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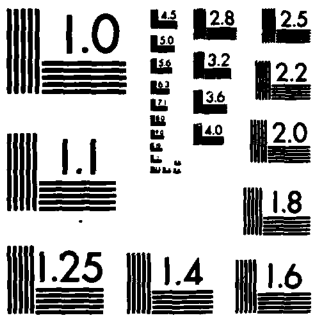

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ARMS TRANSFERS: A SYSTEM DYNAMICS ANALYSIS

FOCUSING ON REGIONAL STABIITY

THESIS

James K. McFetridge
Captain, USAF

AFIT/GOR/OS/83D-8

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ARMS TRANSFERS: A SYSTEM DYNAMICS ANALYSIS FOCUSING ON REGIONAL STABILITY

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science In Operations Research

James K. McFetridge, B.S.

Captain, USAF

December 1983

Approved for public release; distribution unlimited

Preface

This thesis reports the development of an initial attempt to model regional stability with respect to arms transfers. This model is tentative yet encorporates many structures seen in most developing nations. In attempting to encorporate these structures in a comprehensive and useful model, a macro "god's eye " view is taken and high level aggregation used extensively. The importance of this model lies not so much in its findings, or even in its structure, but more so in the comprehensive systems nature of examination of regional stability. Many controversial structures and interrelationships are incorporated in an attempt to broaden the conventional view of stability, and the components contributing to it.

For the reader intersted in the basic structure of the model, Chapter II, and in particular Figure 2.12, provides an overview in terms of causal loop structures. Chapter III provides an in-depth look at the workings of the model, and expands on the basic structures of Chapter II. A quick review of the symbology of system dynamics will aid the interested reader perusing Chapter III.

This thesis is the work of a single mind, aided by others in incountable ways, yet, still containing the biases and perceptions of the author. This model is not an attempt to define absolute truth and implement it in a computer simulation, but rather an attempt to assess stability in new, yet untried ways, incorporating the human and social aspects of a people into the model.

I would like to thank my thesis advisor, Lt Col Thomas D. Clark, Jr., who guided my enthusiastic ramblings to assist me in bring this thesis to fruition. Dr. Joe Cain, my reader, provided me with numerous hours of discussion and forced me to defend and illuminate my ideas to help fill in some of the missing links in the structure, and its operation. Finally, my wife, Mollianne deserves many more thanks than words will express, for it was she who provided support even when all she saw was the back of my head as I intently hammered the keyboard of my computer, Clyde.

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The process of conventional arms transfers, whether it be through outright grant, military aid programs, or sales on the open market has become an integral part of the world political process. Motives espoused for arms transfer actions follow three primary lines; strategic interest, internal influence/political, and economic advantage. Actors in this process may be categorized by level of function as international, national, subnational, or transnational players. The interweaving of actors and motives in the world arms transfer process are a part of a complex and dynamic system. A model is advanced that assesses stability by comparing rates of change of underlying cultural structures with rates of change in embodied technology. The model hypothesizes that arms transfers into a national/regional system may induce increases in instability if the transfer induces additional change in the technology sector. Analysis and construction of a mathematical model develops through the methodology of Systems Dynamics, presenting a model that embodies the precepts of world interdependency and strong regional interrelationships expressed in various feedback loop structures. A mathematical representation of the model using DYNAMO computer code, is used to explore specific arms transfer policy effects in central South America. The transfer of specific arms was found to not increase regional instability.

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Abstract

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ARMS TRANSFERS: A SYSTEM DYNAMICS ANALYSIS FOCUSING ON REGIONAL STABILITY

CHAPTER 1

INTRODUCTION

The process of conventional arms transfers, whether it be through outright grant, military aid programs, or sales on the open market has become an integral part of the world political process. "Arms sales are far more than an economic occurence, a military relationship, or an arms control challenge -- arms sales are foreign policy writ large.(26:3) The very scale of this business is staggering. Conservative estimates for sales alone in 1980 are around $23.7 billion, which is up over 100% from the 1971 level of $11.0 billion.

To many observers the transfer of arms feeds regional instabilities and is the underlying cause for many of the woes of the Third World. They believe that as demands for the newest arms increase, their purchase drains capital that might be otherwise used for development and social programs. A vicious cycle of hopelessness and despair overtakes the people of the nation, which in turn fuels insurrection and the need for more arms by the government structure.

Others see the transfers as a legitimate process, a prerequisite to the conduct of foreign affairs and espouse the transfers on the basis of strategic, political, and economic interests. The issue of the longer term impacts of arms transfers escapes nearly all in their various arguments, and seldom if ever is the substantive issue of stability addressed. In part this stems from the very concept of stability - which at best is tenuous, difficult to express in measurable terms, and highly dependent on the world views of the individual or nation attempting to express the concept.

What then is stability? The Random House College dictionary defines the adjective stable as

> 1. not likely to overturn or collapse. 2.able or likely to continue or last; enduring or permanent. 3. resistant to sudden change or deterioration. 4. reliability and steadiness, as in character, emo tions or attitudes. 5. the ability of an object to maintain or restore its equilibrium when acted upon by forces tending to displace it.(36:1276)

Most individuals have a pretty good idea of a stable object and can recognize one readily; however, in some cases they might have some difficulty determining if the object is truly stable. Examine the situation of an egg set upon an overturned teacup. At a glance it might seem to be stable in its current position. However, closer examination will disclose that it is indeed unstable when applying the definition above, particularly if it is exposed to any external forces. In many ways nation states and regions can be compared to the egg. At first glance they may seem quite stable, however when looking at their infrastructure, they disclose a surprising amount of instability.

One of the major tenents of modern political and sociological theory is that of interconnectedness. Nations do not and cannot rationally exist in the modern world devoid of external influences, or escape the inevitable change that follows. Arms transfers are among one the many forces acting upon the national and regional systems of the world. Attempting to isolate the effect of arms transfers on stability apart from the synergism in the underlying systems is not necessarily effective and may lead to invalid conclusions. Unfortunately, many decisionmakers responsible for the transfers of arms do just this.

Traditionally, decision makers (policy makers) have used the tools at their ready disposal - judgement, intuition, experience, and simple analytical tools. Many sound decisions have resulted from these methods, however the complexity of the interconnected world system itself masks many of the interrelationships existing between components of the system, making it difficult for the decisionmaker to visualize and understand the impact of proposed and current policies. In addition to the direct relationships, complex systems display a complex information feedback structure, adding high order feedback effects throughout the system. (30:6-7)

The study of arms trade, and international affairs in general, concerns itself with the interconnected, interdependent nature of the system in which actions take place. Careful analysts will note the composition of the groups being studied (who), their principle objectives (what), and targets of the activity (why). Traditionally, analysis of arms transfers focuses on the strategic and diplomatic/political aspect of inter-nation activities. Neuman and Harkavy note that

> ... much of the literature still focuses on the mechanics of arms trade. Researchers ... concentrate on one level of analysis or another- domestic or international - failing to to integrate their insight into a broader conceptual framework. (22:vii).

It is clear that the relationships and interactions as seen on the surface of the arms trade imply a deeper relationship within the underlying systems that spawned the arms transfer system. Understanding the structure of these relationships and interactions is necessary to develop appropriate policy for any group dealing within the world arms transfer mechanisms. Quade (27:iii) describes how policymakers and and analysts can work in close concert to develop dynamic policy models that provide not only information, but also a greater understanding of the dynamics of operation of the overall system. Development of a dynamic model focusing on the impact of arms transfers on the stability of a nation and the larger region will provide decision makers with an additional tool in devising rational policies dealing with the impact of the transfer of arms.

Problem Statement

The United States, and many other nations stated policy for arms transfers rests heavily on the concept of stability maintenance, without any determination of a measurable criteria of stability. A dynamic policy model of the arms transfer process incorporating system structure and criteria for stability measurement would enable national decision-makers to study the effects of arms transfer actions on stability within a region or nation over time. This model would also allow decision makers to grasp the dynamic, interconnected nature of the arms transfer process and the nature of the relationships within the system.

