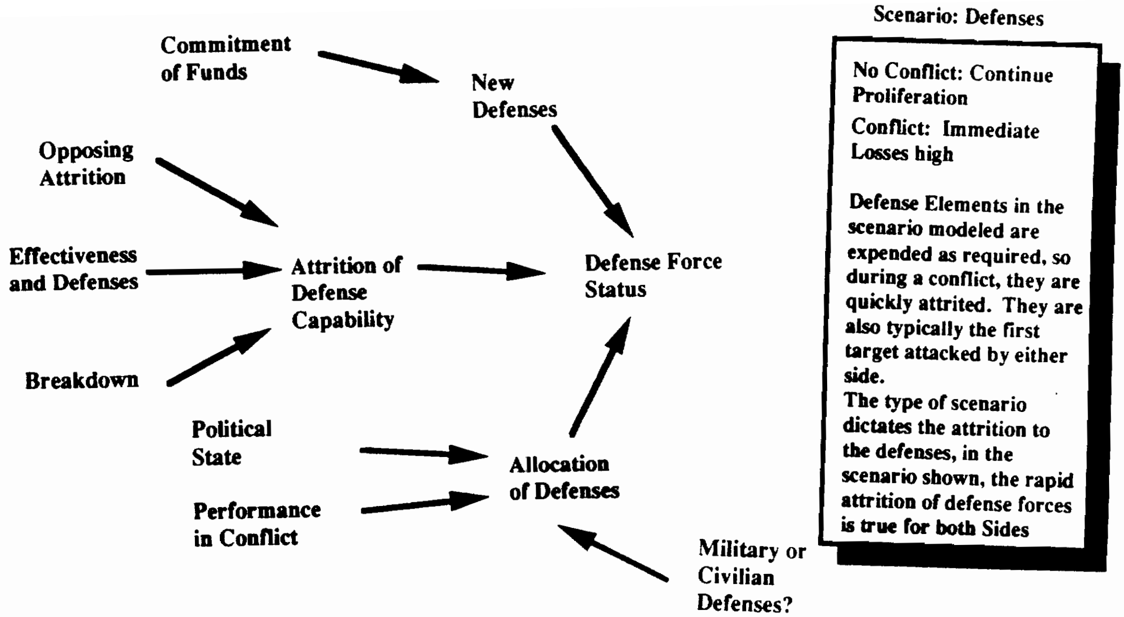


Figure 4.21: Description of the Defense Elements of the System

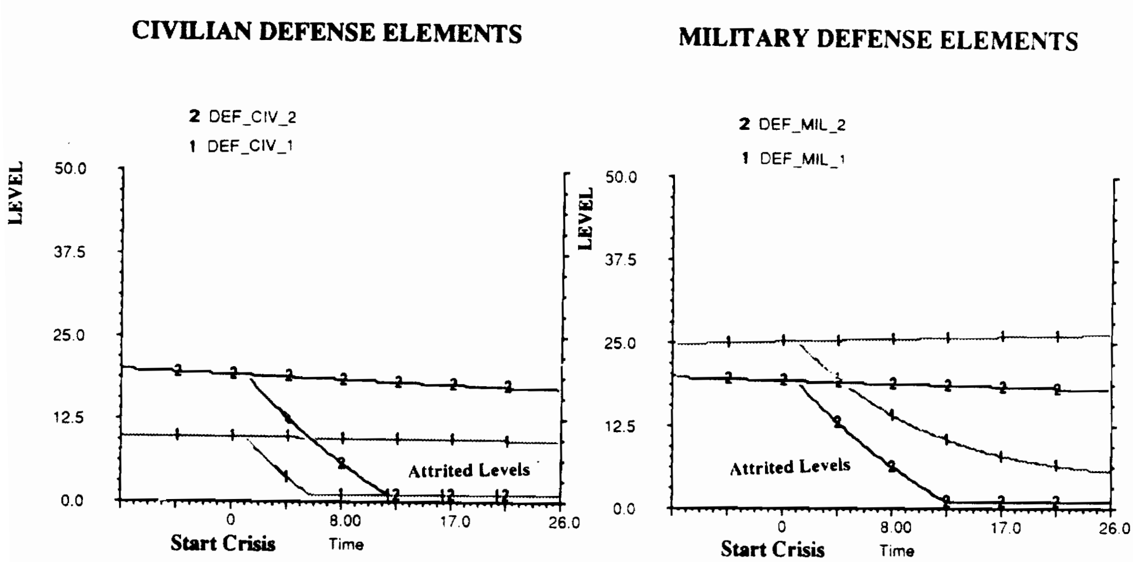


Figure 4.22: Results of Defense Section of System

4.8 User's Interface: Since the system would be eventually expected to act as a model to be used by a battle manager or analyst potentially as a decision support system, the user's interface must be taken into consideration. This means simplification my be important in terms of providing enough sophistication to allow the more expert user access to detailed data he may desire.

In terms of the model development, the variable and system structure are designed to be understood by someone with some knowledge of the scenario and not necessarily versed in computer programming language but rather in terms of names that relate to the physical systems being modeled. The interactions are written in the simplest terms to describe the proper relationships of the elements. The model when running has several interfaces. The causal diagram allows one to see the relative interactions of the system. The "Table" screen allows the user to see in a tabular form any of the elements' behavior over time. The "Graphs" screen allows the ability to graphically portray any trends of the elements as desired. Figure 4.23 shows some examples of the model interfaces.

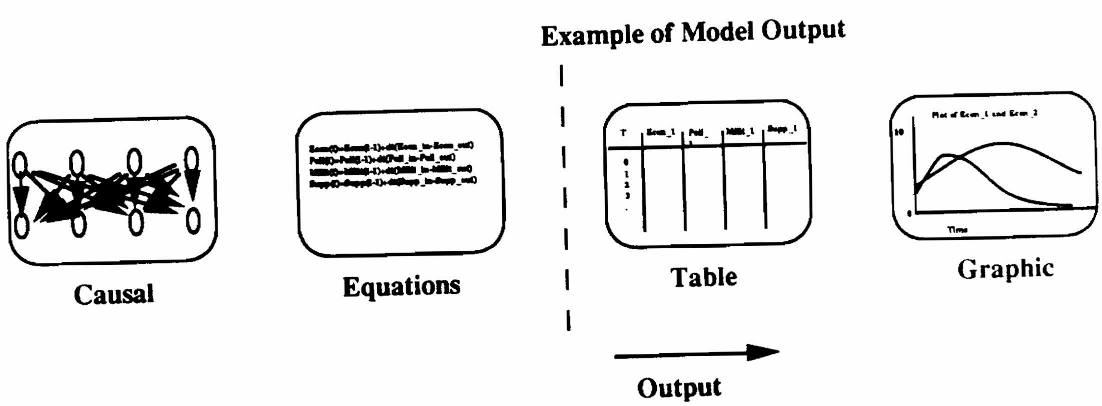


Figure 4.23: Example Screens of Model Interface

Table 4.2: User's Approach to System Elements

SYSTEM ELEMENT	USER INTERFACE
Economic	What-if Analysis to see effect
Political	See the effect on other elements
Military	Analysis and attrition due to conflict
Support	See how much support is required in scenarios

Information shown in Table 4.2 is geared towards an analyst's view of the model. In this case where the analyst is the user, the model's structure is somewhat different than what may be required by other users. If the user is described as one who would require an actual real time user and decision maker interfaces, the more in terms of user friendly interfaces must be incorporated. As the model structure stands now, it's user interface is sufficient to support an analyst who is familiar with the system causal structure and the variables. If the system were to be used by a decision maker who was not familiar with the causal structure and variables behind the system then some accommodations would need to be made such as the use of more user related data descriptions, menus and other input means for the system. Table 4.3 shows how the different level of users have varied requirements.

Table 4.3: Requirements for Various Users

TYPE OF USER	NEED	OUTPUT REQUIRED
Analyst	Data and results	Values over time
Decision Maker	Particular Data	Several Value
Policy Advisor	General Trends	Graphic Trends
Military Commander	Real Time Data	Single Value

The modular structure of the system has as a benefit to the user the fact that they might only wish to work with one side, section or even one variable. More research would need to be done on a case to case basis to determine the level of detail required by specific users.

V. DISCUSSION

5.1 Sensitivities: The approach taken and system structure brought out some interesting sensitivities in the modeling of the system. In particular, since some elements were aggregated much more than others elements, it was of key importance that these were more precisely described. However, the data required to integrate a largely hypothetical quantitative element into a mathematical model cannot be relied on for perfect integrity[19]. Some of the lessons learned from an exercise to find the critical elements is that to have more confidence in results and the model, more detail would be needed. The extra detail could improve the realism of the descriptions of the key elements of the system but would increase the run time and possibly complicate the model to an unacceptable level for a potential user. The introduction of more detail could also result in having one section of the model provide more resolution and data to the remainder of the model.

The actual use of the model is deemed acceptable in terms of run time and hardware and software requirements. Figure 5.1 shows the computer run time for the case indicated on the equipment shown.

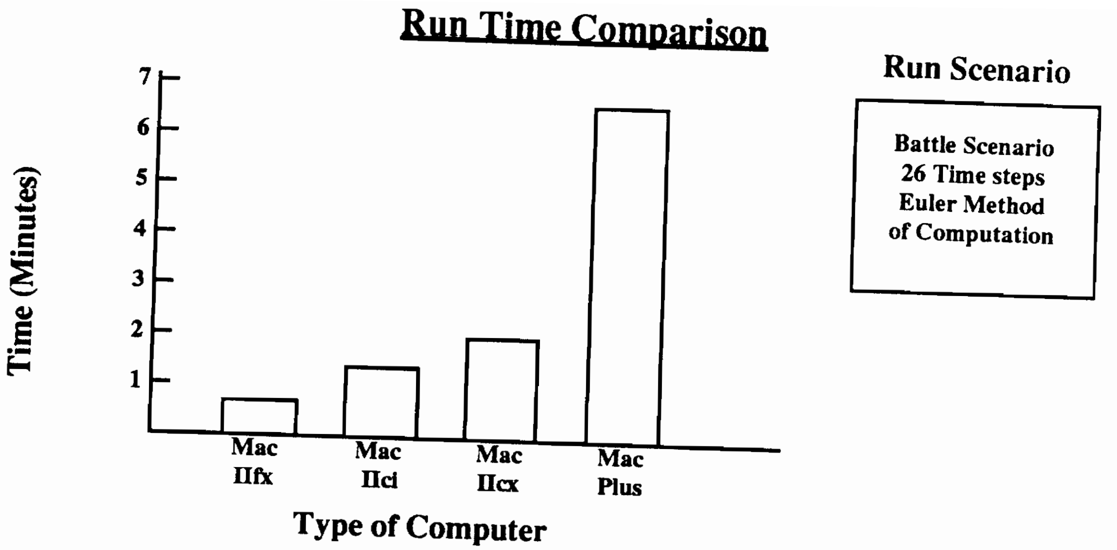


Figure 5.1: Run Time For Various Hardware Systems[20]

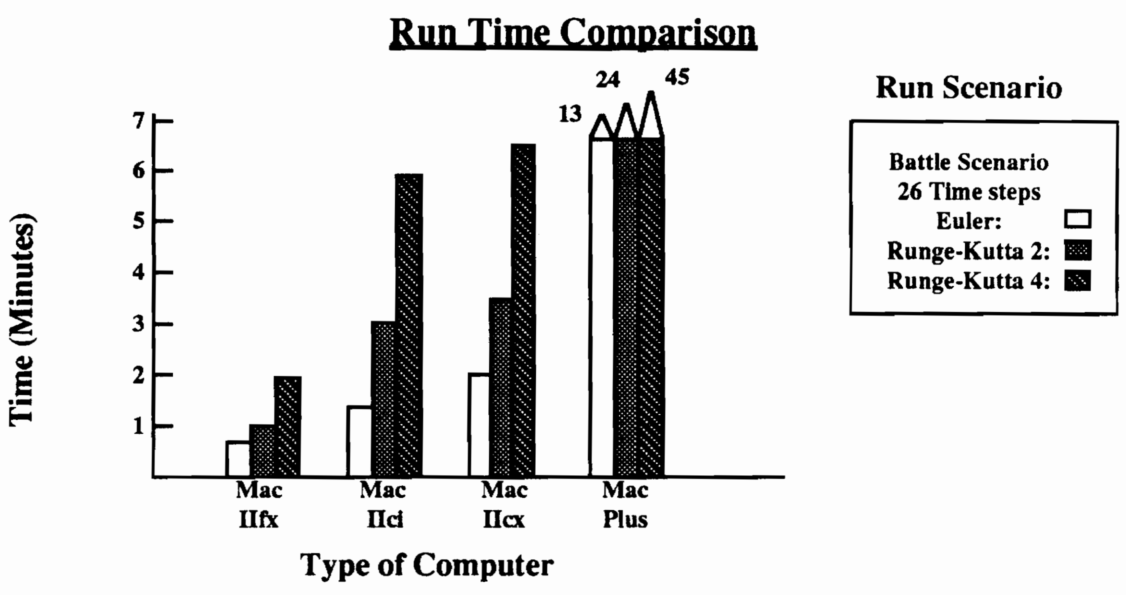


Figure 5.2: Effect of Various Calculation Methods on Run Time[21]

5.2 Future Considerations: Some of the potential future improvements to the system have been discussed throughout the text. But some of the more obvious ones would be to improve the accuracy and breadth of the database for the model. Verification of the mathematical relationships of the model and development of new relationships as required would also be a key step in the next phase of improvement of the model. All of these improvements would have to be evaluated in terms of costs and benefits in the form described in general in Table 5.1.

Table 5.1: Improvements and Expected Costs

Improvement	**Need**	**Cost**
More Detail	Analyst's Need	1/2 LOE
More than "2" Sides	Scenario Revision	1/2 LOE
Accurate Relationships	Research	1/2 LOE
Expert System	Decision Maker Need	2 LOE

The costs shown in Table 5.1 is measured in relation to the amount of time that was required to create the system in the form that it appears in this project. As an example, the 1/2 Level of Effort (LOE) to provide more detail to the model meaning about 2 months of research and implementation time would be needed. The impetus to change would primarily come from users who would evaluate the model and make recommendations to define their needs and preferences. This type of user evaluation could provide invaluable information to the developer as to the best path to proceed on if a future extended user base would be desired. Using computer software which currently exists such as the STELLA Stack, more responsive interfaces could be developed.

In terms of financial benefits of the system, if one were to interest a DOD client that was concerned with analyzing future US strategy and its consequences in some real or projected environments, a payback could be seen if further effort were undertaken to improve the model. With proper financial backing, a custom software package could be created so that STELLA specific elements that appear in the model in its present format, do not appear in an improved format.

While one may be able to think of many improvements to the system, some of the most important would appear to be:

1. The ability to use real time data. This would require processing and data input mechanisms sufficient to support this abbreviated timelines. This type of improvement would be helpful when thinking of the system as a decision support system for a field commander.
2. A major effort to the system if it were ever implemented would be the update of the data and relationships of the model as research, change in structure and revisions of forces required.

VI. CONCLUSIONS

Conclusions: The conclusions are summarized as follows:

Conclusions for Project

1. In the development of the project, it was determined that the attempt to model a global scenario with a potential conflict state is major undertaking.

2. A limit to the level of detail of the model is required to produce a first phase of the overall system. Initially, the model was intended to provide very detailed information along with top level information. Upon completion it was evident that the top level of detail was the primary emphasis of the effort with the more detailed level providing support for these values.

3. The system that was developed in its final format appeared to be very general in format. Side 1 and Side 2 of the system, are similar, the interactions are identical and much of the data is shared. This was purposely done, so that a generic "n" sided system could be developed and used.

4. Results provide insight into the characteristics of the attrition of elements. The analysis performed shows that this type of model would be helpful in

comparing the effects of scenarios to certain perturbations and to compare the levels of elements under these circumstances.

5. The resulting structure in its aggregate level is considered a building block for a more detailed or more specific system based on the need of the user and the availability of data and relationships descriptions. Specific applications for the model include its use for strategic planners and arms control analysts where some quantification of global levels of forces is important. Analysis needs to be performed by legislative elements regarding the implications of budgetary decisions on the general military capabilities of a nation. The trends provided by the model could be used in the long range planning of defense planners and by those who structure forces.

Recommendations: The recommendations that come from the project are as follows:

Recommendations for Project

1. The system structure should be expanded to include more detailed variables into the causal diagram structure. Doing this could increase the user base by showing the global implications of a particular weapons system or element.

2. The user's requirements should be identified and upgraded to the system should include specific implementation of these user's interfaces. The intended users might not be interested in the entire model structure and this customization may increase acceptability of the model by reducing number of variables available.

3. Depending on the scenario that needs to be modeled, further research should be undertaken to update the data and relationships that exist in the system. For instance, databases describing the element values for different scenarios should be developed and used to calibrate the model.

4. Identify which parts of the element interactions could be customized to ensure applicability to specific scenarios. By not including elements that do not affect a certain scenario, more efficiency can be gained by using a customized version.

5. If the system is intended to be used with other models and tools, proper data utilization must be considered as an improvement. In particular, if other models are providing more detailed attrition calculations, then the global model presented in this project should accommodate the data that could be available to it.

VII. SUMMARY

7.1 Summary: The initial undertaking was to develop an integrated system model to describe as much of the world environment as possible while maintained as many details as would interest various types of users. To accomplish this, some of the structure had to be simplified. In this simplification, a certain amount of aggregation was performed. As a result, not only the model and corresponding causal diagram was developed, but also a methodology using a systems approach to develop and integrate model elements describing various systems in the real world.

The user for this type of system was determined to be one of the major drivers of the development of the system. The user's environment would determine the scenario as well as the level of detail required in the model.

Overall, the project personally helped my understanding of how difficult it is to quantify real systems, elements and scenarios of the world. In particular, modeling future scenarios where many different elements are effecting each other, is of vast importance, and often times many of the interactions are overlooked in reality. Everyday, some cause and effect relationships that were not considered end up causing unexpected circumstances to occur. In this approach, aggregation of elements was seen as a solution to the problem of trying to quantify many detailed elements for integration into a top level model for analysis. Hopefully approaches such as the one developed in this project can help further in the understanding of real life situations.

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19. Soviet Military Power, Prospects for Change, DOD, USA, 1989

19. The data used in the model was notional, designed to demonstrate the model's use and capabilities.

20. STELLA Software Manual, Richmond, Vescuso, Peterson. High Performance Systems (Euler Method 1.) Calculate initial values 2.) Calculate flows for t+1 3.) Update Resource Levels 4.) Recalculate flows 5.) Repeat steps 1 - 4 for all time steps)

21. STELLA Software Manual, Richmond, Vescuso, Peterson. High Performance Systems (See 20. for Euler Method, For Runge-Kutta 2nd Order 1.) Calculate initial values 2.) find two estimated values for the level of the flows for t+frac*1 3.) Use a weighted value of flows from these two values and 4.) Recalculate Resource Levels 5.) Continue steps 1 - 4 for all time steps, For Runge-Kutta 4th Order use the steps as in Runge-Kutta 2nd Order but use 4 estimates of the flows for their values at t+frac*1 and use this weighted average to complete step 3 for the new value of the resources. The Runge-Kutta methods allow for accuracy on the order of 10^3 better than the simple Euler methodology which does not take into account the rate of change of the flows.)

APPENDIX:

TECHNICAL ANNEX AND USER'S MANUAL

1. INTRODUCTION

1.1 This supplementary section of the document shall serve the purpose of showing much of the detail behind the project. These details include a description of the data used in the development of the model and system structure. Listings of the variables and relationships used in the causal approach of the project as well as some details of the mathematics of the system are also included.

The development of the project was described in the main document. Diagrams will be presented in this section showing the causal diagram development approach as well as illustrative diagrams that define the fundamental principles.

The computer code of the model in the form of a list of equations is presented in this document as well as a user's guide with some examples of the analysis and runs performed for code evaluation and sensitivity purposes.

Some detailed steps of system development and user information relevant to the system will be provided to help in understanding of the project's design and function. Also, examples of the screens and user interfaces as well as outputs from the model will be provided with details on the causal diagram structure and data flow.

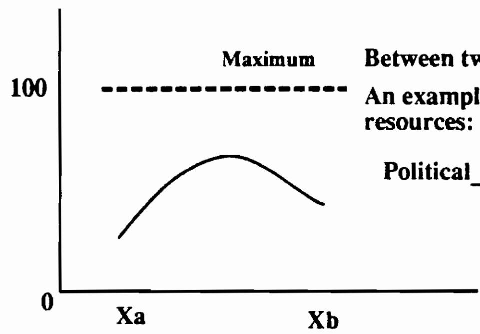
Some runs from the program will be provided in detail as well as results from assumptions made in the progression of the model development. The amount of data provided in this document reflects a level of analysis and research described in the main body of the text. The data involved in the development of the system has been captured in some form in this approach.

2. QUANTIFICATION OF VARIABLES

2.1 Variable Definition: The variables that comprise the system can take many possible forms. The various possible types of variables depends on the type of system or element. For instance, if the element is identified as a military offensive system engaged in a hostile environment, some sort of a continuous attrition function is a relevant function as defined by previous study.

For all of the types of variables, it is important to remember and consider the dimensional integrity of the variables. For the model to work properly, the dimensions of the variables must be considered. See section 7 of the appendix which lists and describes all of the variables in the model. Especially the notionally described variables which have to have dimensional integrity with other unrelated variables in the system.

The Notional Status type of variable takes some arbitrary range and values the variable someplace within these bounds. For convenience, a value between 0 to 100 is typically taken. The variable is meant to act within this range. Figure 2.1 shows an example of this type of variable.



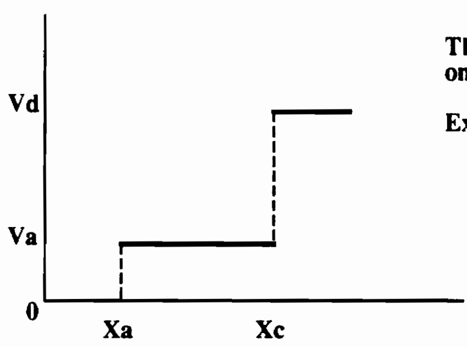
Between two input values the function is on or off

An example from the model is the ability to draw from resources:

Political_1

Figure 2.1: Notional Status Variable

The logical variable in this system is used when a element has influence which is either on or off. These variables are binary and either have one value or another. Figure 2.2 shows an example of a Logical variable.

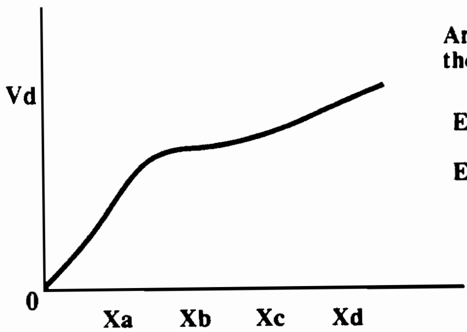


The value of the function varies discretely depending on the input variable

Example: Battle or Conflict Flag

Figure 2.2: Logical Variable

Continuous functions describe variables which act continuously in some form within a range specified. Some functions can be partially continuous. In these cases they can be described as continuous or whatever they are within their respective ranges. Figure 2.3 shows an example of a continuous variable.



An example of a continuous function in the project includes the attrition of the weapons, the use of resources, Etc.

Example:

Economic Resources, Air, Sea, Land Forces

Figure 2.3: Continuous Variable

Discrete functions can describe variables which can be most easily defined by databases of which the models can refer to. These variables can be described by estimations, graphs or lookup tables of data. Figure 2.4 shows an example of this type of variable.

Variable 1	Variable 2	Variable 3	Variable i	Value

Some functions are best described by tabular format

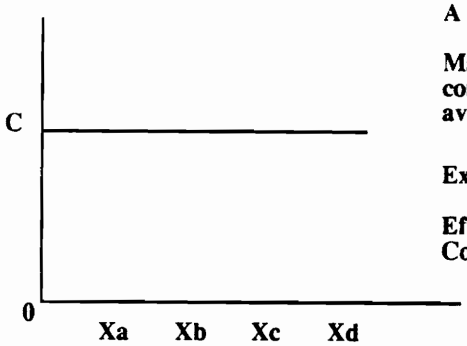
Example:

Allocation of Forces

Allocation of Defenses

Figure 2.4: Discrete Variables

Constants are the simplest variables contained in this model. These variables stay the same throughout the scenario that is under investigation. It can be true that the variable can change its value in some circumstances but as long as within the boundaries and environments required the variable keeps constant then it is considered a constant valued element. Figure 2.5 shows an example of a constant value element.



A common type of function is the constant function

Many of the functions in the model were identified as constant particularly those base on physical actions and availability of some of the resources

Example:

Effectiveness Factors
Costs over a fixed period

Figure 2.5: Constant Element

Other characteristics of elements may include combined functions which are composed of various aspects of the types of variables described above. Some variables may be complex, but the majority of actual values used in the model may be linear or constant and therefore handled in a simpler form.