Research Question

What is the structure of the the world system that leads to the transfer of arms to maintain national identity and ultimately survival? How can this structure be captured in a dynamic model for use in assessing regional stability? How can this model be used to assess impact of arms transfer policies for use by national decision makers? Specifically:

1. What are the significant relationships internal to a national system that cause it to seek arms as policy for national survival, and how might these relationships be related to a structural model to assess arms-seeking behavior?

2. What are the significant relationships external to a national system that cause the nation to seek arms as a policy of national survival, and how might these relationships be expresssed in the internal structural model to explain arms seeking behavior?

3. What criteria form a basis for assessing national stability and what are the significant relationships internal and external to a national system that tend to draw a nation to stability in light of assumed arms seeking behavior?

4. What criteria form a basis for assessing regional stability, and what are the significant relationships between national entities that tend to draw a region to stability of relations in both the long and short term?

5. How can these relationships be incorporated into a model that will allow national decision makers to evaluate the stability repercussions of conventional arms transfers?

Objectives

The primary objective of this research is to produce a theory-specific, validated structure in which specific policies can be tested and evaluated. Intermediate objectives are to:

1. Synthesize current political science thought concerning arms transfers and regional stability into a coherent world view for construction of a policy model.

2. Develop a policy model of national and regional relationships for analysis of stability in light of assumed arms transfer actions.

3. Verify and validate the model.

4. Use the model to evaluate a specific policy of arms transfers and provide guidance on how this affects regional stability.

5. Provide guidance and instructions on how to use and alter the model for specific policy analysis.

Scope

This research is directed at understanding and modeling regional interactions among nations for use in assessment of regional stability as affected by arms transfers and inventories. Theory development borrows from many diverse sources, and attempts to explain the nature of the dynamic relationship between national interconnectedness, dynamic change, and the role of arms transfers and inventories on system stability. A dynamic model is developed from this theory, and reflects the observation that arms transfers are both instruments causing change and resulting from change-seeking behavior of the national system.

The design model portrays interactions from a "god's eye view", enjoying perfect information and emphasising national level internal aggregation to produce basic structures common to many developing nations. Low levels of aggregation are used only when the particular structure exemplifies a distinct feature of a nation that in itself is critical to the assessment of stability. The model parameters and outputs are designed to show trends that would be associated with the implementation of a particular arms transfer policy. In particular the model reflects a contingency point of view depending heavily on situational variables to assess the impact of the transfer of arms into the regional system. Model time focuses on the relatively near future, 12-18 years hence, with emphasis on assessing trends of future system behavior. In performing this assessment, it is important to note that this model is not designed to predict actual conditions in the future, but rather to extrapolate and expand on current and previously observed behavior in a complex system to assess possible occurences as a result of discrete policy initiatives in the transfer of arms. Furthermore, examination of arms transfer effects on regional stability will focus primarily on regions of developing nations, those nations that have yet to develop the industrial-technical base sufficient to support their arms needs. Stability analysis is conducted on a regional basis, with broad, easily recognized groupings such as the Middle East, Central America, Southeast Asia, South America, and Sub-Saharan Africa used to exemplify regions, and to evaluate stability of the region and of its its constituent states.

This research and design model are not intended to be all comprehensive in expressing all interactions of the international system, but rather it attempts to develop an <u>alternative</u> manner of thinking about the impact of arms transfers on regional stability in light of unique situational variables. Its very design is that of a policy model, designed to help a policy maker assess the impact of discrete policy alternatives on future events.

Background

The world scenario on which the act of transferring arms takes place, is large, complex, and not very well understood.(22:v-vii) Policy makers attempting to assess the impact of a single action of transferring a certain quantity of arms to a particular nation may understand enough of the interactions and interrelationships of the world system to make sound, intuitive decisions that lead to stability in a region, however this is seldom the case. Often decisions are made on the basis of inaccurate information gathered through prejudicial mechanisms, and incorporated into an incomplete or illogical thought processes (2:152). In performing this process, a decision maker depends on models, whether implicit or explicit, conscious or unconscious. Models represent an object, system, or idea in some form other than the entity itself and are present in all decision situations. (34:4) The form of the model is not always clear, often it is no more than a group of random thoughts and perceptions held by the decision maker. When faced with a distinct problem, some decision makers go as far as attempting to explicitly define elements and interrelationships of a mental model in more concrete ways. This model definition may range in sophistication from sketching simple pictures on the back of an envelope to developing sophisticated mathematical equations to be manipulated by high speed digital computers. However, the central purpose of developing a model should be to aid the decision maker in making sound decisions. Elmaghraby identifies five common uses of models :

1. an aid to thought
2. an aid to communication

3. purposes of training and instruction
4. a tool of prediction
5. an aid to experimentation

(34:5)

In examining the overall problem of the impact of transferring arms to country B on its national stability and region ABC's stability, the use of an in-depth model seems quite appropriate. Specifically, the development of a model can help us "organize and sort out hazy concepts and inconsistencies," (34:5) "make the overall structure more comprehensible and reveal important cause and effect relationships," (34:6) and "learn more about internal interactions than we could through manipulation of the real world system itself." (34:7) To adequately perform the task of building an effective policy model, one must investigate the nature of the system in which these transfers take place, the mechanisms that facilitate arms transfer action, and hypothesize the interrelationships to form a rudimentary understanding of a complete system.

Men have been forming models and attempting to justify their use in forming substantive policy concerning arms transfers for a long time.(16:3-4) Some individuals grasp the essential nature of relations in a given time and form workable methods for dealing with the problems of the time. Policy makers deciding on the distribution of arms borrowed, modified, and adapted many seemingly rational models developed to deal with a complex world. With their use, the essential arguments supporting the use of the model, the perceptions of the underlying world system, and the bias of the original authors become a part of the substantive policy of a nation. In the next section, several of the favorite arguments both supporting and decrying the transfer of arms are introduced and critically examined in light of cultural bias.

Philosopy of Arms Transfers

The call for the curtailment of the transfer of arms runs strong through the twentieth century. Peace movements of the late 1800's and early 1900's decried the development of automatic machine guns as "a weapon too terrible to consider" that would certainly lead to the domination of all mankind by the possesor. Krups Arms Works in Germany and other "merchants of death" were raked across the editorial pages in capitals across the world. However, their efforts at curtailment were cut short in the "war to end all wars." Disarmament of the defeated Germany was enforced through the Treaty of Versailles with the implicit notion that a nation without arms would be unable to contemplate war as a political instrument. The isolationist movement of the United States was accompanied by a lull in the production of arms and worldwide depression. Little was heard from the disarmament camps until it became obvious that Nazi Germany and Japan had undertaken massive armament programs and were prepared for war once again. The cries for isolation and appeasement cascaded with the denunciation of all forms of arms. As the cries for disarmament continue today, the sole added argument is that the sales of arms stifles growth in developing countries by diverting funds from development programs. One might wonder if indeed there is anything new under the sun. Despite a recent rising tide of opposition in the western nations against continuing this trade, there is little evidence that the arms transfer process will cease its operations in the forseeable future. In contrast to the largely emotional arguments of the disarmanent advocates, the leaders and policy makers of nearly every country in the world cite elaborate arguments based on four predominant themes: strategic interest, nuclear non-proliferation, political influence, and economic advantage.

Strategic Interest.

The arguments for strategic interest motivated arms sales and transfers are advanced primarily by superpower, hegemony-oriented authors. The essence of their arguments follows a line of reasoning that in the world system, more powerful nation states have interests in the security and stability of allied or friendly nations, due in part to their geographical loction that allows the control of scarce resources or control actions against adversarial nations. Supporting these allies with arms support makes good sense and contributes to a stable world system.

A recent expression of this sentiment was the "Nixon Doctrine",a specific United States policy practiced on a global scale in the early 1970's. This doctrine essentially stated that the United States would not be solely responsible for the security needs of all the "free" world, but would. help its friends and alies hold the line. The United States would aid in the equipping, training, and organizing of internal armed organizations to meet the security needs of the nation involved. Concurrent with the advancement of this doctrine, the United States dramatically decreased its direct military aid programs, and emphasized the outright purchase of arms and military training through the Foreign Military Sales (FMS) program (35). The desired outcome was, and still is the decrease of the expense of American involvement to maintain its strategic worldwide interests. However, certain areas of the world hold considerable strategic interest for Americans, due to, in some cases, economic ties (Middle East oil producers), strategic prepositioning requirements (Republic of the Phillipines), or idealogical commitments (NATO, Republic of Korea). As a result, the United States directly maintains forces, facilities, and stores material in support of these strategic interests. These forces and materials are normally in addition to aid provided to host nations, and are independent of host nation controls. As such, they represent direct involvement in the affairs of the host nation.

Nuclear Non-proliferation.

Also considered under the broad concept of strategic interest is the topic of the non-proliferation of nuclear weapons. This line of argument advances the hypothesis that if advanced conventional arms are not sold to friends and allies (or even potential friends, these developing nations will attempt to develop nuclear weapons to assure national security. (26:29) The Reagan administration in particular has advanced the transfer of sophisticated conventional weapons as a surrogate for the national development of nuclear weapons. This has become a topic for national debate.

Pierre sees this argument as having a fatal flaw in that conventional weapon are no real surrogate for nuclear weapons, as the nuclear weapons impart a sense of "exclusiveness" to the possessors, and that nearly any nation can obtain the benefits of sophisticated conventional weapons with sufficient funds. (26:31) Burt aptly notes that "while new weapons may be able to perform in roles now assigned to nuclear weapons, their ability to replace the elements of psychological deterrence and political commitment stemming from the stationing of nuclear weapons on

Korean soil is questionable." (3:97) He concludes that much more effort in distinguishing between the ability of conventional arms to be substituted in "nuclear roles" versus "nuclear commitments." (3:104) Clearly, the potential for controversy is great. It appears, however, that the uncertainties due to psychological motivations of differing national leaders in the procurement of nuclear weapons will likely preclude any substantial policy developments.

<u>Political Influence</u>.

The argument of political influence or leverage is held in high regard by many espousing internal control of a "lesser" nation state and the concept of bipolar hegemony. The argument implies that the transferral of sophisticated modern weapons will assure influence over the recipient of the arms. Cited in these arguments are the logistic/support requirements of moderns arms (implying an eternal linkage with the producers/suppliers), the prestige factor imparted on the ruler by the mere possession of weapons (implying favor with the superpower and a degree of international recognition), and power over the exercise of foreign policy by the recipient (when warmaking depends on the munificence of the supplier). This approach for arms sales and transfers has a long history of disappointments and policy setbacks. Modern examples of the setbacks include Soviet expulsion from Egypt in 1972, the overthrow of the Shah in Iran in 1979 (largely ending United States influence), and the 1975 evacuation of Saigon (indicating failure of the United States "Vietnamization" program).

Recent embellishments to this argument of influence and control came as a result of President Carter's "Human Rights" embargoes of the late 1970's. The Carter hypothesis advanced the concept that withholding of arms from sales would result in internal national reforms of "human rights" activities. Proponents of this argument are still active in the arms transfer process to this day, however this policy is in large scoffed at by potential recipient nations due to world economic situations and the availability of sophisticated arms on the world market. As a result, this policy has been ineffective in reaching United States goals of reducing arms transfers.

Economics.

The argument of economic viability is held in high esteem by all those who produce arms or who aspire to produce arms for sale on the world market. This argument states briefly that the selling of arms is like any other economic venture, to be undertaken in the pursuit of commerce, and that as such has no moral implications other than that of profit. France has aspired to and held this position since the early post-World War II period by developing a close alliance of government and industry to develop an independent (largely from the United States) arms industry. As a result of this development, France has the third largest export arms sales in the world, behind the United States and the Soviet Union. (16:26) Other arguments supporting the economic nature of arms sales include restoring balance of payments with OPEC petroleum suppliers, maintaining the competitive edge ("if we don't sell it to them, someone else will"), assuring domestic capability of arms production for a potential war, maintaining domestic full employment and contributing to economic independence arguments. The Soviets, in particular, look to the sales of weapons as a tool to obtain scarce foreign currency for technological expansion. Although all major arguments smack of protectionism,the nature of this argument points to the often pervasive nature of global interdependence and the implications that arms sales have in areas apart from the purely military, political,and economic realm.

Clearly, from the depth of these arguments, one could reasonably deduce that arms transfers will continue to be an integral part of an interconnectd world. But what then is the nature of this world environment that spawns such intense competition in the realm of arms transfers.

Interconnection and Arms Transfers.

In no other time since the dawn of recorded history has the world system been so dominated by interconnection and interdependence.(12) There is no one country that could reasonably maintain its current situation and standards of life in isolation from all others. In fact, the hallmarks of our modern world is its sense of interconnection and interdependence. Scarcely can one event take place in any nation without its effect being felt around the globe.

Economically, this interconnection is vividly illustrated by the impact of OPEC and its recent oil embargoes of 1973 and 1975. Even the most isolated nation suddenly found itself in a no-win situation when faced with rising prices for the valuable commodity. When one considers that this embargo was initially triggered as a policy option exercised by the multi-national Arab League in response to the unfavorable situation that Egypt found itself in 36 hours after attacking Israel positions in the 1973 war (39:246) the degree of interconnection and interdependence takes on startling proportions.

From a military perspective, consider this. The recent assasination of Egyptian President Anwar Sadat took place as he stood on a platform fabricated of steel purchased in Japan, reviewing a crack armored batallion trained by the United States Army pass by in American M-60 tanks, while Mirage 3 jet fighters purchased from France passed low overhead. His flanking security guards clutched Israeli-produced machine guns, while his assassin sprayed the platform with a rounds of ammunition from his Chinese copy of the Russian AK-47 attack rifle.(26:12)

Additionally, one finds the world system to be very dynamic with change a basic underlying premise and basis for many expectations. The poor expect to become not-as-poor, and the well-off expect that their standard of living will continue to improve. However there exists a certain logical contradiction in continuous change. "Most men may wish for a more perfect social equilibrium, a few men may consciously act to attain it -- usually by resisting all direct and indirect attempts to modify what has come down from the past." (12:608) It is on the broad canvas of interacting social systems that we see the arms transfer process take place; a subset of intricate interpersonal relations shaped by the underlying values of the individual man. Although man may be conservative in nature, change has been sought by the few "socially deviant individuals acting in asocial ways" (12:609) and has been a prime mover in the development of mankind, and the world system.

Players

Assessing regional or the underlying individual national stability takes on an added dimension of complication when the action of many, diverse forces on a system are considered. Clearly, this very interconnectedness spawns internal change within all participants, and feeds on the growth of technology to maintain its own growth.

The conceptualization of such a complex, interwoven system is in no part an easy task. One cannot always clearly identify actors involved in the processes of arms transfers and sales, and often a single player will assume differing identities contingent on its level of interconnection and communication in the world system. Political scientists have developed a rudimentary scheme for identifying groups of common actors by level of involvement and types of functions observed in the world system . These groups of actors include:

-- International - Players of this group are characterized as a collective body of legitimate nation-states, or nation state representatives united for a common purpose. Groups of this type include the United Nations, NATO, the Common Market, and OPEC. The goals of the individual states making up the collectives lend a distinctive international personality to each. In practice this group has little power without instruments of force or economics contributed voluntarily by the national participants and as a rule, have little power or influence on the conduct of global affairs.

-- National - This group is characterized by the existance of unique nation-states described in terms of its political mechanisms, economic structures, geographical boundaries, and the people that comprise it. Traditionally the major emphasis of analysis of arms transfers has been concentrated on relations among national groups.