3. USER'S INFORMATION

3.1 Interfaces: The eventual use of this system was identified in the background and introduction of the project. This description was general and this section will attempt to show approaches used to support user's needs in more detail. These needs will be identified and the appropriate interface from the model will be identified.

Some of the key interface means for the system include software screens, data, etc. Screen examples are shown in Figure 3.1. Figure 3.2 shows the very top level graphical environment, where the two different side's elements are placed on different portions of the model's causal diagram workspace. Figures 3.1 through 3.5 show examples of the various interfaces that exist with the model.

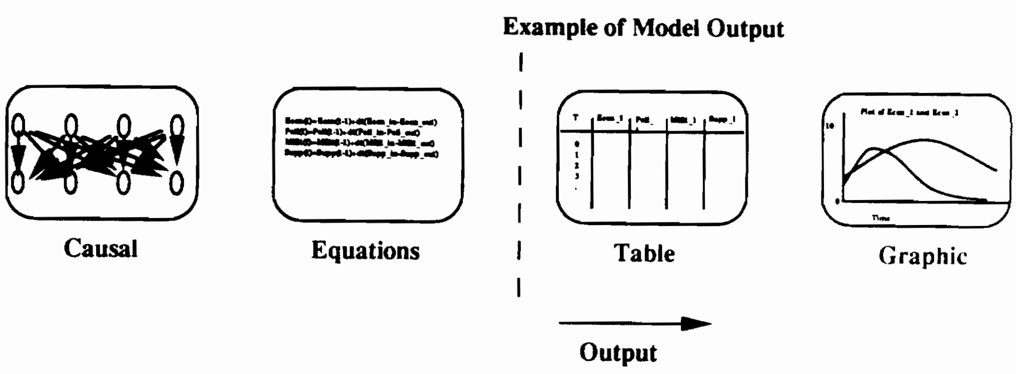


Figure 3.1: Example Screens for Model

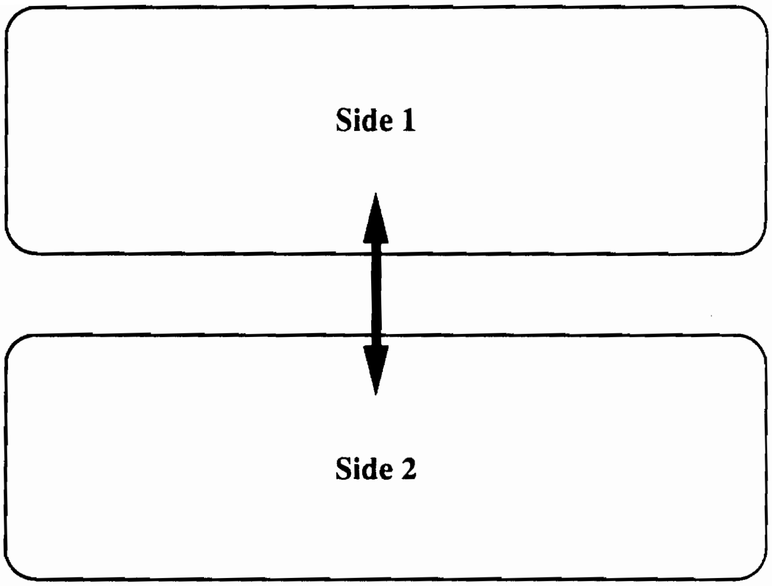
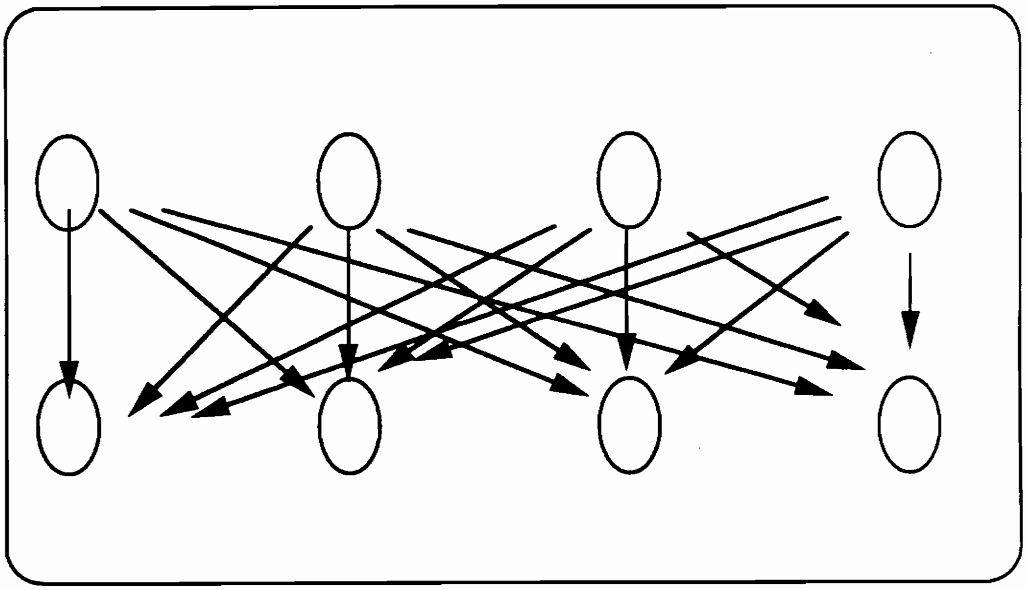


Figure 3.2: "N" Sided Requirements of Users



Causal

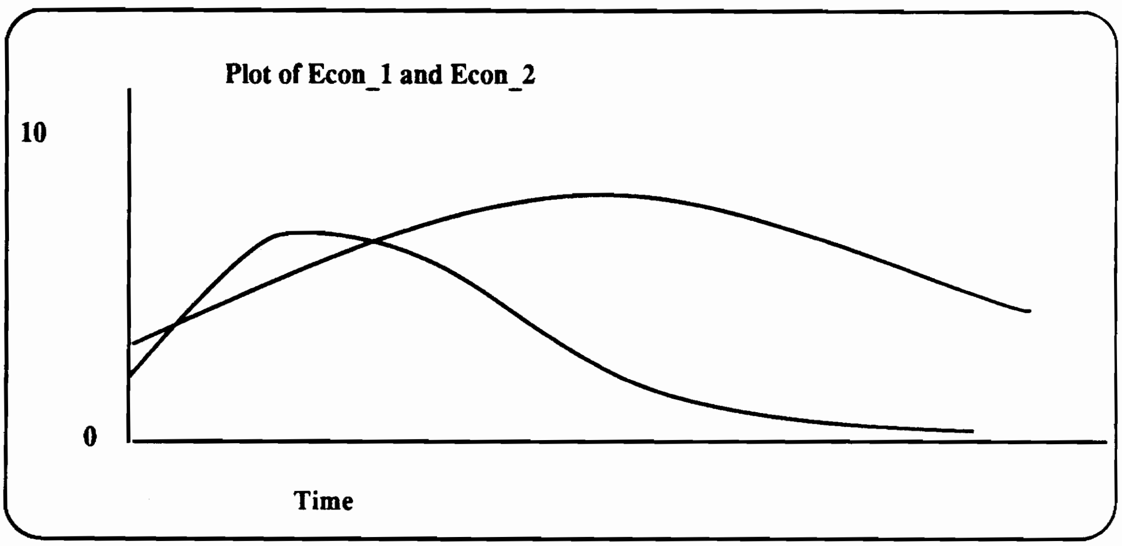
Econ(t)=Econ(t-1)+dt(Econ_in-Econ_out)
Poli(t)=Poli(t-1)+dt(Poli_in-Poli_out)
Milit(t)=Milit(t-1)+dt(Milit_in-Milit_out)
Supp(t)=Supp(t-1)+dt(Supp_in-Supp_out)

Equations

Figure 3.3: Causal Diagram and Equation Model Interface

T	Econ_1	Poli_1	Milit_1	Supp_1
0				
1				
2				
3				
.				

Table



Graphic

Figure 3.4: Graphical and Tabular Model Interface

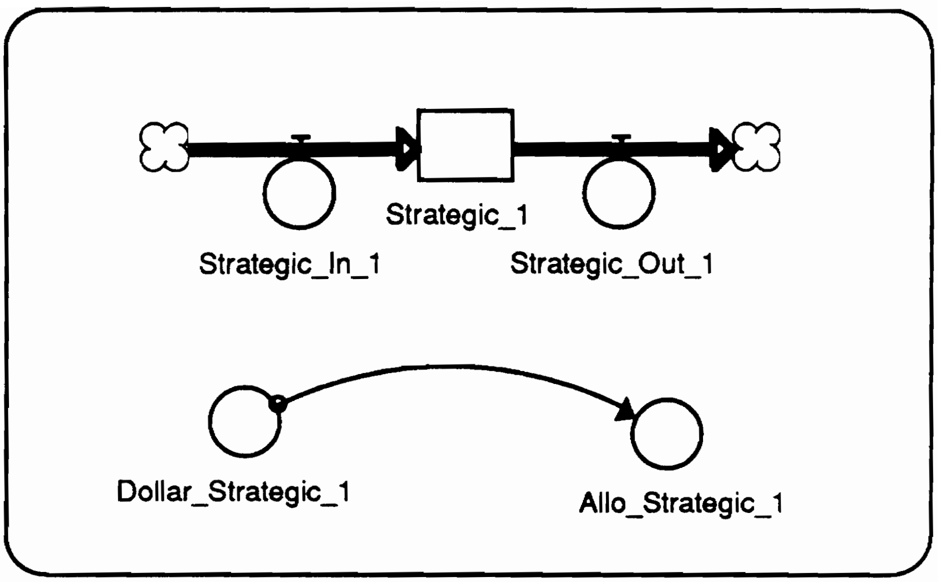


Figure 3.5: Causal Diagram Interface

4. STRUCTURE OF SYSTEM

4.1 Detailed Causal Diagram: Figure 4.1 shows the format and locations of the major sections of the causal diagram.

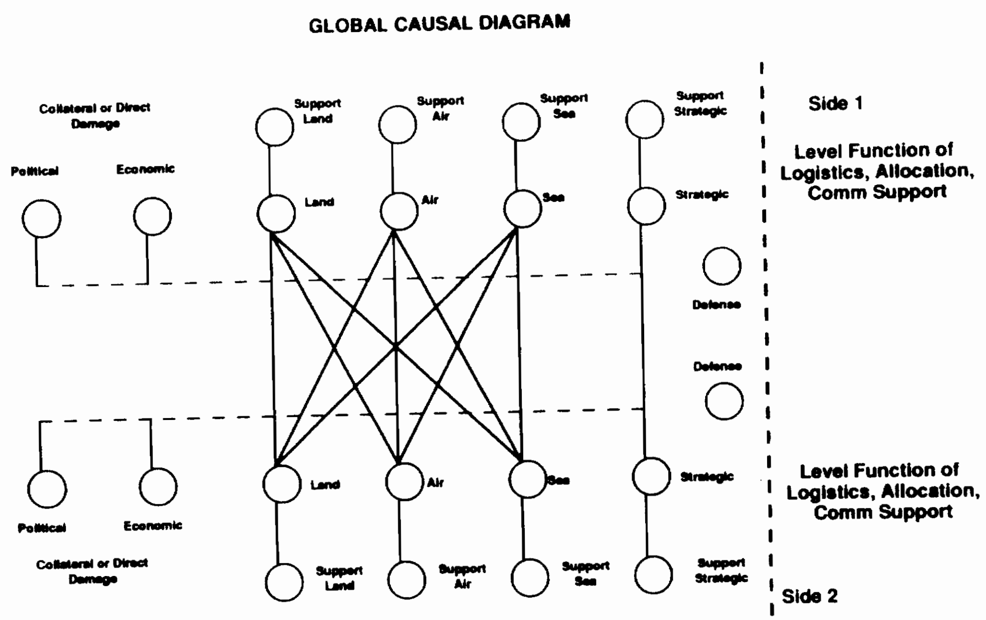
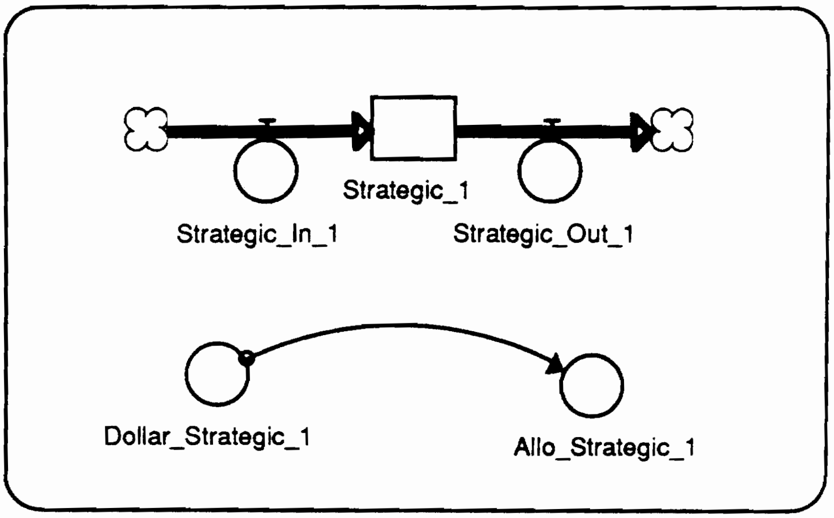


Figure 4.1: Causal Diagram Structure

Section 5 of this appendix provide the entire system causal diagram. In the causal diagram that follows it should be noted how the STELLA software denotes the various types of elements within the context of the system. The following Figure 4.2 shows the elements and their meaning in the system.



Strategic_In_1: **Input to Strategic Elements**

Strategic_1: **Strategic Resources**

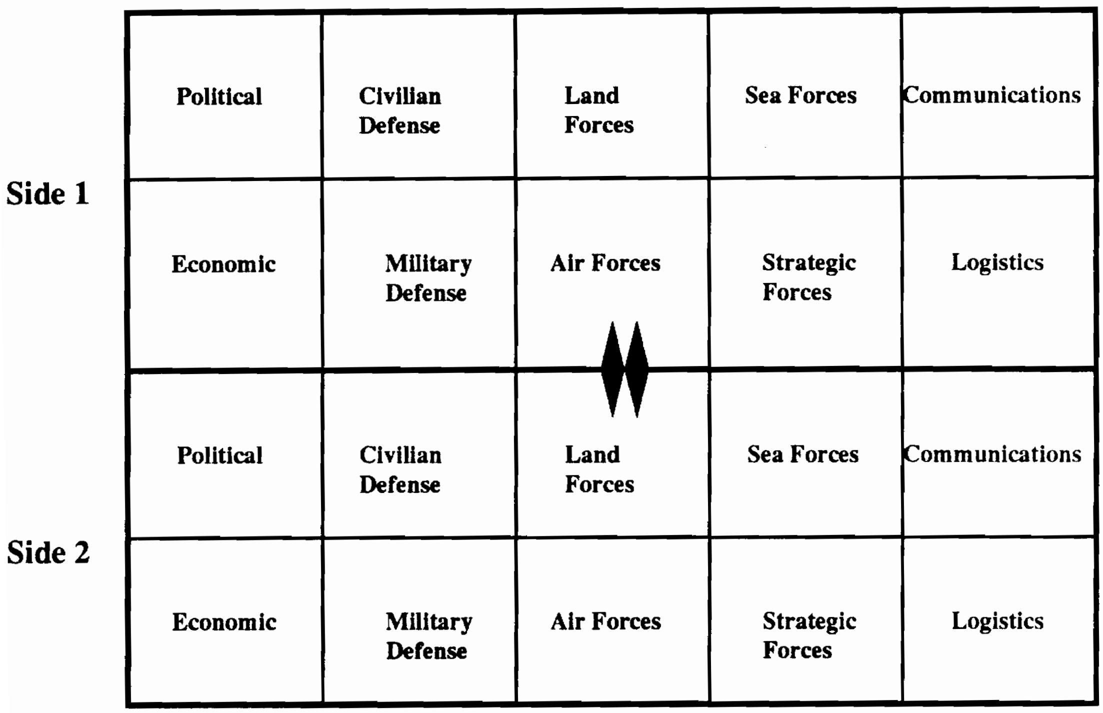
Strategic_Out_1: **Outflow of Strategic Elements**

Dollar_Strategic_1: **Constant Cost per Strategic Elements**

Allo_Strategic_1: **Variable Allocation of Strategic Forces**

Figure 4.2: Causal Diagram Element Description

5. Complete Causal Diagram



5. Side 1 and Side 2 Causal Diagram Structure

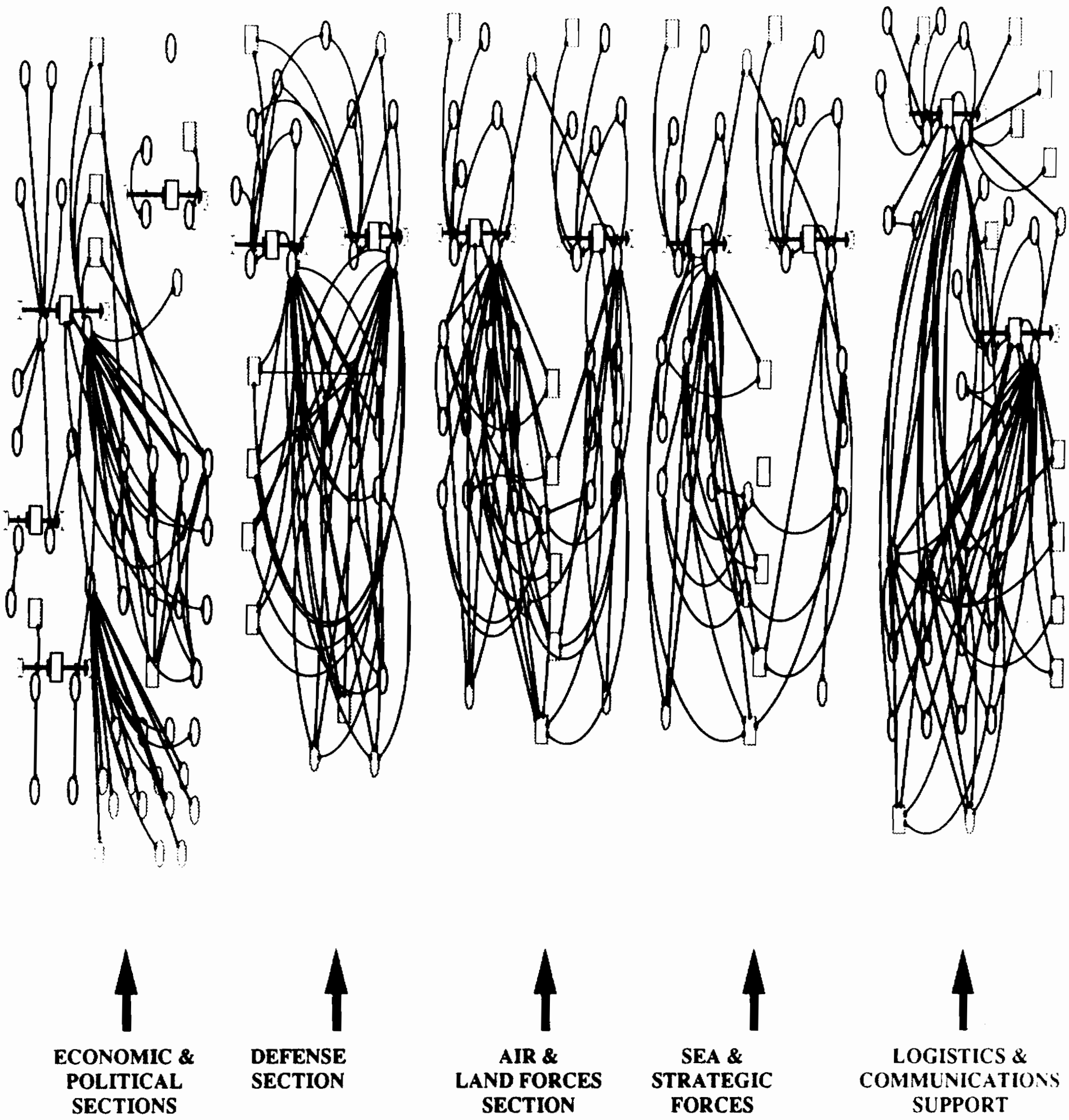
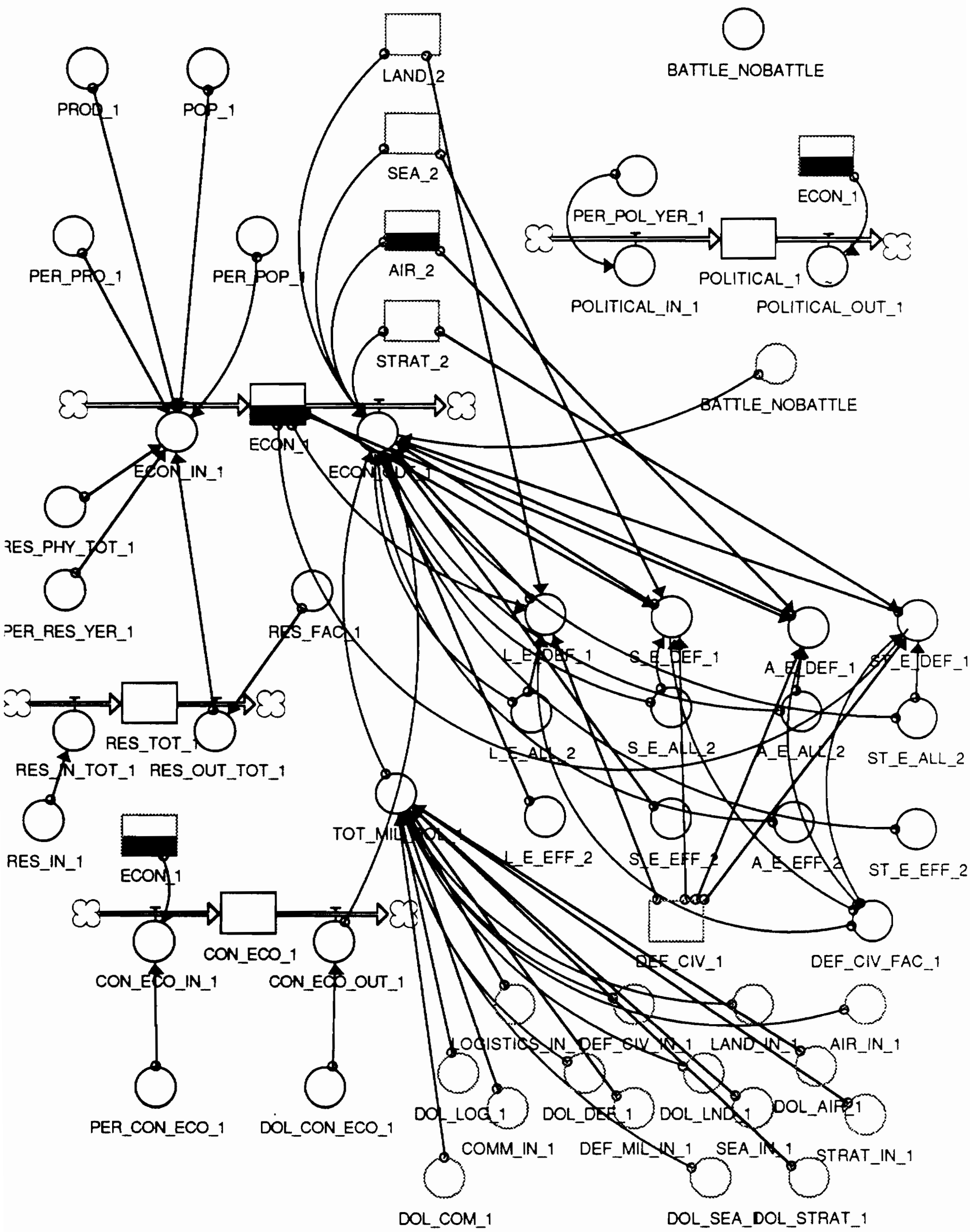
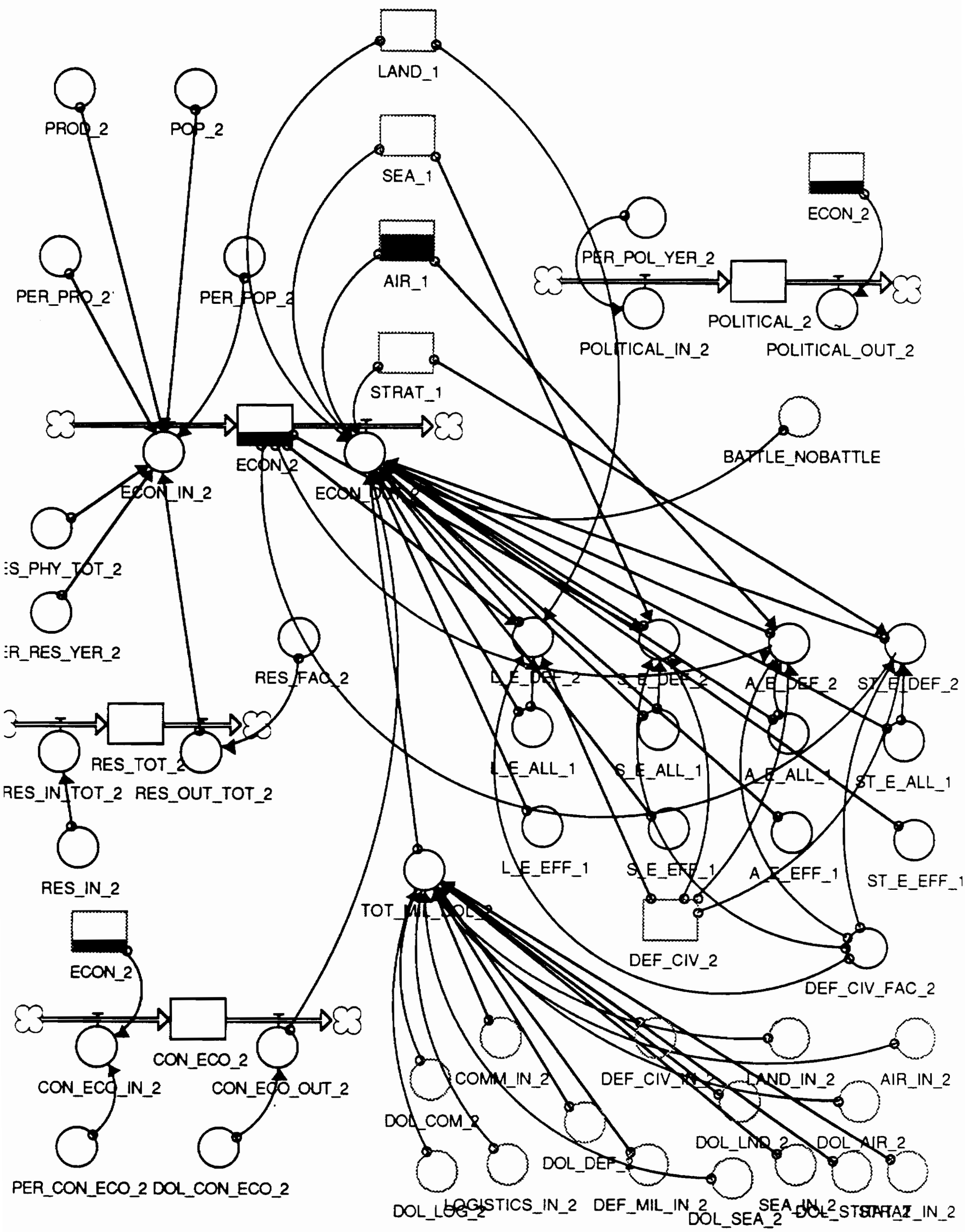