-- Subnational - These actors include the large, national private and public bureaucracies (including the military), smaller interest groups, and influential individuals acting within the national setting. The interplay of internal interest groups resulting in national policy determines the direction of the nation state as a whole, particularly in the area of arms transfers.

-- Transnational - This group can be broken into two distinct sub-groups. The first are those multinational corporations or state-run enterprises that are primarily economically oriented towards profit (and arm sales). A large transnational player may also be a subnational player in each local nation-state, however its allegiance and activity are oriented towards the parent corporations and its goals. Examples of such actors include EXXON, Northrop, and SNEMCA. This first group also contains such major international religious, and political organizations such as the Catholic church and the Communist Party. Their role may not be as direct in the actual transfer of weapons, however their impact on popular opinion and belief is substantial and transcends national boundaries.

The other major group of transnational actors includes revolutionary/reactionary movements, which are generally maintained and supported by nations and individuals external to the target country. These groups are characterized by a general lack of international legitimacy, that is they have not been recognized as nation-states in their own in the international community, usually due to lack of geographical definition, or lack legitimate power in the world scheme. Examples of such groups include Irish Republican Army, U.S. supported Nicaraguan guerrillas, PLO, and the Red Brigade. These revolutionary groups hold a most unfavorable image among those seeking to control arms trade, and are often condemned the loudest by the ruling elites. The economic statistics, however, show that these actors are but a small and rather insignificant part of the total arms transfer phenomena, generally posessing only the most rudimentary, and unsophisticated arms.

Background Summary

Identifying the "who" and the "where" in the arms transfer process may indeed be the easiest process of formulating a model for this particualar analysis. Government documents, bills of lading, receipts for purchase are all part of the complicated process of arms transfers and identify the many players involved. Identifying the "why" of the transfer process however, is nowhere nearly as easy a process. Arguments for and against the transfer of arms were examined in light of the development of models for sound decision making. Overall, the individual can be easily overwhelmed by the very volume of information to make policy that serves the national interest. After examining the background of arms transfers, it will be instructive to examine other examples of analysis in the open literature that support a reasoned approach to dealing with arms transfers in light of a world system, and to examine methodologies in approaching this task.

Review of Literature

Overview.

This review looks first at work done at the Air Force Institute of Technology (AFIT) over the past 3 years on the subject of arms trade. These works relied heavily on computerized System Dynamics techniques and met with mixed success. The results of an additional System Dynamics model that attempted to develop a large scale world model are also examined. The next section reviews analytical techniques used to assess stability in warfare and in arms control processes. The final section summarizes several recently advanced concepts on the nature of the arms trade itself, focusing on the human and cultural aspects of the trade process. As a conclusion, a summary of the major concepts is expressed as a series of observations providing direction and impetus for discussion of methodology for model building and the techniques in use for this research.

System Dynamics Techniques.

Several models of the arms transfer process have been proposed and computerized using System Dynamics techniques over the past three years by graduate students at the Air Force Institute of Technology. These efforts are reviewed below.

Chipman and Cunningham, 1979 (4) - This study focused attention on the United States as an arms seller in the international marketplace, and attempted to advance policy alternatives based on a model that extensively divided the United States into decision sectors. The system description included such sectors as the U.S. economic sector, arms production sector, political sector and similar sectors for an aggregated external world. Although a complete computerization of the model was not successful due to computer resource constraints, the richness of complexity in its structure provides a good indication of the bureaucratic complexity involved in selling arms in the United States.

Clark, 1981 (6) - This study built directly on Chipman and Cunningham's earlier work, simplifying some of the structures and mechanisms to achieve a working computerization. This study still focused on the effects that U.S. arms transfers had on the rest of the world, and considered the rest of the world in small regional groupings, making specific requests on the United States. This model did not allow for unilateral actions by the United States in response to strategic considerations, however it did include such variables as national economic enhancement, social and moral advancement, and regional instability.

Nickell, 1982 (25)- This study intended to explore the implications of arms transfers on regional stability, however due to the author's definition of regional stability ("increase in arms sales due to perceived threat")(25:138) the model essentially provided no further definition of the work Chipman, Cunningham, and Clark. A particularly interesting approach of aggregation and averaging was applied to determine characteristics of a world system of 19 distinct regions.

Meadows,1972 (19) - The attempt to model a world system met with extreme criticism and general world attention in 1972 with the presentation of the "WORLD2" model developed by Dennis Meadows for a Club of Rome project. This model took a holistic approach to the behavior of the world as a closed ecosystem identifying such major sectors as world population, capital, available land, non-renewable resources, and pollution.(19) This model approached the system from a Malthusian point of view, negating the possibility of technological advancement, alternative habitats, or energy flows into the ecosystem. The conclusion of this study indicated catastrophic failure of the world system unless policies were undertaken to stabilize the levels of population, pollution, and so forth to achieve an equilibrium condition. The more important conclusion from the perspective of this study is that a large scale dynamic world model is feasible using computer modeling techniques.

Analytical Techniques

The use of analytical mathematical techniques of the traditional operations research field has been restricted generally to force-on-force conflict modeling using the techniques of game theory, stochastic equations, and Lanchester equations. Saaty (32) effectively uses the tools of game theory to describe political conflict situations and methods of accomplishing stable solutions in the disarmament and arms control process. He makes a number of poignant and observations on the nature of international affairs, advancing:

> ...How people differ in their bargaining methods depends on patterns cultivated in games and sports. These patterns are often derived from zero-sum games and applied to bargaining situations with incomplete information (which are nonzero-sum). (32:111)

> ... It is in the nature of countries that are dedicated to games (particularly sports) to develop a highly competitive attitude ... that must be carefully distinguished from aggression. (32:111)

The author extends these basic principles to explore concepts of stability and strategies to achieve stability in simple conflict situations using multiple player, nonzero-sum game theory.(32:163) He additionally advances possible computer applications for use in conflict resolution and developing policies for stability.(32:176). Although many ideas are advanced, the author concludes that the mathematical/analytical framework for in-depth analysis and policy formulation may not be of sufficient sophistication to deal adequately with more than two distinct players at a given time.

In contrast to Saaty's conclusions are the findings of Soviet operations researchers published in Forecasting In Military Affairs: A Soviet View (5). The integration of sophisticated analytical mathematical models into their military (and assumed political) processes provides decision makers with a previously explored set of solution techniques to achieve victory or at least minimize potential loses. The current thought of these individuals is that all actions can be quantified in some manner and subjected to rigorous scientific examination. From this quantification an optimum strategy (policy) can be found accomplishing the goals of the nation. Stability is numerically defined in terms of correlation of forces and quantifications of the will to continue. The development of mathematical methods concurs with the thoughts of modern Marxism-Leninism, in that

> The laws of the external world, of nature,... 'form the basis of the goal directed activities of

man.' ... Thus the existence of laws in the evolution of nature and society forms the basis for scientific forecasting. (5:63)

The overall impression gained from this work is that the Soviets are actively pursuing avenues of research including game theoretics,and Lanchester equations to develop policies leading to victory when the correlation of forces is to their advantage, or stability when an error has been made or the situation warrants.

Recent Dynamic Approaches

The preponderance of recent literature on arms trade and control is heavily biased towards the nature and volume of trade, about its "geting out of hand", and about "revolutionary" new weapons that threaten to disrupt world stability. Yet, a review of earlier arms trade literature of the 1930's and 1890's is surprisingly similar and makes one wonder if there is indeed anything new under the sun.(23:319) Precepts and guidelines for stability exercised by the United States in the past century have included such diverse thought and practice as:

- Monroe Doctrine,
- "War-to-end-all-wars,"
- Wilsonian "League of Nations,"
- Protectionism,
- "Lend-Lease",
- World War II,
- Marshall Plan,
- Containment,
- NATO,SEATO,CENTO,
- MAD,
- Mutual Deterrence,
- Nuclear non-proliferation,
- SALT
- Nixon Doctrine,
- Carter Doctrine,
- Mutually Balanced Force Reductions, and
- START.