Diagram Shows the actual STELLA Structure for one side's elements

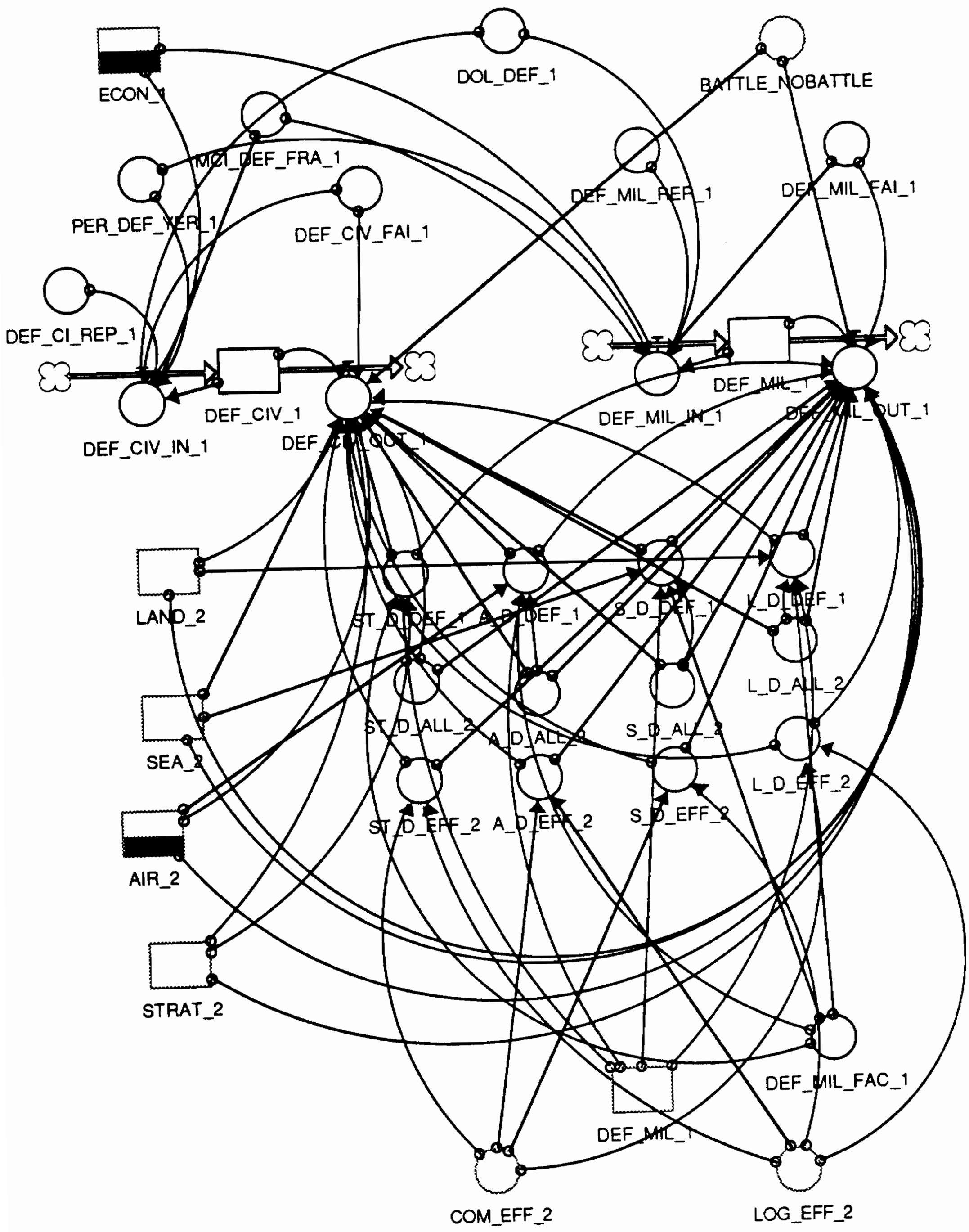
5. Causal Diagram (Economic/Political Side 1)



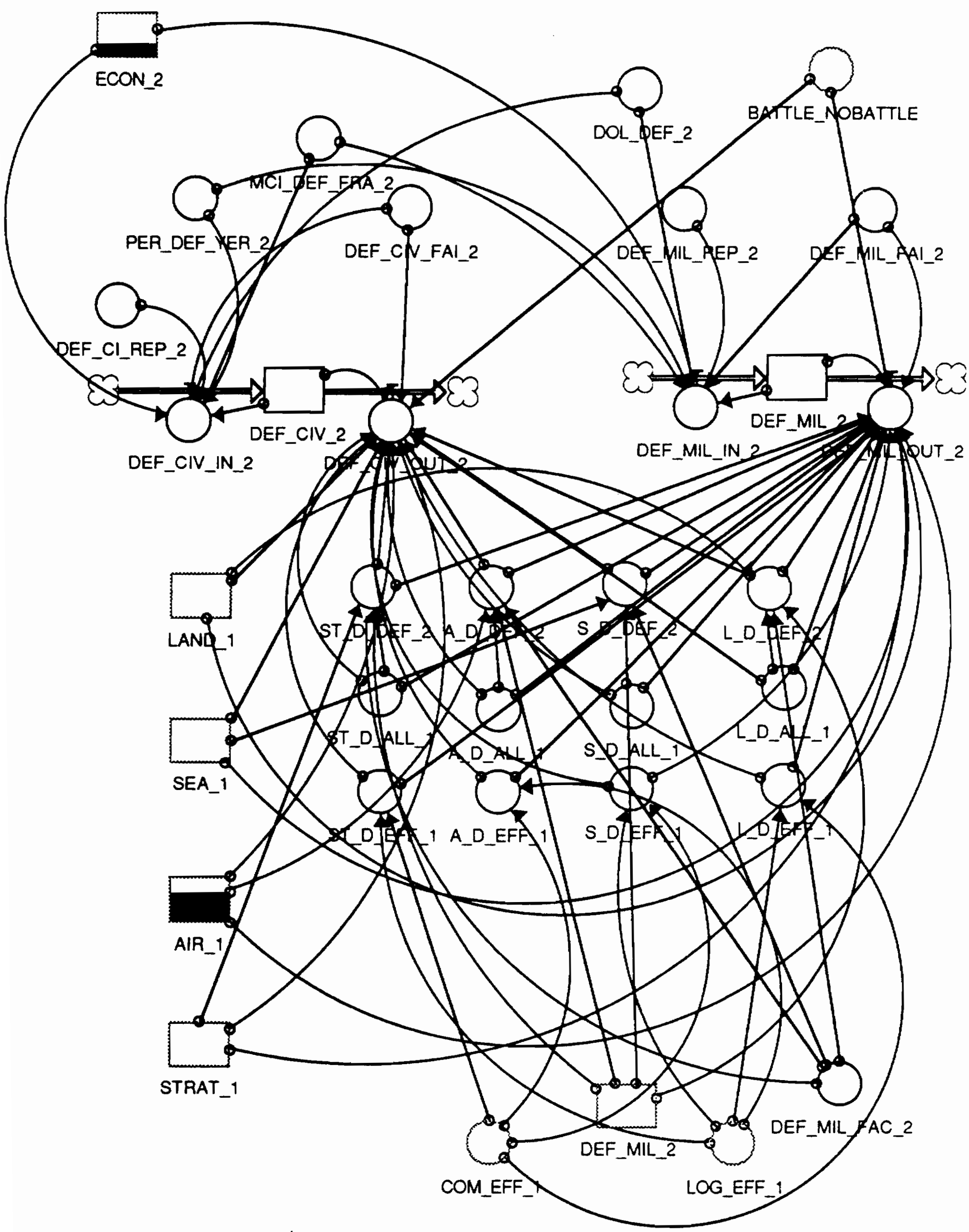
5. Causal Diagram (Economic/Political Side 2)



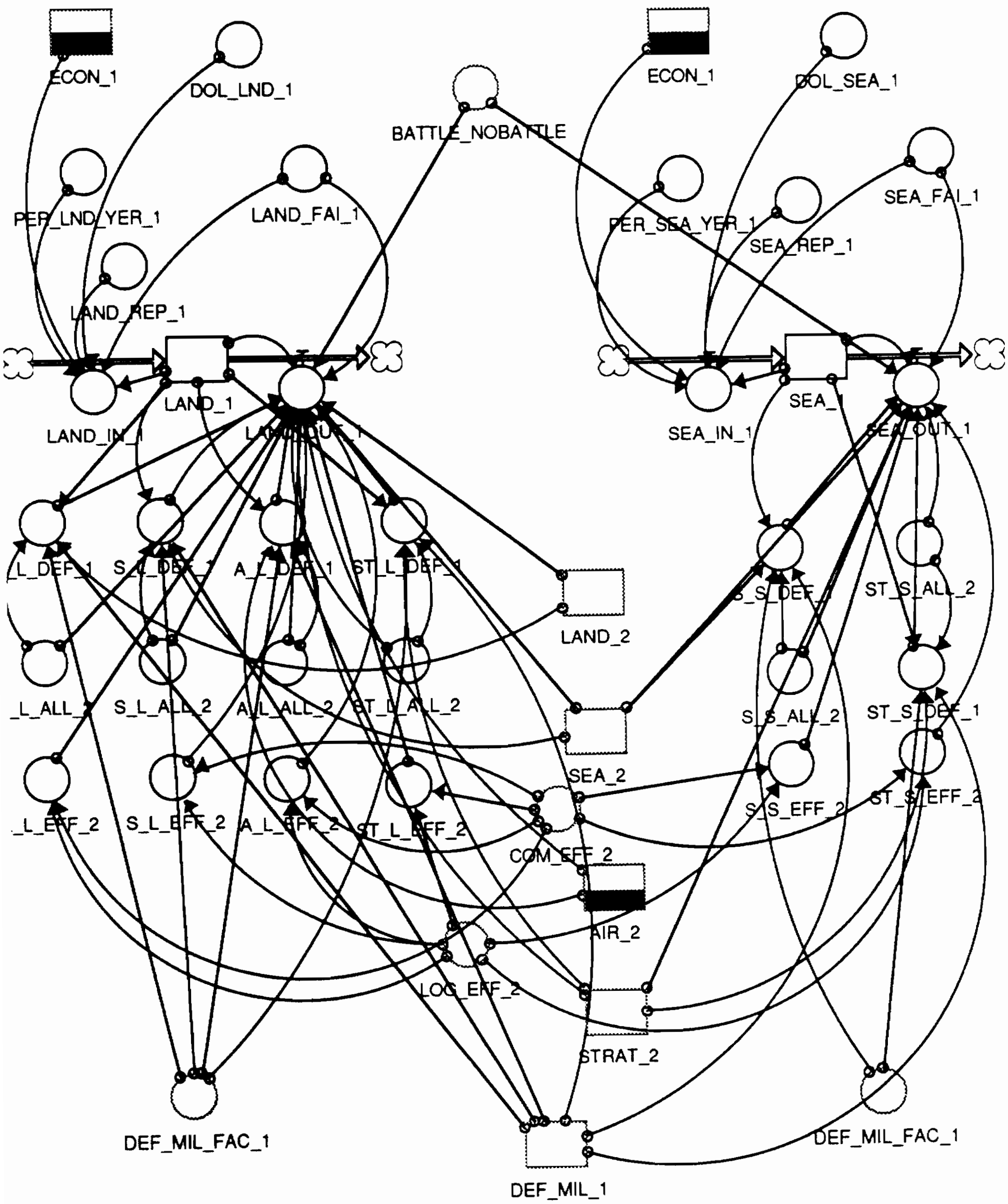
5. Causal Diagram (Defenses Side 1)



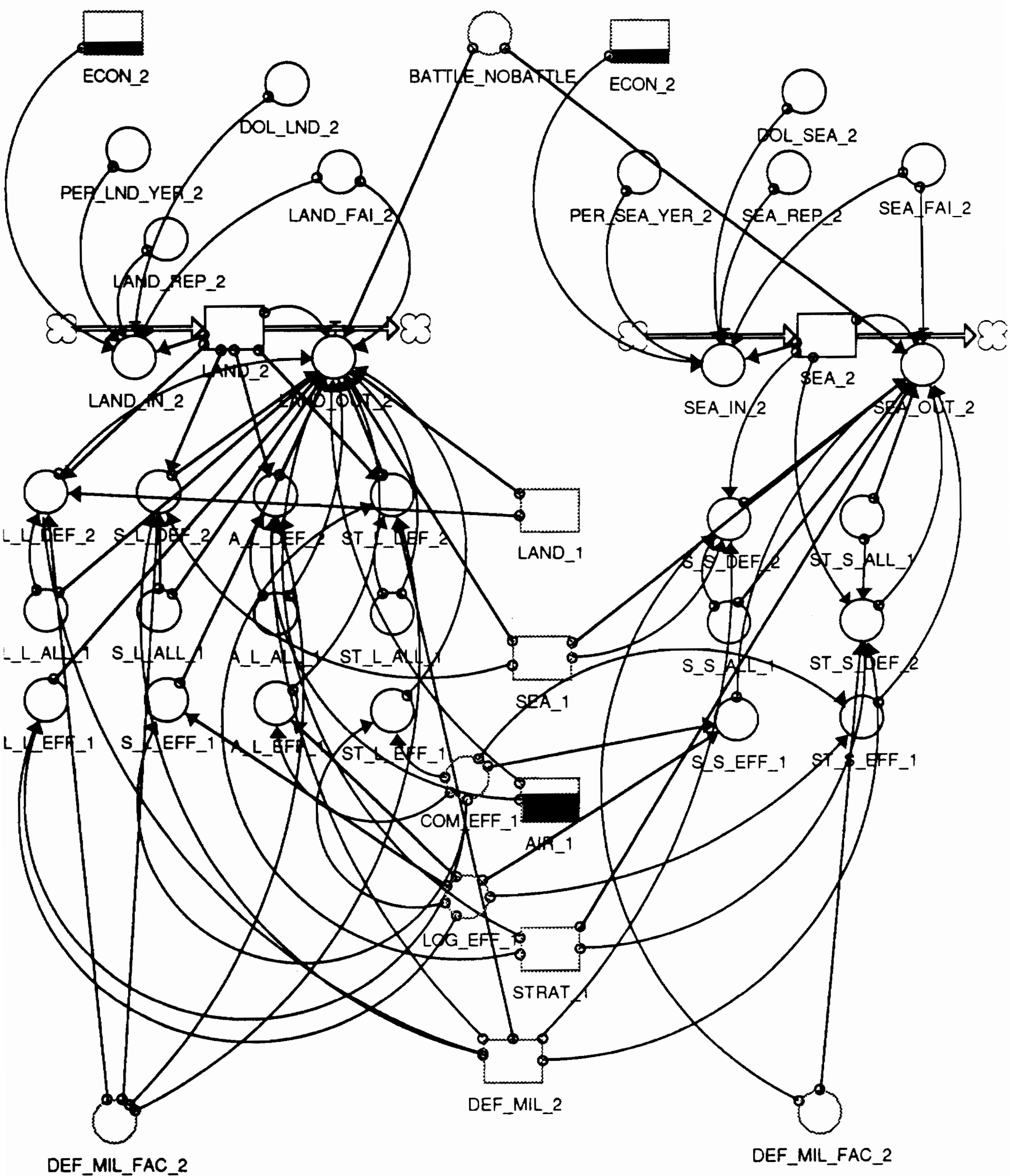
5. Causal Diagram (Defenses Side 2)



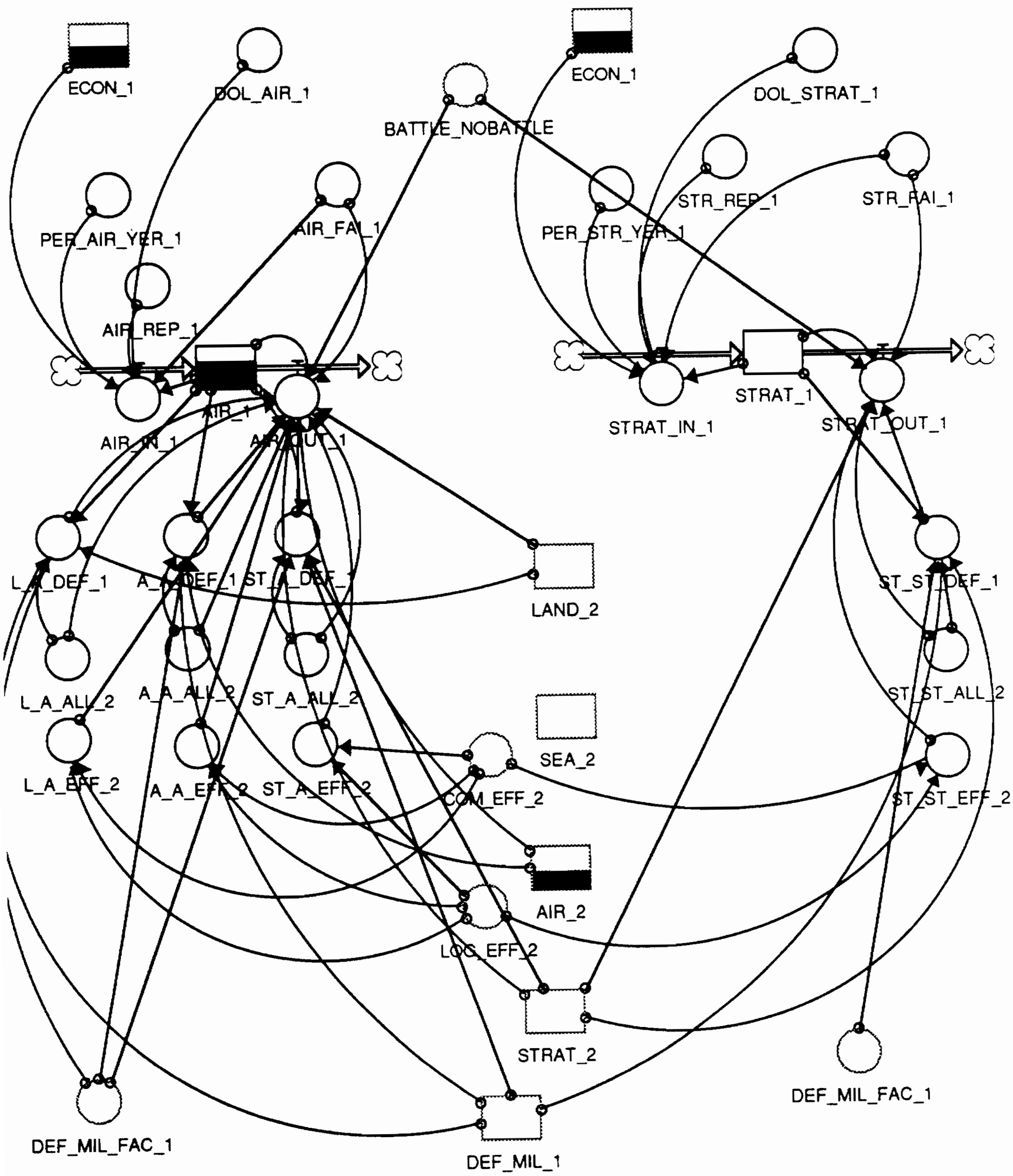
5. Causal Diagram (Land/Sea Side 1)



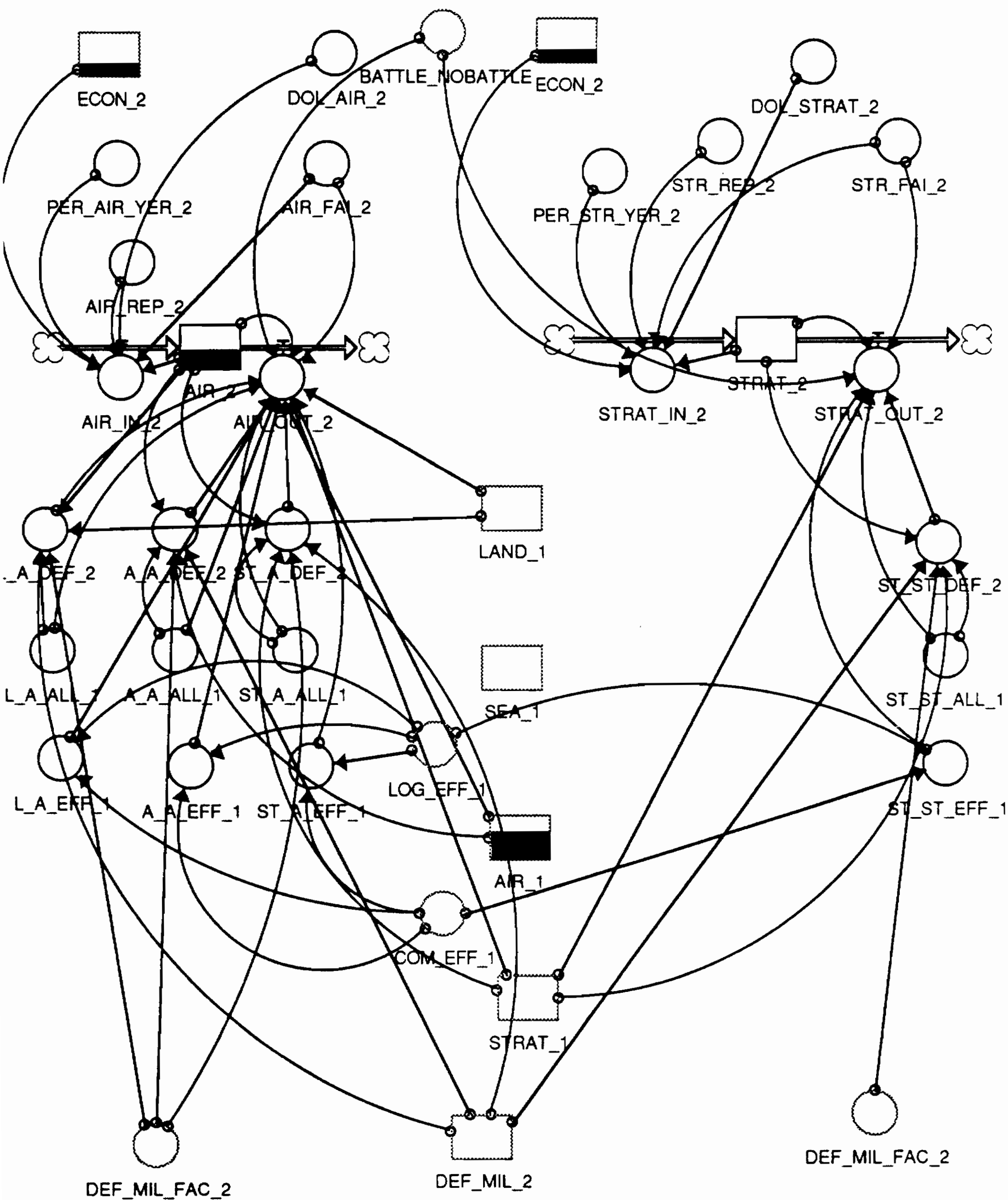
5. Causal Diagram (Land/Sea Side 2)



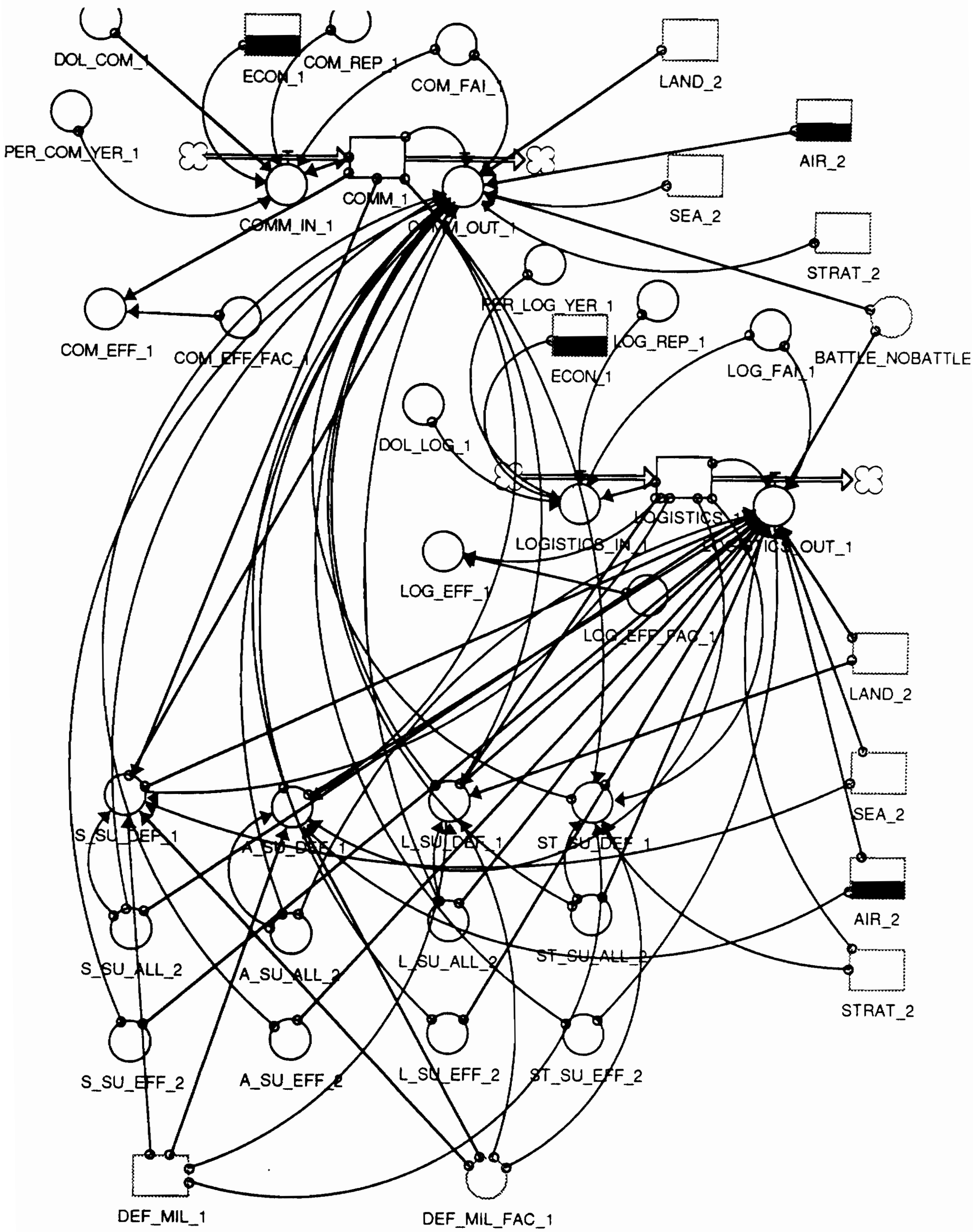
5. Causal Diagram (Air/Strategic Side 1)



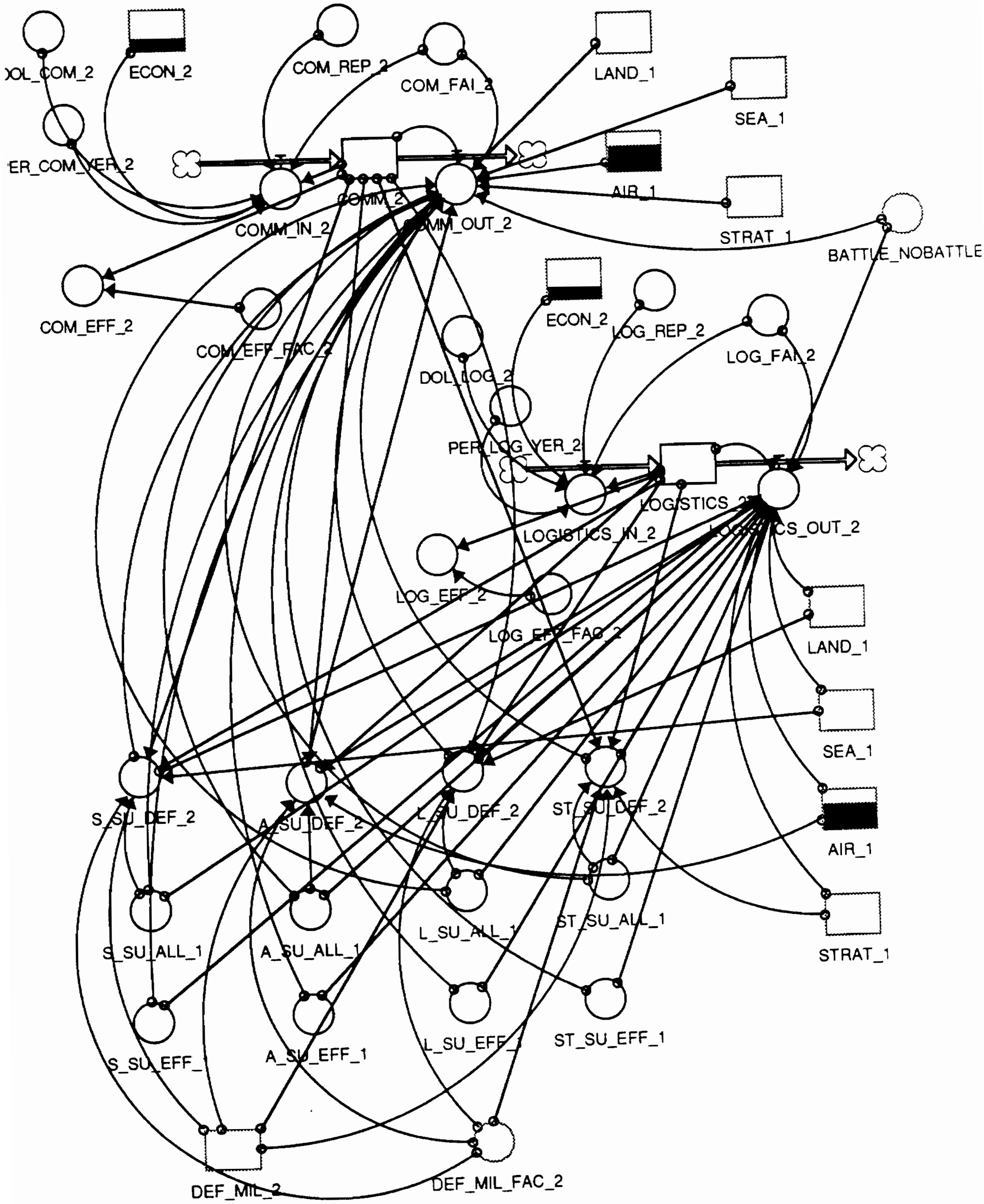
5. Causal Diagram (Air/Strategic Side 2)



5. Causal Diagram (Support Side 1)



5. Causal Diagram (Support Side 2)



6. LIST OF VARIABLES

6.1 The following 9 pages provide a list of variables as well descriptions of the variables that were used for the system.

The following definitions are provided to clarify some of the terminology used in the list:

<u>Variable Name:</u>

*_1 -	Side 1 Elements
*_2 -	Side 2 Elements
ECON_* -	Economic Related
POL_* -	Political Related
STR_* -	Strategic Forces
SEA_* -	Sea Forces
LND_* -	Land Forces
AIR_* -	Air Forces
DEF_* -	Defense Forces
DOL_* -	Economic Cost
*_ALL -	Allocation
*_EFF -	Effectiveness
*_DEF -	Defenses

6. List of Variables

Element	Description	Function Type	Initial Value	Dimension
AIR_1	Air Forces Side 1	Resource	61	# Div
AIR_2	Air Forces Side 2	Resource	56	# Div
COMM_1	Communication Support Side 1	Resource	214	# Div Spt
COMM_2	Communication Support Side 2	Resource	232	# Div Spt
CON_ECO_1	Non Military Economic Side 1	Resource	2000	$
CON_ECO_2	Non Military Economic Side 2	Resource	500	$
DEF_CIV_1	Civilian Defense Side 1	Resource	10	# Units
DEF_CIV_2	Civilian Defense Side 2	Resource	20	# Units
DEF_MIL_1	Military Defense Side 1	Resource	25	# Units
DEF_MIL_2	Military Defense Side 2	Resource	20	# Units
ECON_1	Economic Level Side 1	Resource	5000	$
ECON_2	Economic Level Side 2	Resource	3000	$
LAND_1	Land Forces Side 1	Resource	28	# Div
LAND_2	Land Forces Side 2	Resource	48	# Div
LOGISTICS_1	Logistics Support Side 1	Resource	214	# Div Spt
LOGISTICS_2	Logistics Support Side 2	Resource	232	# Div Spt
POLITICAL_1	Political Level Side 1	Level	80	Level
POLITICAL_2	Political Level Side 2	Level	55	Level
RES_TOT_1	Reserve Economic Level Side 1	Resource	1250	$
RES_TOT_2	Reserve Economic Level Side 2	Resource	500	$
SEA_1	Sea Forces Side 1	Resource	45	# Div
SEA_2	Sea Forces Side 2	Resource	36	# Div
STRAT_1	Strategic Forces Side 1	Resource	80	# Div
STRAT_2	Strategic Forces Side 2	Resource	92	# Div
AIR_FAI_1	Air Forces Failure Rate Side 1	Constant	0.020	# Fai/# Div*dT
AIR_FAI_2	Air Forces Failure Rate Side 2	Constant	0.030	# Fai/# Div*dT
AIR_IN_1	Air Forces Increase Side 1	Rate	0.605	# Div/dT
AIR_IN_2	Air Forces Increase Side 2	Rate	0.484	# Div/dT
AIR_OUT_1	Air Forces Decrease Side 1	Rate	1.210	# Div/dT
AIR_OUT_2	Air Forces Decrease Side 2	Rate	1.640	# Div/dT
AIR_REP_1	Air Forces Replacement Side 1	Constant	0.150	# Rep/# Fai*dT
AIR_REP_2	Air Forces Replacement Side 2	Constant	0.100	# Rep/# Fai*dT
A_A_ALL_1	Air to Air Force Allocation Side 1	Constant	0.300	# Atk/# Div
A_A_ALL_2	Air to Air Force Allocation Side 2	Constant	0.300	# Atk/# Div
A_A_DEF_1	Air to Air Force Defense Factor Side 1	Variable	0.829	Frac Leakage
A_A_DEF_2	Air to Air Force Defense Factor Side 2	Variable	0.741	Frac Leakage

6. List of Variables

Element	Description	Function Type	Initial Value	Dimension
A_A_EFF_1	Air to Air Force Effectiveness Side 1	Variable	0.208	Frac Damaged
A_A_EFF_2	Air to Air Force Effectiveness Side 2	Variable	0.250	Frac Damaged
A_D_ALL_1	Air to Defense Force Allocation Side 1	Constant	0.100	# Atk/# Div
A_D_ALL_2	Air to Defense Force Allocation Side 2	Constant	0.100	# Atk/# Div
A_D_DEF_1	Air to Defense Force Defense Side 1	Variable	0.859	Frac Leakage
A_D_DEF_2	Air to Defense Force Defense Side 2	Variable	0.898	Frac Leakage
A_D_EFF_1	Air to Defense Force Effectiveness Side 1	Variable	0.176	Frac Damaged
A_D_EFF_2	Air to Defense Force Effectiveness Side 2	Variable	0.212	Frac Damaged
A_E_ALL_1	Air to Economic Force Allocation Side 1	Constant	0.100	# Atk/# Div
A_E_ALL_2	Air to Economic Force Allocation Side 2	Constant	0.100	# Atk/# Div
A_E_DEF_1	Air to Economic Force Defense Side 1	Variable	0.999	Frac Leakage
A_E_DEF_2	Air to Economic Force Defense Side 2	Variable	0.998	Frac Leakage
A_E_EFF_1	Air to Economic Force Effectiveness Side 1	Constant	0.100	Frac Damaged
A_E_EFF_2	Air to Economic Force Effectiveness Side 2	Constant	0.100	Frac Damaged
A_L_ALL_1	Air to Land Force Allocation Side 1	Constant	0.100	# Atk/# Div
A_L_ALL_2	Air to Land Force Allocation Side 2	Constant	0.100	# Atk/# Div
A_L_DEF_1	Air to Land Force Defense Side 1	Variable	0.873	Frac Leakage
A_L_DEF_2	Air to Land Force Defense Side 2	Variable	0.956	Frac Leakage
A_L_EFF_1	Air to Land Force Effectiveness Side 1	Variable	0.160	Frac Damaged
A_L_EFF_2	Air to Land Force Effectiveness Side 2	Variable	0.500	Frac Damaged
A_SU_ALL_1	Air to Support Force Allocation Side 1	Constant	0.300	# Atk/# Div
A_SU_ALL_2	Air to Support Force Allocation Side 2	Constant	0.300	# Atk/# Div
A_SU_DEF_1	Air to Support Force Defense Side 1	Variable	0.963	Frac Leakage
A_SU_DEF_2	Air to Support Force Defense Side 2	Variable	0.945	Frac Leakage
A_SU_EFF_1	Air to Support Force Effectiveness Side 1	Constant	0.020	Frac Damaged
A_SU_EFF_2	Air to Support Force Effectiveness Side 2	Constant	0.020	Frac Damaged
BATTLE_NOBATTLE	Conflict Indicator	Logical	0	Logical
COMM_IN_1	Communications Support Increase Side 1	Rate	1.230	# Div Spt/dT
COMM_IN_2	Communications Support Increase Side 2	Rate	0.348	# Div Spt/dT
COMM_OUT_1	Communications Support Decrease Side 1	Rate	1.710	# Div Spt/dT
COMM_OUT_2	Communications Support Decrease Side 2	Rate	1.570	# Div Spt/dT
COM_EFF_1	Communications Support Effectiveness Side	Variable	0.256	# Div Sppt
COM_EFF_2	Communications Support Effectiveness Side	Variable	0.235	# Div Sppt
COM_EFF_FAC_1	Communications Effectiveness Factor Side 1	Constant	0.300	Support Factor
COM_EFF_FAC_2	Communications Effectiveness Factor Side 2	Constant	0.300	Support Factor
COM_FAI_1	Communications Failures Side 1	Constant	0.010	# Fai/# Div*dT

6. List of Variables

Element	Description	Function Type	Initial Value	Dimension
COM_FAI_2	Communications Failures Side 2	Constant	0.010	# Fai/# Div*dT
COM_REP_1	Communications Replacement Rate Side 1	Constant	0.100	# Rep/# Fai*dT
COM_REP_2	Communications Replacement Rate Side 2	Constant	0.100	# Rep/# Fai*dT
CON_ECO_IN_1	Non Military Economic Increase Side 1	Rate	212	$/dT
CON_ECO_IN_2	Non Military Economic Increase Side 2	Rate	128	$/dT
CON_ECO_OUT_1	Non Military Economic Decrease Side 1	Rate	10	$/dT
CON_ECO_OUT_2	Non Military Economic Decrease Side 2	Rate	10	$/dT
DEF_CIV_FAC_1	Civilian Defense Factor Side 1	Constant	0.200	Defense Factor
DEF_CIV_FAC_2	Civilian Defense Factor Side 2	Constant	0.300	Defense Factor
DEF_CIV_FAI_1	Civilian Defense Failure Rate Side 1	Constant	0.010	# Fai/# Div*dT
DEF_CIV_FAI_2	Civilian Defense Failure Rate Side 2	Constant	0.010	# Fai/# Div*dT
DEF_CIV_IN_1	Civilian Defense Increase Side 1	Rate	0.041	# Div/dT
DEF_CIV_IN_2	Civilian Defense Increase Side 2	Rate	0.065	# Div/dT
DEF_CIV_OUT_1	Civilian Defense Decrease Side 1	Rate	0.099	# Div/dT
DEF_CIV_OUT_2	Civilian Defense Decrease Side 2	Rate	0.199	# Div/dT
DEF_CI_REP_1	Civilian Defense Replacement Side 1	Constant	0.200	# Rep/# Fai*dT
DEF_CI_REP_2	Civilian Defense Replacement Side 2	Constant	0.200	# Rep/# Fai*dT
DEF_MIL_FAC_1	Military Defense Factor Side 1	Constant	0.100	# Div
DEF_MIL_FAC_2	Military Defense Factor Side 2	Constant	0.150	# Div
DEF_MIL_FAI_1	Military Defense Failure Rate Side 1	Constant	0.010	# Fai/# Div*dT
DEF_MIL_FAI_2	Military Defense Failure Rate Side 2	Constant	0.010	# Fai/# Div*dT
DEF_MIL_IN_1	Military Defense Increase Side 1	Rate	0.135	# Div/dT
DEF_MIL_IN_2	Military Defense Increase Side 2	Rate	0.068	# Div/dT
DEF_MIL_OUT_1	Military Defense Decrease Side 1	Rate	0.249	# Div/dT
DEF_MIL_OUT_2	Military Defense Decrease Side 2	Rate	0.199	# Div/dT
DEF_MIL_REP_1	Military Defense Replacement Rate Side 1	Constant	0.200	# Rep/# Fai*dT
DEF_MIL_REP_2	Military Defense Replacement Rate Side 2	Constant	0.150	# Rep/# Fai*dT
DOL_AIR_1	Air Forces Cost per Unit Side 1	Constant	50	Div/$
DOL_AIR_2	Air Forces Cost per Unit Side 2	Constant	40	Div/$
DOL_COM_1	Communications Forces Cost per Unit Side 1	Constant	20	Div/$
DOL_COM_2	Communications Forces Cost per Unit Side 2	Constant	20	Div/$
DOL_CON_ECO_1	Non Military Economic Cost Side 1	Constant	10	$
DOL_CON_ECO_2	Non Military Economic Cost Side 2	Constant	10	$
DOL_DEF_1	Defense Forces Cost per Unit Side 1	Constant	60	Div/$
DOL_DEF_2	Defense Forces Cost per Unit Side 2	Constant	60	Div/$
DOL_LND_1	Land Forces Cost per Unit Side 1	Constant	40	Div/$

6. List of Variables

Element	Description	Function Type	Initial Value	Dimension
DOL_LND_2	Land Forces Cost per Unit Side 2	Constant	30	Div/$
DOL_LOG_1	Logistics Forces Cost per Unit Side 1	Constant	70	Div/$
DOL_LOG_2	Logistics Forces Cost per Unit Side 2	Constant	70	Div/$
DOL_SEA_1	Sea Forces Cost per Unit Side 1	Constant	40	Div/$
DOL_SEA_2	Sea Forces Cost per Unit Side 2	Constant	20	Div/$
DOL_STRAT_1	Strategic Forces Cost per Unit Side 1	Constant	20	Div/$
DOL_STRAT_2	Strategic Forces Cost per Unit Side 2	Constant	15	Div/$
ECON_IN_1	Economic Level Increase Side 1	Rate	100	$/dT
ECON_IN_2	Economic Level Increase Side 2	Rate	79	$/dT
ECON_OUT_1	Economic Level Decrease Side 1	Rate	10	$/dT
ECON_OUT_2	Economic Level Decrease Side 2	Rate	10	$/dT
LAND_FAI_1	Land Force Failure Rate Side 1	Constant	0.020	# Fai/# Div*dT
LAND_FAI_2	Land Force Failure Rate Side 2	Constant	0.020	# Fai/# Div*dT
LAND_IN_1	Land Force Increase Side 1	Rate	0.326	# Div/dT
LAND_IN_2	Land Force Increase Side 2	Rate	0.413	# Div/dT
LAND_OUT_1	Land Force Decrease Side 1	Rate	0.555	# Div/dT
LAND_OUT_2	Land Force Decrease Side 2	Rate	0.949	# Div/dT
LAND_REP_1	Land Forces Replacement Rate Side 1	Constant	0.300	# Rep/# Fai*dT
LAND_REP_2	Land Forces Replacement Rate Side 2	Constant	0.300	# Rep/# Fai*dT
LOGISTICS_IN_1	Logistics Level Increase Side 1	Rate	0.444	# Div/dT
LOGISTICS_IN_2	Logistics Level Increase Side 2	Rate	0.438	# Div/dT
LOGISTICS_OUT_1	Logistics Level Decrease Side 1	Rate	1.280	# Div/dT
LOGISTICS_OUT_2	Logistics Level Decrease Side 2	Rate	1.340	# Div/dT
LOG_EFF_1	Logistics Elements Effectiveness Side 1	Variable	0.384	# Div Sppt
LOG_EFF_2	Logistics Elements Effectiveness Side 2	Variable	0.535	# Div Sppt
LOG_EFF_FAC_1	Logistics Effectiveness Factor Side 1	Constant	0.600	Support Factor
LOG_EFF_FAC_2	Logistics Effectiveness Factor Side 2	Constant	0.800	Support Factor
LOG_FAI_1	Logistics Elements Failure Rate Side 1	Constant	0.010	# Fai/# Div*dT
LOG_FAI_2	Logistics Elements Failure Rate Side 2	Constant	0.010	# Fai/# Div*dT
LOG_REP_1	Logistics Elements Replacement Rate Side 1	Constant	0.300	# Rep/# Fai*dT
LOG_REP_2	Logistics Elements Replacement Rate Side 2	Constant	0.300	# Rep/# Fai*dT
L_A_ALL_1	Land to Air Forces Allocation Side 1	Constant	0.100	# Atk/# Div
L_A_ALL_2	Land to Air Forces Allocation Side 2	Constant	0.100	# Atk/# Div
L_A_DEF_1	Land to Air Force Defenses Side 1	Variable	0.978	Frac Leakage
L_A_DEF_2	Land to Air Force Defenses Side 2	Variable	0.955	Frac Leakage
L_A_EFF_1	Land to Air Force Effectiveness Side 1	Variable	0.064	Frac Damaged