A vital shortcoming of each of these policies for stability is that none really provided the decision maker with a well-defined, or quantifiable, action-leading-to-behavior model establishing decision structures for rational policy development. In particular, the practice of policy making has tended to focus on one level of analysis when several levels may be operable.

In general, these policies fall into two broad categories, those working from a domestic perspective and those responding to only international strategic balances and weapons counts. Across the board they fail to examine the larger theoretical questions in their assumptions of the international behavior of national systems and national immunity to a larger world system. (22:vii) There have been few assessments by policy makers after the actual policy implementation attempting to quantify or assess stability repercussions of the policy in the field. Analysis of actual achievements has largely been selectively applied when a policy proved successful, and hidden away like dirty laundry when less than sucessful. (When was the last time anyone saw an anlysis pointing to the overwhelming success of the Monroe Doctrine, or the League of Nations?)

An exception to the generalized linear policy making and implementation has been in the realm of nuclear arms limitations policies. Stability is traditionally assessed by counting weapons, with feedback of compliance immediately provided to the decision makers , particularly when the other side was cheating.

The nature of policy in the United States, and throughout the world, indicates that many leaders hold to open-loop, non-feedback oriented, internally held world models.(23:219) As long as expansion is possible, and there exists room for error in the system, this orientation is satisfactory. Implementing simplistic solutions without understanding the nature of the system and the structure that contributes to problems is largely unproductive and may lead to unexpected results, particularly when examined in light of counterintuitive systems behavior. (34:37)

Recent publications citing the need for a unified, interconnected systematic approach to arms transfer processes abound. Some authors [Neuman (23), Benoit(23:220), and Einaudi (23:220)] have gone as far as to suggest that arms transfers are not necessarily malevolent, and that the process may have positive spinoffs of technology transfer, educational development, and bolstering of GNP. Neuman, in particular, uses a systems point of view, conceiving states as integrated systems, with actions in one sector affecting other sectors as well, and makes important hypothesis' concerning the nature of arms trade and impacts on the individual nation state. The major tenents of her developed model include:

> 1. Development is an untidy, complex process. It can thought of as a seies of circles in which improved levels of living and knowledge lead to higher productivity, and high productivity in turn leads to higher levels of living. A stable internal and external environment is necessary at key stages of the process for positive, rather than negative, growth to occur.
>
> 2. Catalysts for change come from many sectors of society, not just the industrial sector.
>
> 3. Employment, economic trade activity, and GNP per capita are indicators of regional and national socioeconomic growth.
>
> 4. Skilled manpower, infrastructure, and industrial productivity closely related to the

development process. Changes in these factors will be reflected in socioeconomic indicators of growth.

5. In the long run, regardless of sector, development strategies which produce skilled manpower, build infrastructure, and create demand for domes ic industrial products will generate positive growth consequences for the society as a whole.

6. The technological sophistication of arms transfers determine the impact that they have on society. The particular socioeconomic system determines the absorbtive capacity of the military. Over time, societal feedback into the military sector determines dollar value and technological sophistication for future arms procurements.

7. Arms transfers can, if rationally planned, contribute to the economic growth and productivity of developing countries.

8. Learning what mix of military technology is best suited to the developmental needs of different societies, and how they can make the best developmental use of it, may help Third World leaders establish rational policy and procurement policies, aid U.S policy makers to formulate consistent arms-transfer programs and, in the long run, contribute to a pragmatic and receptive arms-control climate in the Third World. (23:234)

This series of propositions fares well when tested intuitively and may well be among the most rational and sane course for the interconnected world system. In addition to these propositions, Neuman develops a rudimentary causal loop diagram showing the relationships advanced in her propositions, and provides a good framework for future investigation. Causal loop diagrams are designed to explain interactions between two or more variables in a dynamic system, with action-response behavior taken between two variables taken one at a time.* By explicitly

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* The specifics of causal loop diagrams, their use, and construction is addressed in Chapter II. Specific examples are provided, and the methodology illustrated. For more information see Richardson and Pugh (30).

stating behavior of system variables, a decision maker can explore system ramifications of specific policy actions within a formalized model.

Stephen Rosen explored the effects of assymetrical proliferation on regional stability with respect to inclusion of new, sophisticated land-based arms technology. He envisions the global arms transfer phenomena as system characterized "by patterns of structural stategic dependancy not unlike the relationships of structural economic dependancy." (31:110) He observes that the driving forces of current conventional arms research and development stem primarily from superpower and major power desires to affect the European military balance and global superpower strategic balance. Arms transfer to developing nations occurs as a peripheral, "spillover" of the Eurocentric system. In addition to discussing the potential impact of specific types of developing technologies on the conduct of war, Rosen stresses the importance of the human factor in battle. His argument essentially states that although the quality and sophistication of arms possessed by potential adversaries factors strongly into relative military strength ,the human factor is often overlooked, and is a strong determinant of relative strength. He argues that

> ... a considerable body of historical evidence points to the conclusion that sound training, well-considered tactics, and the individual competence of personnel have a much greater effect on combat outcomes than any normal differences in weapons hardware.(31:126)

He additionally stresses the importance of Malcolm Currie's argument that

> ...a technological breakthrough or surprise is less likely to take the form of an unforseen new

> weapon per se than of an innovative use of a known technology on the basis of a superior understanding of its ultimate significance on the battlefield.-(31:126)

He concludes that any attempts by exporting nations to control the proliferation of conventional arms by not exporting, will simply add another random element into an already confused situation and that the results may be even less pleasing than the current situation.

In his extensive review of the arms sales phenomena , Pierre (26) makes some excellent generalizations concerning trends of arms trades and attempts to strike some balances, particularly from a United States point of view. He lays out many of the dilemmas facing exporters of arms. In particular, he observes that many nations that have been exporting to retain influence over another nation's internal affairs are finding themselves under the influence of the importer. He also makes such observations that arms by themselves do not cause wars, but that wars come as a result of a widely connected system of which the arms are but a small part.(26:5) His political considerations of the arms trade sy=tem emphasize the human dimension in the process, however he attempts to support all his reasons and rationale for arms trade and possible control with purely policical considerations. His arguments at times tend to lose touch with the human element, and forget that political power is not by itself an end to a means, but rather an instrument used by men in complex relationships.

Conclusions

The review of current literature indicates some points that should be considered before embarking on an investigation into the world arms trade process. These points are summarized below.

1. The world is a complicated, interconnected system with no easily discerned solutions to any problem. The individuals that have the best success in illuminating and explaining the world tend to have a systematic form of analysis and expression.

2. Pure applicaton of analytical mathematics presents difficulties in explaining complex systems as the modeling process often isolates the system from the model to allow the abstraction required by these techniques. Serious application of mathematics to systems analysis can do much to aid the decision maker, however the system must first be understood in sufficient depth assuring that its behavior is accurately represented mathematically.

3. When a system is modeled mathematically, either using analytical or simulation techniques, the results reflect the lowest level of sophistication of the model and as such carry the weaknesses and strengths of the assumptions underlying the model. The most sophisticated model built on faulty assumptions is no better than a simple intuitive model using "guess-timation" techniques.

4. The perceived problems of proliferation of conventional arms trade is symptomatic of periods preceeding large scale regional war. The cry for control of arms appears to be a cry more for control of a system that is perceived to be without direction other than destruction. Understanding the processes that lead to the arms trade is of more importance than understanding the mechanics of arms trade for setting

any policy.

5. When all is said and done, the whole process distills to people in the national setting: their needs, fears, hopes, dreams, and aspirations are all important. Those groups with greater vision and the will to keep that vision to completion, triumph, and in the process grow stronger, intellectually and technically as a people. People do make the difference in every endeavor.