6. List of Variables

Element	Description	Function Type	Initial Value	Dimension
L_A_EFF_2	Land to Air Force Effectiveness Side 2	Variable	0.039	Frac Damaged
L_D_ALL_1	Land to Defense Force Allocation Side 1	Constant	0.100	# Atk/# Div
L_D_ALL_2	Land to Defense Force Allocation Side 2	Constant	0.100	# Atk/# Div
L_D_DEF_1	Land to Defense Force Defenses Side 1	Variable	0.947	Frac Leakage
L_D_DEF_2	Land to Defense Force Defenses Side 2	Variable	0.952	Frac Leakage
L_D_EFF_1	Land to Defense Force Effectiveness Side 1	Variable	0.032	Frac Damaged
L_D_EFF_2	Land to Defense Force Effectiveness Side 2	Variable	0.039	Frac Damaged
L_E_ALL_1	Land to Economic Force Allocation Side 1	Constant	0.100	# Atk/# Div
L_E_ALL_2	Land to Economic Force Allocation Side 2	Constant	0.100	# Atk/# Div
L_E_DEF_1	Land to Economic Force Defenses Side 1	Variable	1.000	Frac Leakage
L_E_DEF_2	Land to Economic Force Defenses Side 2	Variable	1.000	Frac Leakage
L_E_EFF_1	Land to Economic Force Effectiveness Side	Constant	0.100	Frac Damaged
L_E_EFF_2	Land to Economic Force Effectiveness Side	Constant	0.100	Frac Damaged
L_L_ALL_1	Land to Land Force Allocation Side 1	Constant	0.300	# Atk/# Div
L_L_ALL_2	Land to Land Force Allocation Side 2	Constant	0.300	# Atk/# Div
L_L_DEF_1	Land to Land Force Defenses Side 1	Variable	0.934	Frac Leakage
L_L_DEF_2	Land to Land Force Defenses Side 2	Variable	0.940	Frac Leakage
L_L_EFF_1	Land to Land Force Effectiveness Side 1	Variable	0.032	Frac Damaged
L_L_EFF_2	Land to Land Force Effectiveness Side 2	Variable	0.006	Frac Damaged
L_SU_ALL_1	Land to Support Force Allocation Side 1	Constant	0.300	# Atk/# Div
L_SU_ALL_2	Land to Support Force Allocation Side 2	Constant	0.300	# Atk/# Div
L_SU_DEF_1	Land to Support Force Defenses Side 1	Variable	0.986	Frac Leakage
L_SU_DEF_2	Land to Support Force Defenses Side 2	Variable	0.990	Frac Leakage
L_SU_EFF_1	Land to Support Force Effectiveness Side 1	Constant	0.100	Frac Damaged
L_SU_EFF_2	Land to Support Force Effectiveness Side 2	Constant	0.100	Frac Damaged
MCI_DEF_FRA_1	Defenses Military to Civilian Frac Side 1	Constant	0.200	Frac Mil Def
MCI_DEF_FRA_2	Defenses Military to Civilian Frac Side 2	Constant	0.400	Frac Mil Def
PER_AIR_YER_1	Air Forces Percent of Military $ Side 1	Constant	0.004	$/Tot $
PER_AIR_YER_2	Air Forces Percent of Military $ Side 2	Constant	0.004	$/Tot $
PER_COM_YER_1	Comm Forces Percent of Military $ Side 1	Constant	0.004	$/Tot $
PER_COM_YER_2	Comm Forces Percent of Military $ Side 2	Constant	0.001	$/Tot $
PER_CON_ECO_1	Non Military Percent of Economic $ Side 1	Constant	0.004	$/Tot $
PER_CON_ECO_2	Non Military Percent of Economic $ Side 2	Constant	0.004	$/Tot $
PER_DEF_YER_1	Def Forces Percent of Military $ Side 1	Constant	0.001	$/Tot $
PER_DEF_YER_2	Def Forces Percent of Military $ Side 2	Constant	0.001	$/Tot $
PER_LND_YER_1	Land Forces Percent of Military $ Side 1	Constant	0.001	$/Tot $

6. List of Variables

Element	Description	Function Type	Initial Value	Dimension
PER_LND_YER_2	Land Forces Percent of Military $ Side 2	Constant	0.001	$/Tot $
PER_LOG_YER_1	Log Forces Percent of Military $ Side 1	Constant	0.001	$/Tot $
PER_LOG_YER_2	Log Forces Percent of Military $ Side 2	Constant	0.001	$/Tot $
PER_POL_YER_1	Political Percent of Economic $ Side 1	Constant	0.017	$/Tot $
PER_POL_YER_2	Political Percent of Economic $ Side 2	Constant	0.017	$/Tot $
PER_POP_1	GNP $ per Population Side 1	Constant	0.333	$/Pop
PER_POP_2	GNP $ per Population Side 2	Constant	0.083	$/Pop
PER_PRO_1	Production per Population Side 1	Constant	0.833	$/Prod
PER_PRO_2	Production per Population Side 2	Constant	0.333	$/Prod
PER_RES_YER_1	Reserve Economic per Period Side 1	Constant	0.004	$/Tot $
PER_RES_YER_2	Reserve Economic per Period Side 2	Constant	0.004	$/Tot $
PER_SEA_YER_1	Sea Forces Percent of Military $ Side 1	Constant	0.001	$/Tot $
PER_SEA_YER_2	Sea Forces Percent of Military $ Side 2	Constant	0.001	$/Tot $
PER_STR_YER_1	Strat Forces Percent of Military $ Side 1	Constant	0.000	$/Tot $
PER_STR_YER_2	Strat Forces Percent of Military $ Side 2	Constant	0.001	$/Tot $
POLITICAL_IN_1	Political Level Increase Side 1	Rate	0.002	Stab Level
POLITICAL_IN_2	Political Level Increase Side 2	Rate	0.002	Stab Level
POP_1 = 200	Population Side 1	Constant	200	# Pop
POP_2 = 250	Population Side 2	Constant	250	# Pop
PROD_1 = 12	Production Rate Side 1	Constant	12	$ Prod
PROD_2 = 50	Production Rate Side 2	Constant	50	$ Prod
RES_FAC_1	Reserve Economic Factor Side 1	Constant	0.200	$ Res
RES_FAC_2	Reserve Economic Factor Side 2	Constant	0.100	$ Res
RES_IN_1	Reserve Level Increase Side 1	Rate	0.300	$/dT
RES_IN_2	Reserve Level Increase Side 2	Rate	0.300	$/dT
RES_IN_TOT_1	Reserve Input Total Side 1	Variable	0.030	$/Tot $
RES_IN_TOT_2	Reserve Input Total Side 2	Variable	0.060	$/Tot $
RES_OUT_TOT_1	Reserve Output Total Side 1	Variable	0.040	$/Tot $*dT
RES_OUT_TOT_2	Reserve Output Total Side 2	Variable	0.025	$/Tot $*dT
RES_PHY_TOT_1	Reserve Level into Physical Res Side 1	Constant	5500	$
RES_PHY_TOT_2	Reserve Level into Physical Res Side 1	Constant	10000	$
SEA_FAI_1	Sea Force Failure Rate Side 1	Constant	0.010	# Fai/# Div*dT
SEA_FAI_2	Sea Force Failure Rate Side 2	Constant	0.010	# Fai/# Div*dT
SEA_IN_1	Sea Force Increase Side 1	Rate	0.249	# Div/dT
SEA_IN_2	Sea Force Increase Side 2	Rate	0.282	# Div/dT
SEA_OUT_1	Sea Force Decrease Side 1	Rate	0.448	# Div/dT

6. List of Variables

Element	Description	Function Type	Initial Value	Dimension
SEA_OUT_2	Sea Force Decrease Side 2	Rate	0.359	# Div/dT
SEA_REP_1	Sea Force Replacement Rate Side 1	Constant	0.200	# Rep/# Fai*dT
SEA_REP_2	Sea Force Replacement Rate Side 2	Constant	0.250	# Rep/# Fai*dT
STRAT_IN_1	Strategic Force Increase Side 1	Rate	0.419	# Div/dT
STRAT_IN_2	Strategic Force Increase Side 2	Rate	0.353	# Div/dT
STRAT_OUT_1	Strategic Force Decrease Side 1	Rate	0.796	# Div/dT
STRAT_OUT_2	Strategic Force Decrease Side 2	Rate	0.914	# Div/dT
STR_FAI_1	Strategic Force Failure Rate Side 1	Constant	0.010	# Fai/# Div*dT
STR_FAI_2	Strategic Force Failure Rate Side 2	Constant	0.010	# Fai/# Div*dT
STR_REP_1	Strategic Force Replacement Rate Side 1	Constant	0.500	# Rep/# Fai*dT
STR_REP_2	Strategic Force Replacement Rate Side 2	Constant	0.200	# Rep/# Fai*dT
ST_A_ALL_1	Strategic to Air Force Allocation Side 1	Constant	0.100	# Atk/# Div
ST_A_ALL_2	Strategic to Air Force Allocation Side 2	Constant	0.100	# Atk/# Div
ST_A_DEF_1	Strategic to Air Force Defense Side 1	Variable	0.901	Frac Leakage
ST_A_DEF_2	Strategic to Air Force Defense Side 2	Variable	0.950	Frac Leakage
ST_A_EFF_1	Strategic to Air Force Effectiveness Side	Variable	0.064	Frac Damaged
ST_A_EFF_2	Strategic to Air Force Effectiveness Side	Variable	0.077	Frac Damaged
ST_D_ALL_1	Strategic to Defense Force Alloc Side 1	Constant	0.100	# Atk/# Div
ST_D_ALL_2	Strategic to Defense Force Alloc Side 2	Constant	0.100	# Atk/# Div
ST_D_DEF_1	Strategic to Defense Force Def Side 1	Variable	0.776	Frac Leakage
ST_D_DEF_2	Strategic to Defense Force Def Side 2	Variable	0.695	Frac Leakage
ST_D_EFF_1	Strategic to Defense Force Eff Side 1	Variable	0.128	Frac Damaged
ST_D_EFF_2	Strategic to Defense Force Eff Side 2	Variable	0.096	Frac Damaged
ST_E_ALL_1	Strategic to Economic Force Allo Side 1	Constant	0.100	# Atk/# Div
ST_E_ALL_2	Strategic to Economic Force Allo Side 2	Constant	0.100	# Atk/# Div
ST_E_DEF_1	Strategic to Economic Force Def Side 1	Variable	0.999	Frac Leakage
ST_E_DEF_2	Strategic to Economic Force Def Side 2	Variable	1.000	Frac Leakage
ST_E_EFF_1	Strategic to Economic Force Eff Side 1	Constant	0.300	Frac Damaged
ST_E_EFF_2	Strategic to Economic Force Eff Side 2	Constant	0.300	Frac Damaged
ST_L_ALL_1	Strategic to Land Force Allo Side 1	Constant	0.100	# Atk/# Div
ST_L_ALL_2	Strategic to Land Force Allo Side 2	Constant	0.100	# Atk/# Div
ST_L_DEF_1	Strategic to Land Force Defense Side 1	Variable	0.797	Frac Leakage
ST_L_DEF_2	Strategic to Land Force Defense Side 2	Variable	0.859	Frac Leakage
ST_L_EFF_1	Strategic to Land Force Eff Side 1	Variable	0.080	Frac Damaged
ST_L_EFF_2	Strategic to Land Force Eff Side 2	Variable	0.013	Frac Damaged
ST_ST_ALL_1	Strategic to Strategic Force Allo Side 1	Constant	0.300	# Atk/# Div

6. List of Variables

Element	Description	Function Type	Initial Value	Dimension
ST_ST_ALL_2	Strategic to Strategic Force Allo Side 2	Constant	0.300	# Atk/# Div
ST_ST_DEF_1	Strategic to Strategic Force Def Side 1	Variable	0.789	Frac Leakage
ST_ST_DEF_2	Strategic to Strategic Force Def Side 2	Variable	0.789	Frac Leakage
ST_ST_EFF_1	Strategic to Strategic Force Eff Side 1	Variable	0.064	Frac Damaged
ST_ST_EFF_2	Strategic to Strategic Force Eff Side 2	Variable	0.039	Frac Damaged
ST_SU_ALL_1	Strategic to Support Force Allo Side 1	Constant	0.100	# Atk/# Div
ST_SU_ALL_2	Strategic to Support Force Allo Side 2	Constant	0.100	# Atk/# Div
ST_SU_DEF_1	Strategic to Support Force Defense Side 1	Variable	0.991	Frac Leakage
ST_SU_DEF_2	Strategic to Support Force Defense Side 2	Variable	0.907	Frac Leakage
ST_SU_EFF_1	Strategic to Support Force Eff Side 1	Constant	0.200	Frac Damaged
ST_SU_EFF_2	Strategic to Support Force Eff Side 2	Constant	0.100	Frac Damaged
ST_S_ALL_1	Strategic to Sea Force Allocation Side 1	Constant	0.100	# Atk/# Div
ST_S_ALL_2	Strategic to Sea Force Allocation Side 2	Constant	0.100	# Atk/# Div
ST_S_DEF_1	Strategic to Sea Force Defense Side 1	Variable	0.943	Frac Leakage
ST_S_DEF_2	Strategic to Sea Force Defense Side 2	Variable	0.925	Frac Leakage
ST_S_EFF_1	Strategic to Sea Force Eff Side 1	Variable	0.080	Frac Damaged
ST_S_EFF_2	Strategic to Sea Force Eff Side 2	Variable	0.096	Frac Damaged
S_D_ALL_1	Sea to Defense Force Allocation Side 1	Constant	0.100	# Atk/# Div
S_D_ALL_2	Sea to Defense Force Allocation Side 2	Constant	0.100	# Atk/# Div
S_D_DEF_1	Sea to Defense Force Defense Side 1	Variable	0.960	Frac Leakage
S_D_DEF_2	Sea to Defense Force Defense Side 2	Variable	0.923	Frac Leakage
S_D_EFF_1	Sea to Defense Force Effectiveness Side 1	Variable	0.064	Frac Damaged
S_D_EFF_2	Sea to Defense Force Effectiveness Side 2	Variable	0.077	Frac Damaged
S_E_ALL_1	Sea to Economic Force Allocation Side 1	Constant	0.100	# Atk/# Div
S_E_ALL_2	Sea to Economic Force Allocation Side 2	Constant	0.100	# Atk/# Div
S_E_DEF_1	Sea to Economic Force Defense Side 1	Variable	1.000	Frac Leakage
S_E_DEF_2	Sea to Economic Force Defense Side 2	Variable	0.999	Frac Leakage
S_E_EFF_1	Sea to Economic Force Effectiveness Side 1	Constant	0.200	Frac Damaged
S_E_EFF_2	Sea to Economic Force Effectiveness Side 2	Constant	0.200	Frac Damaged
S_L_ALL_1	Sea to Land Force Allocation Side 1	Constant	0.100	# Atk/# Div
S_L_ALL_2	Sea to Land Force Allocation Side 2	Constant	0.100	# Atk/# Div
S_L_DEF_1	Sea to Land Force Defense Side 1	Variable	0.964	Frac Leakage
S_L_DEF_2	Sea to Land Force Defense Side 2	Variable	0.967	Frac Leakage
S_L_EFF_1	Sea to Land Force Effectiveness Side 1	Variable	0.032	Frac Damaged
S_L_EFF_2	Sea to Land Force Effectiveness Side 2	Variable	0.039	Frac Damaged
S_SU_ALL_1	Sea to Support Force Allocation Side 1	Constant	0.100	# Atk/# Div

6. List of Variables

Element	Description	Function Type	Initial Value	Dimension
S_SU_ALL_2	Sea to Support Force Allocation Side 2	Constant	0.100	# Atk/# Div
S_SU_DEF_1	Sea to Support Force Defense Side 1	Variable	0.997	Frac Leakage
S_SU_DEF_2	Sea to Support Force Defense Side 2	Variable	0.995	Frac Leakage
S_SU_EFF_1	Sea to Support Force Effectiveness Side 1	Constant	0.100	Frac Damaged
S_SU_EFF_2	Sea to Support Force Effectiveness Side 2	Constant	0.100	Frac Damaged
S_S_ALL_1	Sea to Sea Force Allocation Side 1	Constant	0.300	# Atk/# Div
S_S_ALL_2	Sea to Sea Force Allocation Side 2	Constant	0.300	# Atk/# Div
S_S_DEF_1	Sea to Sea Force Defense Side 1	Variable	0.933	Frac Leakage
S_S_DEF_2	Sea to Sea Force Defense Side 2	Variable	0.944	Frac Leakage
S_S_EFF_1	Sea to Sea Force Effectiveness Side 1	Variable	0.032	Frac Damaged
S_S_EFF_2	Sea to Sea Force Effectiveness Side 2	Variable	0.039	Frac Damaged
TOT_MIL_DOL_1	Military Total Expenditures Side 1	Variable	128	$
TOT_MIL_DOL_2	Military Total Expenditures Side 2	Variable	88	$
POLITICAL_OUT_1	Political Value Side 1	Rate	0.905	Level Change
POLITICAL_OUT_2	Political Value Side 2	Rate	0.525	Level Change

7. LIST OF EQUATIONS

7.1 The following 9 pages list the equations of the model in the form that they were entered into the STELLA tool. The 14 pages that follow list the equations of the system only reordered and grouped by the software in the order of execution.

7.1 List of Equations

AIR_1 = AIR_1 + dt * (AIR_IN_1 - AIR_OUT_1)
INIT(AIR_1) = 61
AIR_2 = AIR_2 + dt * (AIR_IN_2 - AIR_OUT_2)
INIT(AIR_2) = 56
COMM_1 = COMM_1 + dt * (COMM_IN_1 - COMM_OUT_1)
INIT(COMM_1) = (61+28+45+80)*.8
COMM_2 = COMM_2 + dt * (COMM_IN_2 - COMM_OUT_2)
INIT(COMM_2) = (56+48+36+92)*.68
CON_ECO_1 = CON_ECO_1 + dt * (-CON_ECO_OUT_1 + CON_ECO_IN_1)
INIT(CON_ECO_1) = 2000
CON_ECO_2 = CON_ECO_2 + dt * (-CON_ECO_OUT_2 + CON_ECO_IN_2)
INIT(CON_ECO_2) = 500
DEF_CIV_1 = DEF_CIV_1 + dt * (DEF_CIV_IN_1 - DEF_CIV_OUT_1)
INIT(DEF_CIV_1) = 10
DEF_CIV_2 = DEF_CIV_2 + dt * (DEF_CIV_IN_2 - DEF_CIV_OUT_2)
INIT(DEF_CIV_2) = 20
DEF_MIL_1 = DEF_MIL_1 + dt * (-DEF_MIL_OUT_1 + DEF_MIL_IN_1)
INIT(DEF_MIL_1) = 25
DEF_MIL_2 = DEF_MIL_2 + dt * (-DEF_MIL_OUT_2 + DEF_MIL_IN_2)
INIT(DEF_MIL_2) = 20
ECON_1 = ECON_1 + dt * (ECON_IN_1 - ECON_OUT_1)
INIT(ECON_1) = 5000
ECON_2 = ECON_2 + dt * (ECON_IN_2 - ECON_OUT_2)
INIT(ECON_2) = 3000
LAND_1 = LAND_1 + dt * (LAND_IN_1 - LAND_OUT_1)
INIT(LAND_1) = 28
LAND_2 = LAND_2 + dt * (LAND_IN_2 - LAND_OUT_2)
INIT(LAND_2) = 48
LOGISTICS_1 = LOGISTICS_1 + dt * (LOGISTICS_IN_1 - LOGISTICS_OUT_1)
INIT(LOGISTICS_1) = (61+28+5+80)*.74
LOGISTICS_2 = LOGISTICS_2 + dt * (LOGISTICS_IN_2 - LOGISTICS_OUT_2)
INIT(LOGISTICS_2) = (56+48+36+92)*.58
POLITICAL_1 = POLITICAL_1 + dt * (POLITICAL_IN_1 - POLITICAL_OUT_1)
INIT(POLITICAL_1) = 80
POLITICAL_2 = POLITICAL_2 + dt * (POLITICAL_IN_2 - POLITICAL_OUT_2)
INIT(POLITICAL_2) = 55
RES_TOT_1 = RES_TOT_1 + dt * (RES_IN_TOT_1 - RES_OUT_TOT_1)
INIT(RES_TOT_1) = 1250
RES_TOT_2 = RES_TOT_2 + dt * (RES_IN_TOT_2 - RES_OUT_TOT_2)
INIT(RES_TOT_2) = 500
SEA_1 = SEA_1 + dt * (SEA_IN_1 - SEA_OUT_1)
INIT(SEA_1) = 45
SEA_2 = SEA_2 + dt * (SEA_IN_2 - SEA_OUT_2)
INIT(SEA_2) = 36
STRAT_1 = STRAT_1 + dt * (STRAT_IN_1 - STRAT_OUT_1)
INIT(STRAT_1) = 80

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```
STRAT_2 = STRAT_2 + dt * ( STRAT_IN_2 - STRAT_OUT_2 )
INIT(STRAT_2) = 92
AIR_FAI_1 = .02
AIR_FAI_2 = .03
AIR_IN_1 = (ECON_1*PER_AIR_YER_1)/DOL_AIR_1+AIR_FAI_1*AIR_REP_1*AIR_1
AIR_IN_2 = (ECON_2*PER_AIR_YER_2)/DOL_AIR_2+AIR_FAI_2*AIR_REP_2*AIR_2
AIR_OUT_1 =
AIR_FAI_1*AIR_1+(LAND_2*L_A_ALL_2*L_A_EFF_2)*L_A_DEF_1+(AIR_2*A_A_ALL_2*A_A
_EFF_2)*A_A_DEF_1+(STRAT_2*ST_A_ALL_2*ST_A_EFF_2)*ST_A_DEF_1
AIR_OUT_2 =
AIR_FAI_2*AIR_2+(LAND_1*L_A_ALL_1*L_A_EFF_1)*L_A_DEF_2+(AIR_1*A_A_ALL_1*A_A
_EFF_1)*A_A_DEF_2+(STRAT_1*ST_A_ALL_1*ST_A_EFF_1)*ST_A_DEF_2
AIR_REP_1 = .15
AIR_REP_2 = .10
A_A_ALL_1 = .3
A_A_ALL_2 = .3
A_A_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((A_A_ALL_2*AIR_2)/AIR_1)
A_A_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((AIR_1*A_A_ALL_1)/AIR_2)
A_A_EFF_1 = .65*(LOG_EFF_1+COM_EFF_1)/2
A_A_EFF_2 = .65*(COM_EFF_2+LOG_EFF_2)/2
A_D_ALL_1 = .1
A_D_ALL_2 = .1
A_D_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((AIR_2*A_D_ALL_2)/DEF_MIL_1)
A_D_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((AIR_1*A_D_ALL_1)/DEF_MIL_2)
A_D_EFF_1 = .55*(LOG_EFF_1+COM_EFF_1)/2
A_D_EFF_2 = .55*(COM_EFF_2+LOG_EFF_2)/2
A_E_ALL_1 = .1
A_E_ALL_2 = .1
A_E_DEF_1 = (1-.2*DEF_CIV_FAC_1*DEF_CIV_1)^((A_E_ALL_2*AIR_2)/ECON_1)
A_E_DEF_2 = (1-.1*DEF_CIV_FAC_2*DEF_CIV_2)^((A_E_ALL_1*AIR_1)/ECON_2)
A_E_EFF_1 = .1
A_E_EFF_2 = .1
A_L_ALL_1 = .1
A_L_ALL_2 = .1
A_L_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((A_L_ALL_2*AIR_2)/LAND_1)
A_L_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((A_L_ALL_1*AIR_1)/LAND_2)
A_L_EFF_1 = .5*(COM_EFF_1+LOG_EFF_1)/2
A_L_EFF_2 = .65*(COM_EFF_2+LOG_EFF_2)
A_SU_ALL_1 = .3
A_SU_ALL_2 = .3
A_SU_DEF_1 =
(1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((AIR_2*A_SU_ALL_2)/(LOGISTICS_1+COMM_1))
A_SU_DEF_2 =
(1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((A_SU_ALL_1*AIR_1)/(COMM_2+LOGISTICS_2))
A_SU_EFF_1 = .02
A_SU_EFF_2 = .02
```

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```
BATTLE_NOBATTLE = 0
COMM_IN_1 =
(ECON_1*PER_COM_YER_1)/DOL_COM_1+COM_FAI_1*COM_REP_1*COMM_1
COMM_IN_2 =
(ECON_2*PER_COM_YER_2)/DOL_COM_2+COM_FAI_2*COM_REP_2*COMM_2
COMM_OUT_1 =
COMM_1*COM_FAI_1+(LAND_2*L_SU_ALL_2*L_SU_EFF_2)*L_SU_DEF_1+(SEA_2*S_SU_A
LL_2*S_SU_EFF_2)*S_SU_DEF_1+(AIR_2*A_SU_ALL_2*A_SU_EFF_2)*A_SU_DEF_1+(STRAT
_2*ST_SU_ALL_2*ST_SU_EFF_2)*ST_SU_DEF_1
COMM_OUT_2 =
COMM_2*COM_FAI_2+(LAND_1*L_SU_ALL_1*L_SU_EFF_1)*L_SU_DEF_2+(AIR_1*A_SU_A
LL_1*A_SU_EFF_1)*A_SU_DEF_2+(SEA_1*S_SU_ALL_1*S_SU_EFF_1)*S_SU_DEF_2+(STRAT
_1*ST_SU_ALL_1*ST_SU_EFF_1)*ST_SU_DEF_2
COM_EFF_1 = COMM_1*COM_EFF_FAC_1/200
COM_EFF_2 = COMM_2*COM_EFF_FAC_2/200
COM_EFF_FAC_1 = .3
COM_EFF_FAC_2 = .3
COM_FAI_1 = .01
COM_FAI_2 = .01
COM_REP_1 = .1
COM_REP_2 = .1
CON_ECO_IN_1 = ECON_1*PER_CON_ECO_1
CON_ECO_IN_2 = ECON_2*PER_CON_ECO_2
CON_ECO_OUT_1 = DOL_CON_ECO_1
CON_ECO_OUT_2 = DOL_CON_ECO_2
DEF_CIV_FAC_1 = .2
DEF_CIV_FAC_2 = .3
DEF_CIV_FAI_1 = .01
DEF_CIV_FAI_2 = .01
DEF_CIV_IN_1 =
(ECON_1*PER_DEF_YER_1*MCI_DEF_FRA_1)/DOL_DEF_1+DEF_CI_REP_1*DEF_CIV_FAI_1*
DEF_CIV_1
DEF_CIV_IN_2 =
(PER_DEF_YER_2*MCI_DEF_FRA_2*ECON_2)/DOL_DEF_2+DEF_CI_REP_2*DEF_CIV_FAI_2*
DEF_CIV_2
DEF_CIV_OUT_1 =
DEF_CIV_1*DEF_CIV_FAI_1+(STRAT_2*ST_D_ALL_2*ST_D_EFF_2)*ST_D_DEF_1+(AIR_2*A
_D_ALL_2*A_D_EFF_2)*A_D_DEF_1+(SEA_2*S_D_ALL_2*S_D_EFF_2)*S_D_DEF_1+(LAND_
2*L_D_ALL_2*L_D_EFF_2)*L_D_DEF_1
DEF_CIV_OUT_2 =
DEF_CIV_FAI_2*DEF_CIV_2+(ST_D_ALL_1*ST_D_EFF_1*STRAT_1)*ST_D_DEF_2+(A_D_AL
L_1*A_D_EFF_1*AIR_1)*A_D_DEF_2+(S_D_ALL_1*S_D_EFF_1*SEA_1)*S_D_DEF_2+(L_D_A
LL_1*L_D_EFF_1*LAND_1)*L_D_DEF_2
DEF_CI_REP_1 = .2
DEF_CI_REP_2 = .2
```

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DEF_MIL_FAC_1 = .1
DEF_MIL_FAC_2 = .15
DEF_MIL_FAI_1 = .01
DEF_MIL_FAI_2 = .01
DEF_MIL_IN_1 = (ECON_1*PER_DEF_YER_1*(1-MCI_DEF_FRA_1))/DOL_DEF_1+(DEF_MIL_REP_1*DEF_MIL_FAI_1*DEF_MIL_1)
DEF_MIL_IN_2 = ((1-MCI_DEF_FRA_2)*ECON_2*PER_DEF_YER_2)/DOL_DEF_2+(DEF_MIL_REP_2*DEF_MIL_FAI_2*DEF_MIL_2)
DEF_MIL_OUT_1 =
DEF_MIL_FAI_1*DEF_MIL_1+(L_D_ALL_2*L_D_EFF_2*LAND_2)*L_D_DEF_1+(S_D_ALL_2*S_D_EFF_2*SEA_2)*S_D_DEF_1+(A_D_ALL_2*A_D_EFF_2*AIR_2)*A_D_DEF_1+(ST_D_ALL_2*ST_D_EFF_2*STRAT_2)*ST_D_DEF_1
DEF_MIL_OUT_2 =
DEF_MIL_FAI_2*DEF_MIL_2+(L_D_ALL_1*L_D_EFF_1*LAND_1)*L_D_DEF_2+(S_D_ALL_1*S_D_EFF_1*SEA_1)*S_D_DEF_2+(A_D_ALL_1*A_D_EFF_1*AIR_1)*A_D_DEF_2+(ST_D_ALL_1*ST_D_EFF_1*STRAT_1)*ST_D_DEF_2
DEF_MIL_REP_1 = .2
DEF_MIL_REP_2 = .15
DOL_AIR_1 = 50
DOL_AIR_2 = 40
DOL_COM_1 = 20
DOL_COM_2 = 20
DOL_CON_ECO_1 = 10
DOL_CON_ECO_2 = 10
DOL_DEF_1 = 60
DOL_DEF_2 = 60
DOL_LND_1 = 40
DOL_LND_2 = 30
DOL_LOG_1 = 70
DOL_LOG_2 = 70
DOL_SEA_1 = 40
DOL_SEA_2 = 20
DOL_STRAT_1 = 20
DOL_STRAT_2 = 15
ECON_IN_1 =
RES_OUT_TOT_1+PROD_1*PER_PRO_1+POP_1*PER_POP_1+RES_PHY_TOT_1*PER_RES_YER_1
ECON_IN_2 =
RES_OUT_TOT_2+PROD_2*PER_PRO_2+POP_2*PER_POP_2+RES_PHY_TOT_2*PER_RES_YER_2
ECON_OUT_1
=CON_ECO_OUT_1+(L_E_ALL_2*L_E_EFF_2*LAND_2)*L_E_DEF_1+(S_E_ALL_2*S_E_EFF_2*SEA_2)*S_E_DEF_1+(A_E_ALL_2*A_E_EFF_2*AIR_2)*A_E_DEF_1+(ST_E_ALL_2*ST_E_EFF_2*STRAT_2)*ST_E_DEF_1+TOT_MIL_DOL_1
ECON_OUT_2 =

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CON_ECO_OUT_2+(L_E_ALL_1*L_E_EFF_1*LAND_1)*L_E_DEF_2+(S_E_ALL_1*S_E_EFF_1*SEA_1)*S_E_DEF_2+(A_E_ALL_1*A_E_EFF_1*AIR_1)*A_E_DEF_2+(ST_E_ALL_1*ST_E_EFF_1*STRAT_1)*ST_E_DEF_2+TOT_MIL_DOL_2
LAND_FAI_1 = .02
LAND_FAI_2 = .02
LAND_IN_1 =
(ECON_1*PER_LND_YER_1)/DOL_LND_1+(LAND_REP_1*LAND_FAI_1*LAND_1)
LAND_IN_2 =
(PER_LND_YER_2*ECON_2)/DOL_LND_2+(LAND_REP_2*LAND_FAI_2*LAND_2)
LAND_OUT_1 =
LAND_FAI_1*LAND_1+(ST_L_ALL_2*ST_L_EFF_2*STRAT_2)*ST_L_DEF_1+(A_L_ALL_2*A_L_EFF_2*AIR_2)*A_L_DEF_1+(S_L_ALL_2*S_L_EFF_2*SEA_2)*S_L_DEF_1+(L_L_ALL_2*L_L_EFF_2*LAND_2)*L_L_DEF_1
LAND_OUT_2 =
LAND_FAI_2*LAND_2+(L_L_ALL_1*L_L_EFF_1*LAND_1)*L_L_DEF_2+(S_L_ALL_1*S_L_EFF_1*SEA_1)*S_L_DEF_2+(A_L_ALL_1*A_L_EFF_1*AIR_1)*A_L_DEF_2+(ST_L_ALL_1*ST_L_EFF_1*STRAT_1)*ST_L_DEF_2
LAND_REP_1 = .3
LAND_REP_2 = .3
LOGISTICS_IN_1 =
(ECON_1*PER_LOG_YER_1)/DOL_LOG_1+(LOG_FAI_1*LOG_REP_1*LOGISTICS_1)
LOGISTICS_IN_2
=(PER_LOG_YER_2*ECON_2)/DOL_LOG_2+(LOG_FAI_2*LOG_REP_2*LOGISTICS_2)
LOGISTICS_OUT_1 =
LOG_FAI_1*LOGISTICS_1+(L_SU_ALL_2*L_SU_EFF_2*LAND_2)*L_SU_DEF_1+(S_SU_ALL_2*S_SU_EFF_2*SEA_2)*S_SU_DEF_1+(A_SU_ALL_2*A_SU_EFF_2*AIR_2)*A_SU_DEF_1+(ST_SU_ALL_2*ST_SU_EFF_2*STRAT_2)*ST_SU_DEF_1
LOGISTICS_OUT_2 =
LOG_FAI_2*LOGISTICS_2+(L_SU_ALL_1*L_SU_EFF_1*LAND_1)*L_SU_DEF_2+(S_SU_ALL_1*S_SU_EFF_1*SEA_1)*S_SU_DEF_2+(A_SU_ALL_1*A_SU_EFF_1*AIR_1)*A_SU_DEF_2+(ST_SU_ALL_1*ST_SU_EFF_1*STRAT_1)*ST_SU_DEF_2
LOG_EFF_1 = LOGISTICS_1*LOG_EFF_FAC_1/200
LOG_EFF_2 = LOGISTICS_2*LOG_EFF_FAC_2/200
LOG_EFF_FAC_1 = .6
LOG_EFF_FAC_2 = .8
LOG_FAI_1 = .01
LOG_FAI_2 = .01
LOG_REP_1 = .3
LOG_REP_2 = .3
L_A_ALL_1 = .1
L_A_ALL_2 = .1
L_A_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((L_A_ALL_2*LAND_2)/AIR_1)
L_A_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((LAND_1*L_A_ALL_1)/AIR_2)
L_A_EFF_1 = .2*(LOG_EFF_1+COM_EFF_1)/2
L_A_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
L_D_ALL_1 = .1

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```
L_D_ALL_2 = .1
L_D_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((L_D_ALL_2*LAND_2)/DEF_MIL_1)
L_D_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((L_D_ALL_1*LAND_1)/DEF_MIL_2)
L_D_EFF_1 = .1*(LOG_EFF_1+COM_EFF_1)/2
L_D_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
L_E_ALL_1 = .1
L_E_ALL_2 = .1
L_E_DEF_1 = (1-.2*DEF_CIV_FAC_1*DEF_CIV_1)^((L_E_ALL_2*LAND_2)/ECON_1)
L_E_DEF_2 = (1-.01*DEF_CIV_FAC_2*DEF_CIV_2)^((L_E_ALL_1*LAND_1)/ECON_2)
L_E_EFF_1 = .1
L_E_EFF_2 = .1
L_L_ALL_1 = .3
L_L_ALL_2 = .3
L_L_DEF_1 = (1-.05*DEF_MIL_FAC_1*DEF_MIL_1)^((LAND_2*L_L_ALL_2)/LAND_1)
L_L_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((L_L_ALL_1*LAND_1)/LAND_2)
L_L_EFF_1 = .1*(COM_EFF_1+LOG_EFF_1)/2
L_L_EFF_2 = .1*(COM_EFF_2*LOG_EFF_2)/2
L_SU_ALL_1 = .3
L_SU_ALL_2 = .3
L_SU_DEF_1 =
(1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((L_SU_ALL_2*LAND_2)/(COMM_1+LOGISTICS_1))
L_SU_DEF_2 =
(1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((L_SU_ALL_1*LAND_1)/(COMM_2+LOGISTICS_2))
L_SU_EFF_1 = .1
L_SU_EFF_2 = .1
MCI_DEF_FRA_1 = .2
MCI_DEF_FRA_2 = .4
PER_AIR_YER_1 = .05*(1/12)
PER_AIR_YER_2 = .05*(1/12)
PER_COM_YER_1 = .05*(1/12)
PER_COM_YER_2 = .015*(1/12)
PER_CON_ECO_1 = .5*(1/12)
PER_CON_ECO_2 = .5*(1/12)
PER_DEF_YER_1 = .015*(1/12)
PER_DEF_YER_2 = .015*(1/12)
PER_LND_YER_1 = .015*(1/12)
PER_LND_YER_2 = .015*(1/12)
PER_LOG_YER_1 = .01*(1/12)
PER_LOG_YER_2 = .01*(1/12)
PER_POL_YER_1 = .2*(1/12)
PER_POL_YER_2 = .2*(1/12)
PER_POP_1 = 4/12
PER_POP_2 = 1/12
PER_PRO_1 = 10/12
PER_PRO_2 = 4/12
PER_RES_YER_1 = .05/12
```

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PER_RES_YER_2 = .05/12
PER_SEA_YER_1 = .015*(1/12)
PER_SEA_YER_2 = .015*(1/12)
PER_STR_YER_1 = .001*(1/12)
PER_STR_YER_2 = .01*(1/12)
POLITICAL_IN_1 = PER_POL_YER_1*.1
POLITICAL_IN_2 = PER_POL_YER_2*.1
POP_1 = 200
POP_2 = 250
PROD_1 = 12
PROD_2 = 50
RES_FAC_1 = .2
RES_FAC_2 = .1
RES_IN_1 = .3
RES_IN_2 = .3
RES_IN_TOT_1 = RES_IN_1*.1
RES_IN_TOT_2 = RES_IN_2*.2
RES_OUT_TOT_1 = RES_FAC_1*.2
RES_OUT_TOT_2 = RES_FAC_2*.25
RES_PHY_TOT_1 = 5500
RES_PHY_TOT_2 = 10000
SEA_FAI_1 = .01
SEA_FAI_2 = .01
SEA_IN_1 =(ECON_1*PER_SEA_YER_1)/DOL_SEA_1+(SEA_1*SEA_REP_1*SEA_FAI_1)
SEA_IN_2 = (ECON_2*PER_SEA_YER_2)/DOL_SEA_2+(SEA_2*SEA_REP_2*SEA_FAI_2)
SEA_OUT_1 =
SEA_1*SEA_FAI_1+(S_S_DEF_1*S_S_ALL_2*S_S_EFF_2*SEA_2)+(ST_S_ALL_2*ST_S_DEF_1*
ST_S_EFF_2*STRAT_2)
SEA_OUT_2 =
SEA_FAI_2*SEA_2+(S_S_DEF_2*S_S_ALL_1*S_S_EFF_1*SEA_1)+(ST_S_ALL_1*ST_S_DEF_2*
ST_S_EFF_1*STRAT_1)
SEA_REP_1 = .2
SEA_REP_2 = .25
STRAT_IN_1 =
(ECON_1*PER_STR_YER_1)/DOL_STRAT_1+(STRAT_1*STR_FAI_1*STR_REP_1)
STRAT_IN_2 =
(ECON_2*PER_STR_YER_2)/DOL_STRAT_2+(STRAT_2*STR_FAI_2*STR_REP_2)
STRAT_OUT_1 =
(STR_FAI_1*STRAT_1)+(ST_ST_DEF_1*ST_ST_ALL_2*ST_ST_EFF_2*STRAT_2)
STRAT_OUT_2 =
(STR_FAI_2*STRAT_2)+(ST_ST_DEF_2*ST_ST_ALL_1*ST_ST_EFF_1*STRAT_1) STR_FAI_1 =
.01
STR_FAI_2 = .01
STR_REP_1 = .5
STR_REP_2 = .2
ST_A_ALL_1 = .1

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ST_A_ALL_2 = .1
ST_A_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_A_ALL_2*STRAT_2)/AIR_1)
ST_A_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((STRAT_1*ST_A_ALL_1)/AIR_2)
ST_A_EFF_1 = .2*(LOG_EFF_1+COM_EFF_1)/2
ST_A_EFF_2 = .2*(COM_EFF_2+LOG_EFF_2)/2
ST_D_ALL_1 = .1
ST_D_ALL_2 = .1
ST_D_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_D_ALL_2*STRAT_2)/DEF_MIL_1)
ST_D_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((STRAT_1*ST_D_ALL_1)/DEF_MIL_2)
ST_D_EFF_1 = .4*(LOG_EFF_1+COM_EFF_1)/2
ST_D_EFF_2 = .25*(COM_EFF_2+LOG_EFF_2)/2
ST_E_ALL_1 = .1
ST_E_ALL_2 = .1
ST_E_DEF_1 = (1-.2*DEF_CIV_FAC_1*DEF_CIV_1)^((ST_E_ALL_2*STRAT_2)/ECON_1)
ST_E_DEF_2 = (1-.025*DEF_CIV_FAC_2*DEF_CIV_2)^((ST_E_ALL_1*STRAT_1)/ECON_2)
ST_E_EFF_1 = .3
ST_E_EFF_2 = .3
ST_L_ALL_1 = .1
ST_L_ALL_2 = .1
ST_L_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_L_ALL_2*STRAT_2)/LAND_1)
ST_L_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((ST_L_ALL_1*STRAT_1)/LAND_2)
ST_L_EFF_1 = .25*(COM_EFF_1+LOG_EFF_1)/2
ST_L_EFF_2 = .2*(COM_EFF_2*LOG_EFF_2)/2
ST_ST_ALL_1 = .3
ST_ST_ALL_2 = .3
ST_ST_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_ST_ALL_2*STRAT_2)/STRAT_1)
ST_ST_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((ST_ST_ALL_1*STRAT_1)/STRAT_2)
ST_ST_EFF_1 = .2*(LOG_EFF_1+COM_EFF_1)/2
ST_ST_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
ST_SU_ALL_1 = .1
ST_SU_ALL_2 = .1
ST_SU_DEF_1 =
(1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_SU_ALL_2*STRAT_2)/(LOGISTICS_1+COMM_1))
ST_SU_DEF_2 =
(1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((ST_SU_ALL_1+STRAT_1)/(COMM_2+LOGISTICS_2))
ST_SU_EFF_1 = .2
ST_SU_EFF_2 = .1
ST_S_ALL_1 = .1
ST_S_ALL_2 = .1
ST_S_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_S_ALL_2*STRAT_2)/SEA_1)
ST_S_DEF_2 = (1-.1*DEF_MIL_2*DEF_MIL_FAC_2)^((ST_S_ALL_1*STRAT_1)/SEA_2)
ST_S_EFF_1 = .25*(LOG_EFF_1+COM_EFF_1)/2
ST_S_EFF_2 = .25*(COM_EFF_2+LOG_EFF_2)/2
S_D_ALL_1 = .1
S_D_ALL_2 = .1
S_D_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((S_D_ALL_2*SEA_2)/DEF_MIL_1)

7.1 List of Equations

S_D_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((S_D_ALL_1*SEA_1)/DEF_MIL_2)
S_D_EFF_1 = .2*(LOG_EFF_1+COM_EFF_1)/2
S_D_EFF_2 = .2*(COM_EFF_2+LOG_EFF_2)/2
S_E_ALL_1 = .1
S_E_ALL_2 = .1
S_E_DEF_1 = (1-.1*DEF_CIV_FAC_1*DEF_CIV_1)^((S_E_ALL_2*SEA_2)/ECON_1)
S_E_DEF_2 = (1-.1*DEF_CIV_FAC_2*DEF_CIV_2)^((S_E_ALL_1*SEA_1)/ECON_2)
S_E_EFF_1 = .2
S_E_EFF_2 = .2
S_L_ALL_1 = .1
S_L_ALL_2 = .1
S_L_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((S_L_ALL_2*SEA_2)/LAND_1)
S_L_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((S_L_ALL_1*SEA_1)/LAND_2)
S_L_EFF_1 = .1*(COM_EFF_1+LOG_EFF_1)/2
S_L_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
S_SU_ALL_1 = .1
S_SU_ALL_2 = .1
S_SU_DEF_1 =
(1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((S_SU_ALL_2*SEA_2)/(COMM_1+LOGISTICS_1))
S_SU_DEF_2 =
(1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((S_SU_ALL_1*SEA_1)/(COMM_2+LOGISTICS_2))
S_SU_EFF_1 = .1
S_SU_EFF_2 = .1
S_S_ALL_1 = .3
S_S_ALL_2 = .3
S_S_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((S_S_ALL_2*SEA_2)/SEA_1)
S_S_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)/((S_S_ALL_1*SEA_1)/SEA_2)
S_S_EFF_1 = .1*(LOG_EFF_1+COM_EFF_1)/2
S_S_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
TOT_MIL_DOL_1 =
LOGISTICS_IN_1*DOL_LOG_1+(DEF_CIV_IN_1+DEF_MIL_IN_1)*DOL_DEF_1+LAND_IN_1*
DOL_LND_1+AIR_IN_1*DOL_AIR_1+COMM_IN_1*DOL_COM_1+SEA_IN_1*DOL_SEA_1+ST
RAT_IN_1*DOL_STRAT_1
TOT_MIL_DOL_2
=COMM_IN_2*DOL_COM_2+(DEF_CIV_IN_2+DEF_MIL_IN_2)*DOL_DEF_2+LAND_IN_2*D
OL_LND_2+AIR_IN_2*DOL_AIR_2+LOGISTICS_IN_2*DOL_LOG_2+SEA_IN_2*DOL_SEA_2+
STRAT_IN_2*DOL_STRAT_2
POLITICAL_OUT_1 = graph(ECON_1)
(
0.0,0.0200),(500.00,0.0900),(1000.00,0.150),(1500.00,0.215),(2000.00,0.480),(2500.00,0.480),(3000.
00,0.510),(3500.00,0.500),(4000.00,0.570),(4500.00,0.710),(5000.00,0.905)
POLITICAL_OUT_2 = graph(ECON_2)
(
0.0,0.0200),(300.00,0.420),(600.00,0.430),(900.00,0.460),(1200.00,0.430),(1500.00,0.435),(1800.00,0
.440),(2100.00,0.430),(2400.00,0.430),(2700.00,0.465),(3000.00,0.525)

7.2 List of Equations (In Order of Execution)

```
{Initialization equations}
INIT(AIR_1) = 61
INIT(AIR_2) = 56
INIT(COMM_1) = (61+28+45+80)*.8
INIT(COMM_2) = (56+48+36+92)*.68
INIT(CON_ECO_1) = 2000
INIT(CON_ECO_2) = 500
INIT(DEF_CIV_1) = 10
INIT(DEF_CIV_2) = 20
INIT(DEF_MIL_1) = 25
INIT(DEF_MIL_2) = 20
INIT(ECON_1) = 5000
INIT(ECON_2) = 3000
INIT(LAND_1) = 28
INIT(LAND_2) = 48
INIT(LOGISTICS_1) = (61+28+5+80)*.74
INIT(LOGISTICS_2) = (56+48+36+92)*.58
INIT(POLITICAL_1) = 80
INIT(POLITICAL_2) = 55
INIT(RES_TOT_1) = 1250
INIT(RES_TOT_2) = 500
INIT(SEA_1) = 45
INIT(SEA_2) = 36
INIT(STRAT_1) = 80
INIT(STRAT_2) = 92
AIR_FAI_1 = .02
AIR_FAI_2 = .03
PER_AIR_YER_1 = .05*(1/12)
AIR_REP_1 = .15
DOL_AIR_1 = 50
AIR_IN_1 = (ECON_1*PER_AIR_YER_1)/DOL_AIR_1+AIR_FAI_1*AIR_REP_1*AIR_1
PER_AIR_YER_2 = .05*(1/12)
AIR_REP_2 = .10
DOL_AIR_2 = 40
AIR_IN_2 = (ECON_2*PER_AIR_YER_2)/DOL_AIR_2+AIR_FAI_2*AIR_REP_2*AIR_2
DEF_MIL_FAC_1 = .1
L_A_ALL_2 = .1
L_A_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((L_A_ALL_2*LAND_2)/AIR_1)
A_A_ALL_2 = .3
A_A_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((A_A_ALL_2*AIR_2)/AIR_1)
ST_A_ALL_2 = .1
ST_A_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_A_ALL_2*STRAT_2)/AIR_1)
COM_EFF_FAC_2 = .3
COM_EFF_2 = COMM_2*COM_EFF_FAC_2/200
LOG_EFF_FAC_2 = .8
LOG_EFF_2 = LOGISTICS_2*LOG_EFF_FAC_2/200
```

7.2 List of Equations (In Order of Execution)

```
L_A_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
A_A_EFF_2 = .65*(COM_EFF_2+LOG_EFF_2)/2
ST_A_EFF_2 = .2*(COM_EFF_2+LOG_EFF_2)/2
AIR_OUT_1 =
AIR_FAI_1*AIR_1+(LAND_2*L_A_ALL_2*L_A_EFF_2)*L_A_DEF_1+(AIR_2*A_A_ALL_2*A_A
_EFF_2)*A_A_DEF_1+(STRAT_2*ST_A_ALL_2*ST_A_EFF_2)*ST_A_DEF_1
DEF_MIL_FAC_2 = .15
L_A_ALL_1 = .1
L_A_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((LAND_1*L_A_ALL_1)/AIR_2)
A_A_ALL_1 = .3
A_A_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((AIR_1*A_A_ALL_1)/AIR_2)
ST_A_ALL_1 = .1
ST_A_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((STRAT_1*ST_A_ALL_1)/AIR_2)
LOG_EFF_FAC_1 = .6
LOG_EFF_1 = LOGISTICS_1*LOG_EFF_FAC_1/200
COM_EFF_FAC_1 = .3
COM_EFF_1 = COMM_1*COM_EFF_FAC_1/200
L_A_EFF_1 = .2*(LOG_EFF_1+COM_EFF_1)/2
A_A_EFF_1 = .65*(LOG_EFF_1+COM_EFF_1)/2
ST_A_EFF_1 = .2*(LOG_EFF_1+COM_EFF_1)/2
AIR_OUT_2 =
AIR_FAI_2*AIR_2+(LAND_1*L_A_ALL_1*L_A_EFF_1)*L_A_DEF_2+(AIR_1*A_A_ALL_1*A_A
_EFF_1)*A_A_DEF_2+(STRAT_1*ST_A_ALL_1*ST_A_EFF_1)*ST_A_DEF_2
A_D_ALL_1 = .1
A_D_ALL_2 = .1
A_D_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((AIR_2*A_D_ALL_2)/DEF_MIL_1)
A_D_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((AIR_1*A_D_ALL_1)/DEF_MIL_2)
A_D_EFF_1 = .55*(LOG_EFF_1+COM_EFF_1)/2
A_D_EFF_2 = .55*(COM_EFF_2+LOG_EFF_2)/2
A_E_ALL_1 = .1
A_E_ALL_2 = .1
DEF_CIV_FAC_1 = .2
A_E_DEF_1 = (1-.2*DEF_CIV_FAC_1*DEF_CIV_1)^((A_E_ALL_2*AIR_2)/ECON_1)
DEF_CIV_FAC_2 = .3
A_E_DEF_2 = (1-.1*DEF_CIV_FAC_2*DEF_CIV_2)^((A_E_ALL_1*AIR_1)/ECON_2)
A_E_EFF_1 = .1
A_E_EFF_2 = .1
A_L_ALL_1 = .1
A_L_ALL_2 = .1
A_L_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((A_L_ALL_2*AIR_2)/LAND_1)
A_L_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((A_L_ALL_1*AIR_1)/LAND_2)
A_L_EFF_1 = .5*(COM_EFF_1+LOG_EFF_1)/2
A_L_EFF_2 = .65*(COM_EFF_2+LOG_EFF_2)
A_SU_ALL_1 = .3
A_SU_ALL_2 = .3
```

7.2 List of Equations (In Order of Execution)