The background investigation and literature review indicates that the arms transfer phenomena is both part and parcel of a large, complex, and very dynamic world system. Regional stability assessment in such a system will need to account for interactions among neighboring nations, interactions internal to the nations comprising a region, and differences in national character to explain behavior. Any problem-solving approach that assesses regional stability should encompass these system traits, and explicitly allow a decision maker the latitude of experimentation to determine a good course of action. When possible, graphic representations leading to quantification of essential problem elements should be used, as not only an aid to examining relevant portions of the global system, but also as an aid in communicating to others model hypotheses and assumptions in a clear, unambiguous manner.

Given the requirements of the problem solving technique in addressing this specific problem, the next section describes a methodology appropriate to the task. Specifically, methodology selection is justified with respect to the problem, the major framework and specific steps of analysis using this technique are discussed, and an initial plan for application of the methodology is introduced for assesment of regional stability with respect to transfer of arms.

Methodology

The specific criteria for selection of a problem solving technique described in the last section led to the selection of the methodology of System Dynamics. System Dynamics addresses problems from two perspectives. First, problems are dynamic: they involve variable quantities which change over time. Second, problems involve the notion of feedback: they include processes that serve to alter or reinforce the character of those very processes.(30:1-2) The System Dynamics approach explicitly uses formal computer models, and a precise symbology to express the model structure. System Dynamics methodology design facilitates the handling of large, intricate models of complex systems, such as found in the process of arms transfers and assessment of regional stability.

In addition to meeting specific criteria, this methodology allows a decisionmaker to first gain an intuitive feel for the system being modeled through causal diagramming, and then receive empirical data based on his conceptual model using a mathematical representation of the structures and relationships in the model. The flexibility of this methodology allows policy experimentation for any phase of the model, and will reinforce and bring further insight to the decisionmakers perceptions of the system. In particular, this capability allows analysis of regional stability using modifications of input variable values, decision structures, and information feedback structures.

The use of System Dynamics has been proven an effective modeling technique in such large scale models as the Club of Rome WORLD series, RAND-New York's urban crisis model, and has been used with some success at the Air Force Institute of Technology in modeling U.S. Air Force acquisition and logistic systems.(38,6,25,19)

The System Dynamics Approach

System Dynamics was introduced by Jay W. Forrester at Massachusetts Institute of Technology in the late 1950's in his text, Industrial Dynamics.(30:13) This methodology encompassed the relatively new systems approach of analysis and included Forrester's personal observations of feedback structures that control levels of information or material through rate devices, in a manner very similar to electronic circuitry. In this and later texts, Forrester, and Richardson and Pugh describe System Dynamics as a problem solving approach with applications in policy analysis. Essentially their approach entails examining a system holistically and determining the flows of both information and material among its distinguishable parts (34:124). System Dynamics deals with systems that are closed loop, in which flow across the system boundary is not a function of the behavior being investigated within the system. Internal to every system are multiple, interactive feedback loops that cause characteristic system behavior. System Dynamics uses stylized models known as flow diagrams to explicitly show perceived relationships of situational variables of any dynamic model. Model development focuses on the determination of levels, rates, material flows, information links and decision structures in a structural feedback system. In this methodology, levels are used to represent accumulations in the feedback structure, invoking the imagery of a level of liquid accumulating in a

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* For a review/introduction to the System Dynamics symbology, DYNAMO rate equations, and methodology, see Richardson and Pugh (30).

container. Flows increasing and decreasing a level are called <u>rates</u>, and are controlled by decision structures and information links internal to the system.(30:31) From the structure of feedback loops, rate and level variables representing the interactive dynamics of the system, behavior of the conceptualized system can be simulated by mathematical modeling in a computer language such as DYNAMO. (34:125) Table 1.1 contains the explicit steps of the system dynamics approach given by Forrester (38:13) and Richardson and Pugh (30:27).

After the initial development of a conceptual model, modification can be used to refine and better define the model of the system, or to explore implications of different decision structures, policies, or input variable values on the behavior of the system. The process of System Dynamics can be expressed as a relational diagram as in Figure 1.1.

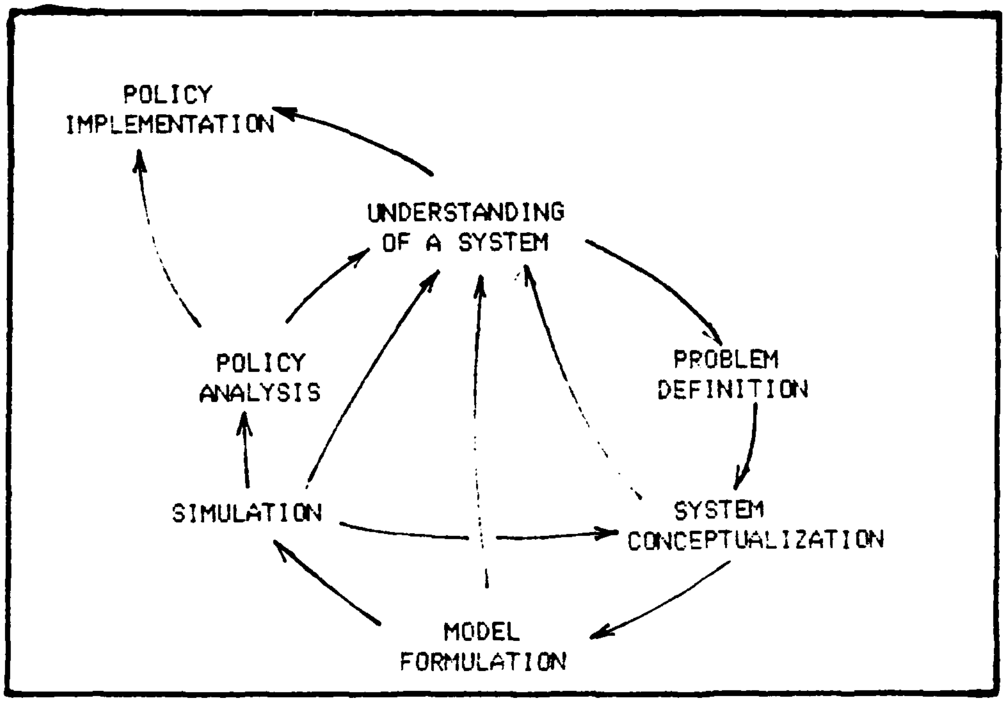

FIGURE 1.1 SYSTEM DYNAMICS MODELING APPROACH (30:17)

Forrester	RICHARDSON-PUGH
1) Identify a problem.	1. Problem identification and definition.
2) Isolate the factors that interact to create the observed symptoms.	2. System Conceptualization.
3) Trace the cause-and-effect information-feedback loops that link decisions to action to resulting information changes and to new decisions.	
4) Formulate decision policies that describe how decisions result from available information streams.	3. Model formulation.
5) Construct a mathematical model of the decision policies, information sources, and interaction of the system components.	
6) Generate system behavior through time with the model.	4. Analysis of model behavior.
7) Compare results to historical data from the actual system.	
8) Revise the model until it is an acceptable representation of the actual system.	5. Model evaluation.
9) Use the model to test modifications to the system.	6. Policy analysis.
10) Alter the real system in directions the model has shown will lead to improved performance.	7. Model use or implementation.

Table 1.1. The System Dynamics Approach (38:13, 30:16)

The iterative refining process is inherent to the development of a detailed understanding of the system, and from that the development of informed "policy recommendations that can be presented, explained, and defended without resorting to the formal model. The model is a means to an end, and that end is understanding." (30:16)

Methodology Application.

This section details the use of System Dynamics in the development of this research. The iterative process is inherent to the process of model building and continues until an accurate model of the system processes is accomplished. The first step of any model construction, after problem definition and selection of methodology, is that of system conceptualization. Conceptualization provides a set of hypothesized causal relationships supported by information gathered during phases of problem definition, modeler perceptions of the system, and past experience with similar systems.