```
A_SU_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((AIR_2*A_SU_ALL_2)/(LOGISTICS_1+C
OMM_1))
A_SU_DEF_2 =
(1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((A_SU_ALL_1*AIR_1)/(COMM_2+LOGISTICS_2))
A_SU_EFF_1 = .02
A_SU_EFF_2 = .02
BATTLE_NOBATTLE = 0
PER_COM_YER_1 = .05*(1/12)
COM_FAI_1 = .01
COM_REP_1 = .1
DOL_COM_1 = 20
COMM_IN_1 =
(ECON_1*PER_COM_YER_1)/DOL_COM_1+COM_FAI_1*COM_REP_1*COMM_1
PER_COM_YER_2 = .015*(1/12)
COM_FAI_2 = .01
COM_REP_2 = .1
DOL_COM_2 = 20
COMM_IN_2 =
(ECON_2*PER_COM_YER_2)/DOL_COM_2+COM_FAI_2*COM_REP_2*COMM_2
S_SU_ALL_2 = .1
S_SU_DEF_1 =
(1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((S_SU_ALL_2*SEA_2)/(COMM_1+LOGISTICS_1))
L_SU_ALL_2 = .3
L_SU_DEF_1 =
(1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((L_SU_ALL_2*LAND_2)/(COMM_1+LOGISTICS_1))
ST_SU_ALL_2 = .1
ST_SU_DEF_1 =
(1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_SU_ALL_2*STRAT_2)/(LOGISTICS_1+COMM_1))
ST_SU_EFF_2 = .1
L_SU_EFF_2 = .1
S_SU_EFF_2 = .1
COMM_OUT_1 =
COMM_1*COM_FAI_1+(LAND_2*L_SU_ALL_2*L_SU_EFF_2)*L_SU_DEF_1+(SEA_2*S_SU_A
LL_2*S_SU_EFF_2)*S_SU_DEF_1+(AIR_2*A_SU_ALL_2*A_SU_EFF_2)*A_SU_DEF_1+(STRAT
_2*ST_SU_ALL_2*ST_SU_EFF_2)*ST_SU_DEF_1
S_SU_ALL_1 = .1
S_SU_DEF_2 =
(1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((S_SU_ALL_1*SEA_1)/(COMM_2+LOGISTICS_2))
L_SU_ALL_1 = .3
L_SU_DEF_2 =
(1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((L_SU_ALL_1*LAND_1)/(COMM_2+LOGISTICS_2))
ST_SU_ALL_1 = .1
ST_SU_DEF_2 =
(1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((ST_SU_ALL_1+STRAT_1)/(COMM_2+LOGISTICS_2))
S_SU_EFF_1 = .1
L_SU_EFF_1 = .1
```

7.2 List of Equations (In Order of Execution)

```
ST_SU_EFF_1 = .2
COMM_OUT_2 =
COMM_2*COM_FAI_2+(LAND_1*L_SU_ALL_1*L_SU_EFF_1)*L_SU_DEF_2+(AIR_1*A_SU_A
LL_1*A_SU_EFF_1)*A_SU_DEF_2+(SEA_1*S_SU_ALL_1*S_SU_EFF_1)*S_SU_DEF_2+(STRAT
_1*ST_SU_ALL_1*ST_SU_EFF_1)*ST_SU_DEF_2
PER_CON_ECO_1 = .5*(1/12)
CON_ECO_IN_1 = ECON_1*PER_CON_ECO_1
PER_CON_ECO_2 = .5*(1/12)
CON_ECO_IN_2 = ECON_2*PER_CON_ECO_2
DOL_CON_ECO_1 = 10
CON_ECO_OUT_1 = DOL_CON_ECO_1
DOL_CON_ECO_2 = 10
CON_ECO_OUT_2 = DOL_CON_ECO_2
DEF_CIV_FAI_1 = .01
DEF_CIV_FAI_2 = .01
PER_DEF_YER_1 = .015*(1/12)
MCI_DEF_FRA_1 = .2
DEF_CI_REP_1 = .2
DOL_DEF_1 = 60
DEF_CIV_IN_1 =
(ECON_1*PER_DEF_YER_1*MCI_DEF_FRA_1)/DOL_DEF_1+DEF_CI_REP_1*DEF_CIV_FAI_1*
DEF_CIV_1
PER_DEF_YER_2 = .015*(1/12)
MCI_DEF_FRA_2 = .4
DEF_CI_REP_2 = .2
DOL_DEF_2 = 60
DEF_CIV_IN_2 =
(PER_DEF_YER_2*MCI_DEF_FRA_2*ECON_2)/DOL_DEF_2+DEF_CI_REP_2*DEF_CIV_FAI_2*
DEF_CIV_2
ST_D_ALL_2 = .1
ST_D_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_D_ALL_2*STRAT_2)/DEF_MIL_1)
S_D_ALL_2 = .1
S_D_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((S_D_ALL_2*SEA_2)/DEF_MIL_1)
L_D_ALL_2 = .1
L_D_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((L_D_ALL_2*LAND_2)/DEF_MIL_1)
ST_D_EFF_2 = .25*(COM_EFF_2+LOG_EFF_2)/2
S_D_EFF_2 = .2*(COM_EFF_2+LOG_EFF_2)/2
L_D_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
DEF_CIV_OUT_1 =
DEF_CIV_1*DEF_CIV_FAI_1+(STRAT_2*ST_D_ALL_2*ST_D_EFF_2)*ST_D_DEF_1+(AIR_2*A
_D_ALL_2*A_D_EFF_2)*A_D_DEF_1+(SEA_2*S_D_ALL_2*S_D_EFF_2)*S_D_DEF_1+(LAND_
2*L_D_ALL_2*L_D_EFF_2)*L_D_DEF_1
ST_D_ALL_1 = .1
ST_D_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((STRAT_1*ST_D_ALL_1)/DEF_MIL_2)
S_D_ALL_1 = .1
S_D_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((S_D_ALL_1*SEA_1)/DEF_MIL_2)
```

7.2 List of Equations (In Order of Execution)

L_D_ALL_1 = .1
L_D_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((L_D_ALL_1*LAND_1)/DEF_MIL_2)
ST_D_EFF_1 = .4*(LOG_EFF_1+COM_EFF_1)/2
S_D_EFF_1 = .2*(LOG_EFF_1+COM_EFF_1)/2
L_D_EFF_1 = .1*(LOG_EFF_1+COM_EFF_1)/2
DEF_CIV_OUT_2 =
DEF_CIV_FAI_2*DEF_CIV_2+(ST_D_ALL_1*ST_D_EFF_1*STRAT_1)*ST_D_DEF_2+(A_D_AL
L_1*A_D_EFF_1*AIR_1)*A_D_DEF_2+(S_D_ALL_1*S_D_EFF_1*SEA_1)*S_D_DEF_2+(L_D_A
LL_1*L_D_EFF_1*LAND_1)*L_D_DEF_2
DEF_MIL_FAI_1 = .01
DEF_MIL_FAI_2 = .01
DEF_MIL_REP_1 = .2
DEF_MIL_IN_1 =
(ECON_1*PER_DEF_YER_1*(1-MCI_DEF_FRA_1))/DOL_DEF_1+(DEF_MIL_REP_1*DEF_MIL_
FAI_1*DEF_MIL_1)
DEF_MIL_REP_2 = .15
DEF_MIL_IN_2 =
((1-MCI_DEF_FRA_2)*ECON_2*PER_DEF_YER_2)/DOL_DEF_2+(DEF_MIL_REP_2*DEF_MIL_
FAI_2*DEF_MIL_2)
DEF_MIL_OUT_1 =
DEF_MIL_FAI_1*DEF_MIL_1+(L_D_ALL_2*L_D_EFF_2*LAND_2)*L_D_DEF_1+(S_D_ALL_2*
S_D_EFF_2*SEA_2)*S_D_DEF_1+(A_D_ALL_2*A_D_EFF_2*AIR_2)*A_D_DEF_1+(ST_D_ALL_
2*ST_D_EFF_2*STRAT_2)*ST_D_DEF_1
DEF_MIL_OUT_2 =
DEF_MIL_FAI_2*DEF_MIL_2+(L_D_ALL_1*L_D_EFF_1*LAND_1)*L_D_DEF_2+(S_D_ALL_1*
S_D_EFF_1*SEA_1)*S_D_DEF_2+(A_D_ALL_1*A_D_EFF_1*AIR_1)*A_D_DEF_2+(ST_D_ALL_
1*ST_D_EFF_1*STRAT_1)*ST_D_DEF_2
DOL_LND_1 = 40
DOL_LND_2 = 30
DOL_LOG_1 = 70
DOL_LOG_2 = 70
DOL_SEA_1 = 40
DOL_SEA_2 = 20
DOL_STRAT_1 = 20
DOL_STRAT_2 = 15
RES_FAC_1 = .2
RES_OUT_TOT_1 = RES_FAC_1*.2
PROD_1 = 12
POP_1 = 200
PER_PRO_1 = 10/12
PER_POP_1 = 4/12
RES_PHY_TOT_1 = 5500
PER_RES_YER_1 = .05/12
ECON_IN_1 =
RES_OUT_TOT_1+PROD_1*PER_PRO_1+POP_1*PER_POP_1+RES_PHY_TOT_1*PER_RES_YE
R_1

7.2 List of Equations (In Order of Execution)

```
RES_FAC_2 = .1
RES_OUT_TOT_2 = RES_FAC_2*.25
PROD_2 = 50
POP_2 = 250
PER_PRO_2 = 4/12
PER_POP_2 = 1/12
RES_PHY_TOT_2 = 10000
PER_RES_YER_2 = .05/12
ECON_IN_2 =
RES_OUT_TOT_2+PROD_2*PER_PRO_2+POP_2*PER_POP_2+RES_PHY_TOT_2*PER_RES_YE
R_2
L_E_ALL_2 = .1
L_E_DEF_1 = (1-.2*DEF_CIV_FAC_1*DEF_CIV_1)^((L_E_ALL_2*LAND_2)/ECON_1)
S_E_ALL_2 = .1
S_E_DEF_1 = (1-.1*DEF_CIV_FAC_1*DEF_CIV_1)^((S_E_ALL_2*SEA_2)/ECON_1)
ST_E_ALL_2 = .1
ST_E_DEF_1 = (1-.2*DEF_CIV_FAC_1*DEF_CIV_1)^((ST_E_ALL_2*STRAT_2)/ECON_1)
L_E_EFF_2 = .1
S_E_EFF_2 = .2
ST_E_EFF_2 = .3
PER_LOG_YER_1 = .01*(1/12)
LOG_FAI_1 = .01
LOG_REP_1 = .3
LOGISTICS_IN_1 =
(ECON_1*PER_LOG_YER_1)/DOL_LOG_1+(LOG_FAI_1*LOG_REP_1*LOGISTICS_1)
PER_LND_YER_1 = .015*(1/12)
LAND_REP_1 = .3
LAND_FAI_1 = .02
LAND_IN_1 =
(ECON_1*PER_LND_YER_1)/DOL_LND_1+(LAND_REP_1*LAND_FAI_1*LAND_1)
PER_SEA_YER_1 = .015*(1/12)
SEA_REP_1 = .2
SEA_FAI_1 = .01
SEA_IN_1 =(ECON_1*PER_SEA_YER_1)/DOL_SEA_1+(SEA_1*SEA_REP_1*SEA_FAI_1)
PER_STR_YER_1 = .001*(1/12)
STR_FAI_1 = .01
STR_REP_1 = .5
STRAT_IN_1 =
(ECON_1*PER_STR_YER_1)/DOL_STRAT_1+(STRAT_1*STR_FAI_1*STR_REP_1)
TOT_MIL_DOL_1 =
LOGISTICS_IN_1*DOL_LOG_1+(DEF_CIV_IN_1+DEF_MIL_IN_1)*DOL_DEF_1+LAND_IN_1*
DOL_LND_1+AIR_IN_1*DOL_AIR_1+COMM_IN_1*DOL_COM_1+SEA_IN_1*DOL_SEA_1+ST
RAT_IN_1*DOL_STRAT_1
```

7.2 List of Equations (In Order of Execution)

```
ECON_OUT_1
=CON_ECO_OUT_1+(L_E_ALL_2*L_E_EFF_2*LAND_2)*L_E_DEF_1+(S_E_ALL_2*S_E_EFF_
2*SEA_2)*S_E_DEF_1+(A_E_ALL_2*A_E_EFF_2*AIR_2)*A_E_DEF_1+(ST_E_ALL_2*ST_E_EF
F_2*STRAT_2)*ST_E_DEF_1+TOT_MIL_DOL_1
L_E_ALL_1 = .1
L_E_DEF_2 = (1-.01*DEF_CIV_FAC_2*DEF_CIV_2)^((L_E_ALL_1*LAND_1)/ECON_2)
S_E_ALL_1 = .1
S_E_DEF_2 = (1-.1*DEF_CIV_FAC_2*DEF_CIV_2)^((S_E_ALL_1*SEA_1)/ECON_2)
ST_E_ALL_1 = .1
ST_E_DEF_2 = (1-.025*DEF_CIV_FAC_2*DEF_CIV_2)^((ST_E_ALL_1*STRAT_1)/ECON_2)
L_E_EFF_1 = .1
S_E_EFF_1 = .2
ST_E_EFF_1 = .3
PER_LND_YER_2 = .015*(1/12)
LAND_REP_2 = .3
LAND_FAI_2 = .02
LAND_IN_2 =
(PER_LND_YER_2*ECON_2)/DOL_LND_2+(LAND_REP_2*LAND_FAI_2*LAND_2)
PER_LOG_YER_2 = .01*(1/12)
LOG_FAI_2 = .01
LOG_REP_2 = .3
LOGISTICS_IN_2
=(PER_LOG_YER_2*ECON_2)/DOL_LOG_2+(LOG_FAI_2*LOG_REP_2*LOGISTICS_2)
PER_SEA_YER_2 = .015*(1/12)
SEA_REP_2 = .25
SEA_FAI_2 = .01
SEA_IN_2 = (ECON_2*PER_SEA_YER_2)/DOL_SEA_2+(SEA_2*SEA_REP_2*SEA_FAI_2)
PER_STR_YER_2 = .01*(1/12)
STR_FAI_2 = .01
STR_REP_2 = .2
STRAT_IN_2 =
(ECON_2*PER_STR_YER_2)/DOL_STRAT_2+(STRAT_2*STR_FAI_2*STR_REP_2)
TOT_MIL_DOL_2
=COMM_IN_2*DOL_COM_2+(DEF_CIV_IN_2+DEF_MIL_IN_2)*DOL_DEF_2+LAND_IN_2*D
OL_LND_2+AIR_IN_2*DOL_AIR_2+LOGISTICS_IN_2*DOL_LOG_2+SEA_IN_2*DOL_SEA_2+
STRAT_IN_2*DOL_STRAT_2
ECON_OUT_2 =
CON_ECO_OUT_2+(L_E_ALL_1*L_E_EFF_1*LAND_1)*L_E_DEF_2+(S_E_ALL_1*S_E_EFF_1*
SEA_1)*S_E_DEF_2+(A_E_ALL_1*A_E_EFF_1*AIR_1)*A_E_DEF_2+(ST_E_ALL_1*ST_E_EFF_
1*STRAT_1)*ST_E_DEF_2+TOT_MIL_DOL_2
ST_L_ALL_2 = .1
ST_L_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_L_ALL_2*STRAT_2)/LAND_1)
S_L_ALL_2 = .1
S_L_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((S_L_ALL_2*SEA_2)/LAND_1)
L_L_ALL_2 = .3
L_L_DEF_1 = (1-.05*DEF_MIL_FAC_1*DEF_MIL_1)^((LAND_2*L_L_ALL_2)/LAND_1)
```

7.2 List of Equations (In Order of Execution)

```
L_L_EFF_2 = .1*(COM_EFF_2*LOG_EFF_2)/2
S_L_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
ST_L_EFF_2 = .2*(COM_EFF_2*LOG_EFF_2)/2
LAND_OUT_1 =
LAND_FAI_1*LAND_1+(ST_L_ALL_2*ST_L_EFF_2*STRAT_2)*ST_L_DEF_1+(A_L_ALL_2*A_
L_EFF_2*AIR_2)*A_L_DEF_1+(S_L_ALL_2*S_L_EFF_2*SEA_2)*S_L_DEF_1+(L_L_ALL_2*L_L
_EFF_2*LAND_2)*L_L_DEF_1
L_L_ALL_1 = .3
L_L_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((L_L_ALL_1*LAND_1)/LAND_2)
S_L_ALL_1 = .1
S_L_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((S_L_ALL_1*SEA_1)/LAND_2)
ST_L_ALL_1 = .1
ST_L_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((ST_L_ALL_1*STRAT_1)/LAND_2)
L_L_EFF_1 = .1*(COM_EFF_1+LOG_EFF_1)/2
S_L_EFF_1 = .1*(COM_EFF_1+LOG_EFF_1)/2
ST_L_EFF_1 = .25*(COM_EFF_1+LOG_EFF_1)/2
LAND_OUT_2 =
LAND_FAI_2*LAND_2+(L_L_ALL_1*L_L_EFF_1*LAND_1)*L_L_DEF_2+(S_L_ALL_1*S_L_EF
F_1*SEA_1)*S_L_DEF_2+(A_L_ALL_1*A_L_EFF_1*AIR_1)*A_L_DEF_2+(ST_L_ALL_1*ST_L_
EFF_1*STRAT_1)*ST_L_DEF_2
LOGISTICS_OUT_1 =
LOG_FAI_1*LOGISTICS_1+(L_SU_ALL_2*L_SU_EFF_2*LAND_2)*L_SU_DEF_1+(S_SU_ALL_2
*S_SU_EFF_2*SEA_2)*S_SU_DEF_1+(A_SU_ALL_2*A_SU_EFF_2*AIR_2)*A_SU_DEF_1+(ST_S
U_ALL_2*ST_SU_EFF_2*STRAT_2)*ST_SU_DEF_1
LOGISTICS_OUT_2 =
LOG_FAI_2*LOGISTICS_2+(L_SU_ALL_1*L_SU_EFF_1*LAND_1)*L_SU_DEF_2+(S_SU_ALL_1
*S_SU_EFF_1*SEA_1)*S_SU_DEF_2+(A_SU_ALL_1*A_SU_EFF_1*AIR_1)*A_SU_DEF_2+(ST_S
U_ALL_1*ST_SU_EFF_1*STRAT_1)*ST_SU_DEF_2
PER_POL_YER_1 = .2*(1/12)
PER_POL_YER_2 = .2*(1/12)
POLITICAL_IN_1 = PER_POL_YER_1*.1
POLITICAL_IN_2 = PER_POL_YER_2*.1
RES_IN_1 = .3
RES_IN_2 = .3
RES_IN_TOT_1 = RES_IN_1*.1
RES_IN_TOT_2 = RES_IN_2*.2
S_S_ALL_2 = .3
S_S_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((S_S_ALL_2*SEA_2)/SEA_1)
ST_S_ALL_2 = .1
ST_S_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_S_ALL_2*STRAT_2)/SEA_1)
S_S_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
ST_S_EFF_2 = .25*(COM_EFF_2+LOG_EFF_2)/2
SEA_OUT_1 =
SEA_1*SEA_FAI_1+(S_S_DEF_1*S_S_ALL_2*S_S_EFF_2*SEA_2)+(ST_S_ALL_2*ST_S_DEF_1*
ST_S_EFF_2*STRAT_2)
S_S_ALL_1 = .3
```

7.2 List of Equations (In Order of Execution)

S_S_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)/((S_S_ALL_1*SEA_1)/SEA_2)
ST_S_ALL_1 = .1
ST_S_DEF_2 = (1-.1*DEF_MIL_2*DEF_MIL_FAC_2)^((ST_S_ALL_1*STRAT_1)/SEA_2)
S_S_EFF_1 = .1*(LOG_EFF_1+COM_EFF_1)/2
ST_S_EFF_1 = .25*(LOG_EFF_1+COM_EFF_1)/2
SEA_OUT_2 =
SEA_FAI_2*SEA_2+(S_S_DEF_2*S_S_ALL_1*S_S_EFF_1*SEA_1)+(ST_S_ALL_1*ST_S_DEF_2*
ST_S_EFF_1*STRAT_1)
ST_ST_ALL_2 = .3
ST_ST_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_ST_ALL_2*STRAT_2)/STRAT_1)
ST_ST_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
STRAT_OUT_1 =
(STR_FAI_1*STRAT_1)+(ST_ST_DEF_1*ST_ST_ALL_2*ST_ST_EFF_2*STRAT_2) ST_ST_ALL_1
= .3
ST_ST_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((ST_ST_ALL_1*STRAT_1)/STRAT_2)
ST_ST_EFF_1 = .2*(LOG_EFF_1+COM_EFF_1)/2
STRAT_OUT_2 =
(STR_FAI_2*STRAT_2)+(ST_ST_DEF_2*ST_ST_ALL_1*ST_ST_EFF_1*STRAT_1)
POLITICAL_OUT_1 = graph(ECON_1)
(
0.0,0.0200),(500.00,0.0900),(1000.00,0.150),(1500.00,0.215),(2000.00,0.480),(2500.00,0.480),(3000.
00,0.510),(3500.00,0.500),(4000.00,0.570),(4500.00,0.710),(5000.00,0.905)
POLITICAL_OUT_2 = graph(ECON_2)
(
0.0,0.0200),(300.00,0.420),(600.00,0.430),(900.00,0.460),(1200.00,0.430),(1500.00,0.435),(1800.00,0
.440),(2100.00,0.430),(2400.00,0.430),(2700.00,0.465),(3000.00,0.525)

{Structure equations}
AIR_1 = AIR_1 + dt * (AIR_IN_1 - AIR_OUT_1)
AIR_2 = AIR_2 + dt * (AIR_IN_2 - AIR_OUT_2)
COMM_1 = COMM_1 + dt * (COMM_IN_1 - COMM_OUT_1)
COMM_2 = COMM_2 + dt * (COMM_IN_2 - COMM_OUT_2)
CON_ECO_1 = CON_ECO_1 + dt * (-CON_ECO_OUT_1 + CON_ECO_IN_1)
CON_ECO_2 = CON_ECO_2 + dt * (-CON_ECO_OUT_2 + CON_ECO_IN_2)
DEF_CIV_1 = DEF_CIV_1 + dt * (DEF_CIV_IN_1 - DEF_CIV_OUT_1)
DEF_CIV_2 = DEF_CIV_2 + dt * (DEF_CIV_IN_2 - DEF_CIV_OUT_2)
DEF_MIL_1 = DEF_MIL_1 + dt * (-DEF_MIL_OUT_1 + DEF_MIL_IN_1)
DEF_MIL_2 = DEF_MIL_2 + dt * (-DEF_MIL_OUT_2 + DEF_MIL_IN_2)
ECON_1 = ECON_1 + dt * (ECON_IN_1 - ECON_OUT_1)
ECON_2 = ECON_2 + dt * (ECON_IN_2 - ECON_OUT_2)
LAND_1 = LAND_1 + dt * (LAND_IN_1 - LAND_OUT_1)
LAND_2 = LAND_2 + dt * (LAND_IN_2 - LAND_OUT_2)
LOGISTICS_1 = LOGISTICS_1 + dt * (LOGISTICS_IN_1 - LOGISTICS_OUT_1)
LOGISTICS_2 = LOGISTICS_2 + dt * (LOGISTICS_IN_2 - LOGISTICS_OUT_2)
POLITICAL_1 = POLITICAL_1 + dt * (POLITICAL_IN_1 - POLITICAL_OUT_1)
POLITICAL_2 = POLITICAL_2 + dt * (POLITICAL_IN_2 - POLITICAL_OUT_2)

7.2 List of Equations (In Order of Execution)

RES_TOT_1 = RES_TOT_1 + dt * (RES_IN_TOT_1 - RES_OUT_TOT_1)
RES_TOT_2 = RES_TOT_2 + dt * (RES_IN_TOT_2 - RES_OUT_TOT_2)
SEA_1 = SEA_1 + dt * (SEA_IN_1 - SEA_OUT_1)
SEA_2 = SEA_2 + dt * (SEA_IN_2 - SEA_OUT_2)
STRAT_1 = STRAT_1 + dt * (STRAT_IN_1 - STRAT_OUT_1)
STRAT_2 = STRAT_2 + dt * (STRAT_IN_2 - STRAT_OUT_2)

{Auxiliary equations}
AIR_IN_1 = (ECON_1*PER_AIR_YER_1)/DOL_AIR_1+AIR_FAI_1*AIR_REP_1*AIR_1
AIR_IN_2 = (ECON_2*PER_AIR_YER_2)/DOL_AIR_2+AIR_FAI_2*AIR_REP_2*AIR_2
L_A_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((L_A_ALL_2*LAND_2)/AIR_1)
A_A_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((A_A_ALL_2*AIR_2)/AIR_1)
ST_A_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_A_ALL_2*STRAT_2)/AIR_1)
COM_EFF_2 = COMM_2*COM_EFF_FAC_2/200
LOG_EFF_2 = LOGISTICS_2*LOG_EFF_FAC_2/200
L_A_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
A_A_EFF_2 = .65*(COM_EFF_2+LOG_EFF_2)/2
ST_A_EFF_2 = .2*(COM_EFF_2+LOG_EFF_2)/2
AIR_OUT_1 =
AIR_FAI_1*AIR_1+(LAND_2*L_A_ALL_2*L_A_EFF_2)*L_A_DEF_1+(AIR_2*A_A_ALL_2*A_A_EFF_2)*A_A_DEF_1+(STRAT_2*ST_A_ALL_2*ST_A_EFF_2)*ST_A_DEF_1
L_A_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((LAND_1*L_A_ALL_1)/AIR_2)
A_A_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((AIR_1*A_A_ALL_1)/AIR_2)
ST_A_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((STRAT_1*ST_A_ALL_1)/AIR_2)
LOG_EFF_1 = LOGISTICS_1*LOG_EFF_FAC_1/200
COM_EFF_1 = COMM_1*COM_EFF_FAC_1/200
L_A_EFF_1 = .2*(LOG_EFF_1+COM_EFF_1)/2
A_A_EFF_1 = .65*(LOG_EFF_1+COM_EFF_1)/2
ST_A_EFF_1 = .2*(LOG_EFF_1+COM_EFF_1)/2
AIR_OUT_2 =
AIR_FAI_2*AIR_2+(LAND_1*L_A_ALL_1*L_A_EFF_1)*L_A_DEF_2+(AIR_1*A_A_ALL_1*A_A_EFF_1)*A_A_DEF_2+(STRAT_1*ST_A_ALL_1*ST_A_EFF_1)*ST_A_DEF_2
A_D_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((AIR_2*A_D_ALL_2)/DEF_MIL_1)
A_D_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((AIR_1*A_D_ALL_1)/DEF_MIL_2)
A_D_EFF_1 = .55*(LOG_EFF_1+COM_EFF_1)/2
A_D_EFF_2 = .55*(COM_EFF_2+LOG_EFF_2)/2
A_E_DEF_1 = (1-.2*DEF_CIV_FAC_1*DEF_CIV_1)^((A_E_ALL_2*AIR_2)/ECON_1)
A_E_DEF_2 = (1-.1*DEF_CIV_FAC_2*DEF_CIV_2)^((A_E_ALL_1*AIR_1)/ECON_2)
A_L_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((A_L_ALL_2*AIR_2)/LAND_1)
A_L_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((A_L_ALL_1*AIR_1)/LAND_2)
A_L_EFF_1 = .5*(COM_EFF_1+LOG_EFF_1)/2
A_L_EFF_2 = .65*(COM_EFF_2+LOG_EFF_2)
A_SU_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((AIR_2*A_SU_ALL_2)/(LOGISTICS_1+COMM_1))
A_SU_DEF_2 =
(1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((A_SU_ALL_1*AIR_1)/(COMM_2+LOGISTICS_2))

7.2 List of Equations (In Order of Execution)

```
COMM_IN_1 =
(ECON_1*PER_COM_YER_1)/DOL_COM_1+COM_FAI_1*COM_REP_1*COMM_1
COMM_IN_2 =
(ECON_2*PER_COM_YER_2)/DOL_COM_2+COM_FAI_2*COM_REP_2*COMM_2
S_SU_DEF_1 =
(1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((S_SU_ALL_2*SEA_2)/(COMM_1+LOGISTICS_1))
L_SU_DEF_1 =
(1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((L_SU_ALL_2*LAND_2)/(COMM_1+LOGISTICS_1))
ST_SU_DEF_1 =
(1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_SU_ALL_2*STRAT_2)/(LOGISTICS_1+COMM_1))
COMM_OUT_1 =
COMM_1*COM_FAI_1+(LAND_2*L_SU_ALL_2*L_SU_EFF_2)*L_SU_DEF_1+(SEA_2*S_SU_A
LL_2*S_SU_EFF_2)*S_SU_DEF_1+(AIR_2*A_SU_ALL_2*A_SU_EFF_2)*A_SU_DEF_1+(STRAT
_2*ST_SU_ALL_2*ST_SU_EFF_2)*ST_SU_DEF_1
S_SU_DEF_2 =
(1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((S_SU_ALL_1*SEA_1)/(COMM_2+LOGISTICS_2))
L_SU_DEF_2 =
(1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((L_SU_ALL_1*LAND_1)/(COMM_2+LOGISTICS_2))
ST_SU_DEF_2 =
(1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((ST_SU_ALL_1+STRAT_1)/(COMM_2+LOGISTICS_2))
COMM_OUT_2 =
COMM_2*COM_FAI_2+(LAND_1*L_SU_ALL_1*L_SU_EFF_1)*L_SU_DEF_2+(AIR_1*A_SU_A
LL_1*A_SU_EFF_1)*A_SU_DEF_2+(SEA_1*S_SU_ALL_1*S_SU_EFF_1)*S_SU_DEF_2+(STRAT
_1*ST_SU_ALL_1*ST_SU_EFF_1)*ST_SU_DEF_2
CON_ECO_IN_1 = ECON_1*PER_CON_ECO_1
CON_ECO_IN_2 = ECON_2*PER_CON_ECO_2
CON_ECO_OUT_1 = DOL_CON_ECO_1
CON_ECO_OUT_2 = DOL_CON_ECO_2
DEF_CIV_IN_1 =
(ECON_1*PER_DEF_YER_1*MCI_DEF_FRA_1)/DOL_DEF_1+DEF_CI_REP_1*DEF_CIV_FAI_1*
DEF_CIV_1
DEF_CIV_IN_2 =
(PER_DEF_YER_2*MCI_DEF_FRA_2*ECON_2)/DOL_DEF_2+DEF_CI_REP_2*DEF_CIV_FAI_2*
DEF_CIV_2
ST_D_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_D_ALL_2*STRAT_2)/DEF_MIL_1)
S_D_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((S_D_ALL_2*SEA_2)/DEF_MIL_1)
L_D_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((L_D_ALL_2*LAND_2)/DEF_MIL_1)
ST_D_EFF_2 = .25*(COM_EFF_2+LOG_EFF_2)/2
S_D_EFF_2 = .2*(COM_EFF_2+LOG_EFF_2)/2
L_D_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
DEF_CIV_OUT_1 =
DEF_CIV_1*DEF_CIV_FAI_1+(STRAT_2*ST_D_ALL_2*ST_D_EFF_2)*ST_D_DEF_1+(AIR_2*A
_D_ALL_2*A_D_EFF_2)*A_D_DEF_1+(SEA_2*S_D_ALL_2*S_D_EFF_2)*S_D_DEF_1+(LAND_
2*L_D_ALL_2*L_D_EFF_2)*L_D_DEF_1
ST_D_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((STRAT_1*ST_D_ALL_1)/DEF_MIL_2)
S_D_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((S_D_ALL_1*SEA_1)/DEF_MIL_2)
```

7.2 List of Equations (In Order of Execution)

L_D_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((L_D_ALL_1*LAND_1)/DEF_MIL_2)
ST_D_EFF_1 = .4*(LOG_EFF_1+COM_EFF_1)/2
S_D_EFF_1 = .2*(LOG_EFF_1+COM_EFF_1)/2
L_D_EFF_1 = .1*(LOG_EFF_1+COM_EFF_1)/2
DEF_CIV_OUT_2 =
DEF_CIV_FAI_2*DEF_CIV_2+(ST_D_ALL_1*ST_D_EFF_1*STRAT_1)*ST_D_DEF_2+(A_D_AL
L_1*A_D_EFF_1*AIR_1)*A_D_DEF_2+(S_D_ALL_1*S_D_EFF_1*SEA_1)*S_D_DEF_2+(L_D_A
LL_1*L_D_EFF_1*LAND_1)*L_D_DEF_2
DEF_MIL_IN_1 =
(ECON_1*PER_DEF_YER_1*(1-MCI_DEF_FRA_1))/DOL_DEF_1+(DEF_MIL_REP_1*DEF_MIL_
FAI_1*DEF_MIL_1)
DEF_MIL_IN_2 =
((1-MCI_DEF_FRA_2)*ECON_2*PER_DEF_YER_2)/DOL_DEF_2+(DEF_MIL_REP_2*DEF_MIL_
FAI_2*DEF_MIL_2)
DEF_MIL_OUT_1 =
DEF_MIL_FAI_1*DEF_MIL_1+(L_D_ALL_2*L_D_EFF_2*LAND_2)*L_D_DEF_1+(S_D_ALL_2*
S_D_EFF_2*SEA_2)*S_D_DEF_1+(A_D_ALL_2*A_D_EFF_2*AIR_2)*A_D_DEF_1+(ST_D_ALL_
2*ST_D_EFF_2*STRAT_2)*ST_D_DEF_1
DEF_MIL_OUT_2 =
DEF_MIL_FAI_2*DEF_MIL_2+(L_D_ALL_1*L_D_EFF_1*LAND_1)*L_D_DEF_2+(S_D_ALL_1*
S_D_EFF_1*SEA_1)*S_D_DEF_2+(A_D_ALL_1*A_D_EFF_1*AIR_1)*A_D_DEF_2+(ST_D_ALL_
1*ST_D_EFF_1*STRAT_1)*ST_D_DEF_2
RES_OUT_TOT_1 = RES_FAC_1*.2
ECON_IN_1 =
RES_OUT_TOT_1+PROD_1*PER_PRO_1+POP_1*PER_POP_1+RES_PHY_TOT_1*PER_RES_YE
R_1
RES_OUT_TOT_2 = RES_FAC_2*.25
ECON_IN_2 =
RES_OUT_TOT_2+PROD_2*PER_PRO_2+POP_2*PER_POP_2+RES_PHY_TOT_2*PER_RES_YE
R_2
L_E_DEF_1 = (1-.2*DEF_CIV_FAC_1*DEF_CIV_1)^((L_E_ALL_2*LAND_2)/ECON_1)
S_E_DEF_1 = (1-.1*DEF_CIV_FAC_1*DEF_CIV_1)^((S_E_ALL_2*SEA_2)/ECON_1)
ST_E_DEF_1 = (1-.2*DEF_CIV_FAC_1*DEF_CIV_1)^((ST_E_ALL_2*STRAT_2)/ECON_1)
LOGISTICS_IN_1 =
(ECON_1*PER_LOG_YER_1)/DOL_LOG_1+(LOG_FAI_1*LOG_REP_1*LOGISTICS_1)
LAND_IN_1 =
(ECON_1*PER_LND_YER_1)/DOL_LND_1+(LAND_REP_1*LAND_FAI_1*LAND_1)
SEA_IN_1 =(ECON_1*PER_SEA_YER_1)/DOL_SEA_1+(SEA_1*SEA_REP_1*SEA_FAI_1)
STRAT_IN_1 =
(ECON_1*PER_STR_YER_1)/DOL_STRAT_1+(STRAT_1*STR_FAI_1*STR_REP_1)
TOT_MIL_DOL_1 =
LOGISTICS_IN_1*DOL_LOG_1+(DEF_CIV_IN_1+DEF_MIL_IN_1)*DOL_DEF_1+LAND_IN_1*
DOL_LND_1+AIR_IN_1*DOL_AIR_1+COMM_IN_1*DOL_COM_1+SEA_IN_1*DOL_SEA_1+ST
RAT_IN_1*DOL_STRAT_1

7.2 List of Equations (In Order of Execution)

ECON_OUT_1
=CON_ECO_OUT_1+(L_E_ALL_2*L_E_EFF_2*LAND_2)*L_E_DEF_1+(S_E_ALL_2*S_E_EFF_2*SEA_2)*S_E_DEF_1+(A_E_ALL_2*A_E_EFF_2*AIR_2)*A_E_DEF_1+(ST_E_ALL_2*ST_E_EFF_2*STRAT_2)*ST_E_DEF_1+TOT_MIL_DOL_1
L_E_DEF_2 = (1-.01*DEF_CIV_FAC_2*DEF_CIV_2)^((L_E_ALL_1*LAND_1)/ECON_2)
S_E_DEF_2 = (1-.1*DEF_CIV_FAC_2*DEF_CIV_2)^((S_E_ALL_1*SEA_1)/ECON_2)
ST_E_DEF_2 = (1-.025*DEF_CIV_FAC_2*DEF_CIV_2)^((ST_E_ALL_1*STRAT_1)/ECON_2)
LAND_IN_2 =
(PER_LND_YER_2*ECON_2)/DOL_LND_2+(LAND_REP_2*LAND_FAI_2*LAND_2)
LOGISTICS_IN_2
=(PER_LOG_YER_2*ECON_2)/DOL_LOG_2+(LOG_FAI_2*LOG_REP_2*LOGISTICS_2)
SEA_IN_2 = (ECON_2*PER_SEA_YER_2)/DOL_SEA_2+(SEA_2*SEA_REP_2*SEA_FAI_2)
STRAT_IN_2 =
(ECON_2*PER_STR_YER_2)/DOL_STRAT_2+(STRAT_2*STR_FAI_2*STR_REP_2)
TOT_MIL_DOL_2
=COMM_IN_2*DOL_COM_2+(DEF_CIV_IN_2+DEF_MIL_IN_2)*DOL_DEF_2+LAND_IN_2*DOL_LND_2+AIR_IN_2*DOL_AIR_2+LOGISTICS_IN_2*DOL_LOG_2+SEA_IN_2*DOL_SEA_2+STRAT_IN_2*DOL_STRAT_2
ECON_OUT_2 =
CON_ECO_OUT_2+(L_E_ALL_1*L_E_EFF_1*LAND_1)*L_E_DEF_2+(S_E_ALL_1*S_E_EFF_1*SEA_1)*S_E_DEF_2+(A_E_ALL_1*A_E_EFF_1*AIR_1)*A_E_DEF_2+(ST_E_ALL_1*ST_E_EFF_1*STRAT_1)*ST_E_DEF_2+TOT_MIL_DOL_2
ST_L_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_L_ALL_2*STRAT_2)/LAND_1)
S_L_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((S_L_ALL_2*SEA_2)/LAND_1)
L_L_DEF_1 = (1-.05*DEF_MIL_FAC_1*DEF_MIL_1)^((LAND_2*L_L_ALL_2)/LAND_1)
L_L_EFF_2 = .1*(COM_EFF_2*LOG_EFF_2)/2
S_L_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
ST_L_EFF_2 = .2*(COM_EFF_2*LOG_EFF_2)/2
LAND_OUT_1 =
LAND_FAI_1*LAND_1+(ST_L_ALL_2*ST_L_EFF_2*STRAT_2)*ST_L_DEF_1+(A_L_ALL_2*A_L_EFF_2*AIR_2)*A_L_DEF_1+(S_L_ALL_2*S_L_EFF_2*SEA_2)*S_L_DEF_1+(L_L_ALL_2*L_L_EFF_2*LAND_2)*L_L_DEF_1
L_L_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((L_L_ALL_1*LAND_1)/LAND_2)
S_L_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)^((S_L_ALL_1*SEA_1)/LAND_2)
ST_L_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((ST_L_ALL_1*STRAT_1)/LAND_2)
L_L_EFF_1 = .1*(COM_EFF_1+LOG_EFF_1)/2
S_L_EFF_1 = .1*(COM_EFF_1+LOG_EFF_1)/2
ST_L_EFF_1 = .25*(COM_EFF_1+LOG_EFF_1)/2
LAND_OUT_2 =
LAND_FAI_2*LAND_2+(L_L_ALL_1*L_L_EFF_1*LAND_1)*L_L_DEF_2+(S_L_ALL_1*S_L_EFF_1*SEA_1)*S_L_DEF_2+(A_L_ALL_1*A_L_EFF_1*AIR_1)*A_L_DEF_2+(ST_L_ALL_1*ST_L_EFF_1*STRAT_1)*ST_L_DEF_2
LOGISTICS_OUT_1 =
LOG_FAI_1*LOGISTICS_1+(L_SU_ALL_2*L_SU_EFF_2*LAND_2)*L_SU_DEF_1+(S_SU_ALL_2*S_SU_EFF_2*SEA_2)*S_SU_DEF_1+(A_SU_ALL_2*A_SU_EFF_2*AIR_2)*A_SU_DEF_1+(ST_SU_ALL_2*ST_SU_EFF_2*STRAT_2)*ST_SU_DEF_1

7.2 List of Equations (In Order of Execution)

LOGISTICS_OUT_2 =
LOG_FAI_2*LOGISTICS_2+(L_SU_ALL_1*L_SU_EFF_1*LAND_1)*L_SU_DEF_2+(S_SU_ALL_1*S_SU_EFF_1*SEA_1)*S_SU_DEF_2+(A_SU_ALL_1*A_SU_EFF_1*AIR_1)*A_SU_DEF_2+(ST_SU_ALL_1*ST_SU_EFF_1*STRAT_1)*ST_SU_DEF_2
POLITICAL_IN_1 = PER_POL_YER_1*.1
POLITICAL_IN_2 = PER_POL_YER_2*.1
RES_IN_TOT_1 = RES_IN_1*.1
RES_IN_TOT_2 = RES_IN_2*.2
S_S_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((S_S_ALL_2*SEA_2)/SEA_1)
ST_S_DEF_1 = (1-.1*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_S_ALL_2*STRAT_2)/SEA_1)
S_S_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
ST_S_EFF_2 = .25*(COM_EFF_2+LOG_EFF_2)/2
SEA_OUT_1 =
SEA_1*SEA_FAI_1+(S_S_DEF_1*S_S_ALL_2*S_S_EFF_2*SEA_2)+(ST_S_ALL_2*ST_S_DEF_1*ST_S_EFF_2*STRAT_2)
S_S_DEF_2 = (1-.1*DEF_MIL_FAC_2*DEF_MIL_2)/((S_S_ALL_1*SEA_1)/SEA_2)
ST_S_DEF_2 = (1-.1*DEF_MIL_2*DEF_MIL_FAC_2)^((ST_S_ALL_1*STRAT_1)/SEA_2)
S_S_EFF_1 = .1*(LOG_EFF_1+COM_EFF_1)/2
ST_S_EFF_1 = .25*(LOG_EFF_1+COM_EFF_1)/2
SEA_OUT_2 =
SEA_FAI_2*SEA_2+(S_S_DEF_2*S_S_ALL_1*S_S_EFF_1*SEA_1)+(ST_S_ALL_1*ST_S_DEF_2*ST_S_EFF_1*STRAT_1)
ST_ST_DEF_1 = (1-.2*DEF_MIL_FAC_1*DEF_MIL_1)^((ST_ST_ALL_2*STRAT_2)/STRAT_1)
ST_ST_EFF_2 = .1*(COM_EFF_2+LOG_EFF_2)/2
STRAT_OUT_1 =
(STR_FAI_1*STRAT_1)+(ST_ST_DEF_1*ST_ST_ALL_2*ST_ST_EFF_2*STRAT_2) ST_ST_DEF_2 = (1-.2*DEF_MIL_FAC_2*DEF_MIL_2)^((ST_ST_ALL_1*STRAT_1)/STRAT_2)
ST_ST_EFF_1 = .2*(LOG_EFF_1+COM_EFF_1)/2
STRAT_OUT_2 =
(STR_FAI_2*STRAT_2)+(ST_ST_DEF_2*ST_ST_ALL_1*ST_ST_EFF_1*STRAT_1)
OLITICAL_OUT_1 = graph(ECON_1)
(
0.0,0.0200),(500.00,0.0900),(1000.00,0.150),(1500.00,0.215),(2000.00,0.480),(2500.00,0.480),(3000.00,0.510),(3500.00,0.500),(4000.00,0.570),(4500.00,0.710),(5000.00,0.905)
POLITICAL_OUT_2 = graph(ECON_2)
(
0.0,0.0200),(300.00,0.420),(600.00,0.430),(900.00,0.460),(1200.00,0.430),(1500.00,0.435),(1800.00,0

P.440),(2100.00,0.430),(2400.00,0.430),(2700.00,0.465),(3000.00,0.525)

8. MODEL REQUIREMENTS

8.1 An analyst using the model would require certain types and levels of data to achieve results consummate with that he or she desires. Table 8.1 shows some of the fundamental model and data requirements for a typical analysis run where the analyst is interested in the levels of various military forces at his disposal.

Table 8.1: Model and Data Requirements

1) # OF WEAPONS OR ELEMENTS
2) EFFECTIVENESS OF A WEAPON A ON OPPOSING ELEMENTS
3) SUPPLY REQUIREMENTS OF ELEMENT A
4) SURVIVABILITY OF A DUE TO OTHER FACTORS
5) ATTRITION FROM OPPOSING ELEMENTS
6) COMMAND LINKS AND HIERARCHY
7) DEFENSE FROM ELEMENT K TO DEFEND I FROM J
8) PRODUCTION RATE OF ELEMENT
9) COM LINKS REQUIRED TO OPERATE
10) ECONOMIC EFFECTS OF CONFLICT
11) POLITICAL EFFECTS OF CONFLICT

Figure 8.1 shows where these requirements fit in the overall use and design of a proper scenario for the system.

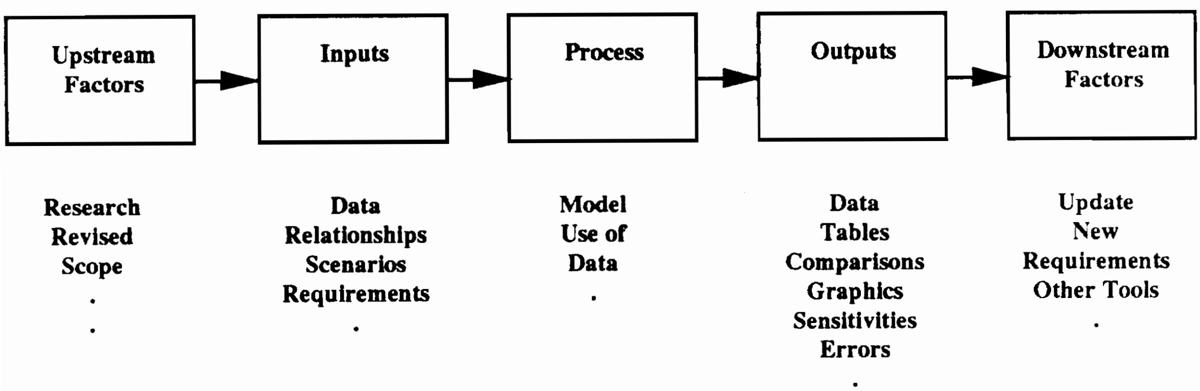

Figure 8.1: Model Requirements on the System Level

9. SOME ANALYSIS GOALS

9.1 Analysis for the project was performed for two primary reasons as described in the main body of text. First during the development of the model, the relationships that were researched and used needed to be verified and analysis in the forms of test runs and performance evaluations showed where variables and key measures of effectiveness could have been in error and were corrected or adjusted. The second primary reason was to show demonstrations of how the model and system definitions would be used in a practical sense.

Table 9.1: Potential List of Analysis Cases

1) FIND EQUILIBRIUM LEVEL
2) ATTRITION RATES OF VARIOUS SYSTEMS OVER TIME
3) MINIMUM NUMBER OF ELEMENTS FOR SUCCESSFUL DEFENSE
4) INCREASE INVESTMENT INTO SOME WEAPONS SYSTEMS
5) DECREASE EFFECTIVENESS OF SOME WEAPONS SYSTEMS
6) ALLOW ONE SIDE TO DOMINATE MILITARILY

In the section 7 of the main report, several charts are provided showing the activity of several variables of the system. Results showing the levels of the major elements are shown for both side 1 and side 2.

10. ENCLOSURES

10.1 Included with this report is one disk which includes the model developed with the STELLA software package. The file is called PROJ5904 Level_1_3. This file includes a copy of the complete model of the system described in this report.