In this particular instance, information gleaned by extensive literature review, interacting with personal observations and experiences led to rough models of the essential nature of the arms transfer system. Confirmation of the suitability of the initial conceptualization and model formulation resulted from discovery of recent work in a similar vein undertaken by Kahlid Saeed. (33). Saeed assessed stability from a political/economic perspective in which he combined a number of factors such as desire for control, government type, and desire for equality to derive an scaled factor describing national stability. Borrowing this technique of using a number of readily quantifiable variable values to construct a surrogate measure of stability aided in formulation of other variables of similar nature.

In addition to using methods of Saeed, this particular application of the System Dynamics approach uses an aggregate of nations, each individually defined through the use of common national structures, to model a regional system. Within the regional system are individual nation subsystems, each uniquely identified by discrete variables such as Gross Domestic Product, literacy level, average age of population, and quantity/age of weapons held in inventory. These nations are vertically integrated into a region to determine perceived threat from neighbors, and collectively express a regional stability factor based on the national internal stability of the member states.

Each nation state is broken into three primary sectors, interconnectedness intensity, level of technology, and level of cultural legacy. Integration of these sectors into national systems and the national system into the regional system provides a vehicle for analysis. By defining each sector as an individual part of the whole national structure, the modeler gains insight into the interactions making up the sector before attempting to understand the interaction between the sectors, hopefully leading to a better understanding of the world system.

Within each sector, a causal diagram was constructed to depict the relationships between key variables with emphasis given to those relationships and variables as seen critical to assessing stability under assumed arms trade actions. By refining each sector until its behavior matches observed behavior and the general structure of the system being modeled, face validity is assured, and aggregation into a completed nation-state model eased. From the completed causal diagram, flow diagrams are developed explicitly stating the levels, rates, and information flows integral to each sector and the system at large.

In keeping with the general development scheme using System Dynamics, the completed flow diagrams were computerized and quantified using DYNAMO. Forrester and Pugh explicitly developed DYNAMO as a means of bringing quantitative results to the process of System Dynamics, and is described as a "computer program which compiles and executes continuous simulation models." (30:1) The advantages of DYNAMO include its easy to understand notation for the novice and its effectiveness in in dynamically simulating feedback systems.(30:ii)

Additional sector testing was accomplished using SUPERCALC, a CP/M based microcomputer software package. This methodology of working small variable response with respect to user varied inputs provided a better intuitive feel for expected behavior of the overall model than would have attempting to run a completed model without understanding behavior in the subsector region. The ready availability of a small microcomputer to test small sectors eliminated some of the intractability and user frustration normally encountered when running even a small program on a larger mainframe system.

The process of validation and verification of the completed model added much to the iterative nature of the System Dynamics approach. Individual sectors were developed and computerized for verification of behavior before integrating them into a whole in the national system. The national systems were then combined into regional systems to form an integrated system, and subjected to numerous tests for verification and validation. Verification is concerned primarily with the operation of the computerized model. The researcher asks the question "Does this model do what I think I told it to do?", and is concerned with such matters as debugging code,and assuring variables are manipulated as desired. Validation deals with the question of "How well does this model reflect the real system being modeled?" The researcher deals in this realm more with decision structures, logic flows, feedback looping, and conceptual design. The process of validation results from the careful construction of the computer model using liberal commenting in the source code, describing key relationships and rationale, and real time correction of computer "bugs." Of the two processes of validation and verification, validation of the model is the more difficult to establish, in part due to the nearly subjective nature of variables used, and due to the difficulties encountered in integrating conflicting interdisciplinary points of view into a comprehensive model. Both validation and verification are discussed in depth in Chapter IV. The next chapter describes implementation of theory developed in earlier portions of this chapter through the use of causal loop and flow diagrams, and details hypothesized relationships in the world system of arms transfers.

Order of Presentation

Chapters Two through Five contain in-depth discussion of the implementation of the research methodology satisfying the research objectives, policy evaluations, and recommendations for further research. Specifically, Chapter Two details the conceptual model through the use of causal loop diagrams supporting basic propositions advanced in Chapter One. In this model the interrelationships and feedback structures reflect the interconnected nature of the world system, and how arms transfers might impact on individual national sectors and on the completed model.

Chapter Three contains the details of the DYNAMO code and System Dynamics flow diagrams used to support this model, and includes additional supporting material required to develop a workable, verifiable computer model. Simplifying assumptions are discussed and specific table functions of perceived system parameters are also discussed. This chapter is recommended only for those interested in the actual internal structures of the DYNAMO coded model.

Chapter Four, Validation and Verification, test results on individual sectors and on the completed model establish verification of the operation of the model. An in-depth discussion of the problems of validation accompany arguments establishing the validity of this model for use in policy analysis.

Chapter Five, Policy Experimentation, contains descriptions of test procedures demonstrating the behavior of the developed model under specific policy loadings, and assessing the possible implications that these experiments have in the real world.

Chapter Six contains conclusions of this study, and makes specific recommendations for improvement of the model, and potential areas of exploration for the interested individual.

CHAPTER TWO

THE MODEL

Introduction

In the last chapter, the introduction to the problem of assessing regional and national stability in light of ongoing arms transfers explored some of the background of the problem, reviewed other's work in attempting to solve similar problems, and identified the methodology of this research. In this chapter, the concepts of model building will be expanded, the methodology further expounded, a framework constructed, and hypotheses of causality and interrelationships introduced.

Model Building

In the first chapter, we approached the examination of the prevalent rationale for conducting or abstaining from the conduct of arms trade from a modelists point of view. Predominant uses of models included framing thought, communicating, training, predicting, and experimenting. Robert Pugh aptly states states the reason for building a model:

> Constructing a model helps you put the complexities and possible uncertainties attending the decision-making problem into a logical framework amenable to comprehensive analysis... In short, the model is a vehicle for arriving at a well-structured view of reality. (30:33)

The methodology of system dynamics explicitly calls for the development of detailed models. This is, in part, due to their advantages in addressing the many interrelations of multiple entities of a complex system, but also to support conceptualizaton of the system to be investigated through simulation techniques.

Refutationism, Rationalism, and Model Building

In building any model, there needs to be an underlying philosophy to guide development of theoretical relationships, postulate impacts of dynamic change in a system, and provide a methodlolgy for assessing valididty of the model. Holding with the traditional system dynamics approach developed by Forrester, this model was developed using the dual framework of refutationism and rationalism.

The refutationist philosophical framework for analysis was formalized by Sir Karl Popper, and is the framework generally recognized as the scientific method. In this view "science progresses principally by subjecting theories to possible error, and exploiting actual error for improving theories."(30:62) Furthermore, this methodology advances the "principle of causality" which is described as

> ..."the simple rule that we not abandon the search for universal laws and for a coherent theoretical system, nor even give up our attempts to explain causally any kind of event we can describe..."(30:63)

and as such, governs the conduct of the researcher. In using causal explanations, the researcher can take the relationships as being universal statements and attempt to vigorously validate them through their many points of contact with reality.

In contrast, the rationalist philosophy depends heavily on Kant's premise of "synthetic a priori" facts or premises of unquestionable truth. In this approach, one takes the view that the basic premises upon which a model is structured and logic with which the premises are connected, are, without question, true. They are accepted without the requirement for rigorous validation; therefore the model upon which they are based is, by definition, sound.(34:213) Forrester further explains this argument:

> Much of the behavior of systems rests on relationships and interactions that are believed, and correctly so, to be important but that for a long time will evade quantitative measure. Unless we take our best estimates of these relationships and include them in a system model, we are in fact saying that they make no difference and can be omitted. It is far more serious to omit a relationship that is believed to be important than to include it at a low level accuracy that fits the plausible range of uncertainty.
>
> If one believes a relationship to be important, he acts accordingly and makes the best use he can of information available. He is willing to let his reputation rest on his keenness of perception and interpretaton. (34:213)

In particular, development of the model in this research takes place under the refutationist view, but with a disclaimer of a rationalist's methodology. When possible, illustration, analogy, or expert opinion accompany major premises as they are integrated into the large whole of the modeled system focusing on the impact of arms transfers on regional stability.

Change, the Interconnected World, and Arms Transfers

In developing a model of a regional system functioning under arms transfer behavior, many theorists and political scientists have taken a relatively static view of the world system. Their models and rationalizations deal predominantly with one dimensional models dealing with one area of expertise. In focusing on this single topic, many theorists lose sight of the dynamics of the overall problem, and often lose sight of the many interconnected parts that have a critical impact on the eventual effect of arms transfers in a regional system.(22:vi) In particular, Neuman notes that "no theory of regional, conventional stability which is comparable to the theory of deterrence has been developed..." (23:232) Esoteric and emotional arguments focusing on a single element of the arms transfer process fill the popular press and scholarly literature, yet nearly all ignore the underlying systems nature of the world environment.(23:220-221)

In attacking a problem from a systems approach, one attempts to study the the total system performance rather than concentrating on its parts. In trying to establish substantial policy, it is critical that the decision maker recognizes the extreme complexity of systems he is attempting to affect, and attempts to establish some form of structure on his analysis of possible policy impact. The systems approach to analysis can help the decision maker, in part due to its methodology, and in part due to its success in varied fields of study. To aid in this process, systems analysts have identified six basic elements of all complex systems. Shannon details these characteristics as follows:

> 1. <u>Change</u>. The present condition or state of a system is the integrated result of the past and foundation for the future. No real world system remains static over a long period of time. ...
>
> 2. <u>Environment</u>. Each system has its own environment and is in fact a subsystem of some broader system.

The environment of a system is a set of elements and their relevant properties,... and consists of all external variables that can effect its state.

3. Counterintuitive Behavior. Cursory examination of complex systems will sometimes indicate needed corrective action, which is often ineffective or even adverse in effect.... Obvious solutions may actually intensify a problem rather than solve it.

4. Drift to low performance. Complex systems generally drift toward a condition of reduced performance over time.

5. Interdependency. No activity in a complex system takes place in total isolation. ... real world activities generally parallel and ultimately influence one another.

6. Organization. Virtually all complex systems consist in highly organized elements or components. Parts ... interact to carry out the function of the system. (34:36-37)

In failing to explicitly address the system characteristics of the underlying nations that make up a regional system, analysts and decisionmakers attempting to establish sound policies may fall short of their goals. In fact, in dealing with the subject of arms transfers and regional stability, "stabilizing" activities may lead to counter-intuitive results. The question is how to apply a systems approach to form a rigorous model to assess the effects of arms transfers on regional stability.

The assessment of the effects of arms transfers on regional stability starts with the formulation of a specific model. By applying Shannon's six characteristics of a system to describe and systematize the environment of arms transfers, a solid framework for analysis is built. The methodology of System Dynamics, and DYNAMO computerization follows this framework in later stages of the research. Chapter I identified the essential elements of interdependency, and described some examples of historical counterintuitive behavior. Development of the model will point to aspects of organization inherent to the world arms transfer system, and specific nation/region computerizations in Chapter IV will explicitly detail the unique environment of each subsystem. The remaining discussion prior to formulation of a preliminary causal diagram will deal with change in the system and reflect on its effects on stability.

Change.

Underlying this interconnected, interdependent system is the inherent concept of continual change. Sociologists and cultural geographers use several measures to reflect societal predilection to change and the resulting societal interconnection within a larger world system. Gomez and Green both define a scale with "preliterate" or "traditional" on the low end and "modern" on the high end to describe societal values towards change. (11,12:345) Gomez identified per capita use of fossil fuels, per cent of population directly supporting in agriculture, and per capita consumption of protein as indices of interconnectedness and "moderness." His model defines modern society as characterized by a high degree of interconnection and interdependence, employing fossil fuels as a primary energy source for its extensive industrialization, producing food using capital intensive methods, and embracing change as a way of life. The other end of the spectrum finds the traditional society relatively isolated from the world around it, relying heavily on its human labor force for all forms of production, and holding doggedly to traditional value systems as an insulation from the shocks of the interconnected world.

Political scientists scale nations in similar manner citing the undeveloped and developing nations of the "Third and Fourth Worlds" (25:12) as examples of largely traditional societies. The other end of the scale contains nations holding the status of superpower or major power. Currently, the United States embodies all essential elements of a modern society. In this particular model, the "modern-traditional" scale for ranking countries is particularly valuable when assessing the impact arms transfers on regional and national stability.

This model considers change as a constant factor, totally lacking a moral value, that must be coped with and adapted to as a condition for survival. Sociologists identify man and his social systems as basically conservative in that they seek stability, or at least manageable change, in social systems. Specifically,

> They (men) have clung tenaciously to what has come down to them from the past.Culture and the social institutions which transmit culture to succeeding generations are themselves conservative forces.(12:608)

In human social systems, the dichotomy of stability versus change seems to confound the clear definition of ultimate system goals by social scientists and policy makers alike. On one hand, change is expected for the betterment of the system, while change that leads to unexpected results is feared and to be avoided. The seeming contradiction of goals appears irrational and counters many assumptions of man's rationality. These difficulties express themselves in many levels of the world system, including the level in which we observe the phenomena of arms transfers. How can one deal with this apparent dichotomy in a model, and what then is the nature of change in national social systems?

In any system, the introduction of new goods, services, or information changes that system in some manner, even if the new is found to be unsuitable to the situation and ultimately discarded. The change may be imperceptible to a casual observer, or may be time delayed in its impact, however the effects of the change are still recorded in the society. The national system is a subset of the generalized world system, and a supersystem of the nation's internal systems. These systems interact in complex and intricate ways, and a minor occurence at a low level may magnify and synergistically interact with other ongoing processes to cause an effect greater than the impetus itself. This flow of thought can be useful, particualarly when attempting to assess the impact of arms transfers on national and regional stability.

Herein lies the nature of conflict and assesment of stability. If indeed man transmits culture and social institutions as a conservative force, then his continual seeking of change is in contradiction to this conservation process and man's very nature. Gomez and Green both identify that there is cost in change, a distinctly human cost. (11;12:615) Those who are either unable to change due to age, or unwilling to change due to strongly held beliefs and moral values are too often swept aside in the rush towards change. The resulting alienation and societal separation results in bitterness in some individuals towards the change instrument, and in others, a need to bond to people of similar circumstances. Change can become the antithesis of life processes in any system, particularly when the ability to cope with change in a constructive manner fails.

The following illustrates a part of the nature and effects of change on individuals in society. Emile Durkheim undertook a study relating a number of factors including religious affiliation to determine an underlying cause of high rates of suicide in the West. He defined the term anomia: normlessness, uprootedness, individualism cut off from family, religious, and community ties. With this index he was able to explain an apparent paradox of high suicide rates during both extreme boom and extreme depressed economic periods, and a lower rate in the midranges. He hypothesized that change caused by depressed conditions destroyed normal aspirations and expectations, and that boom period change similarly destroyed settled patterns and social relationships, both being forms of extreme "anomia". In the perspective of the developing arms transfer model, Emile's "anomia" reflects the ideas of Green and Gomez about change and reactions towards change.

If similar mechanisms exist in human societies that exist in individuals, then it is possible that in situations where change exceeds the capability or desires of a societal group to absorb the change, societal instability will result. The nature of the instability may not be the same in every situation. Recall that environment plays a crucial role in defining a system, and that not all societal groups are the same. Durkheim insisted that his theory of anomia must be interpreted from a contingency point of view. The influence of these factors leading to anomia depend on the situational variables; that which devastates one individual may strengthen yet another. It is the central hypothesis of this model that the same is true of the larger social framework of the international, interconnected system. Change that tends to overwhelm one nation may aid yet another nation to grow in strength.

The same may be true of the transfer of arms. Depending on the specific national situation, societal change required to absorb specific arms transfers might strengthen some nations, yet devastate others. If the invividual phenomena is reflected to the overall society, then the specific ability of the national system to absorb the specific change of acquiring advanced armaments determines the impact on a nation's stability and on the overall regional stability, at least as significantly as the traditional arguments of need, strategy, and economics.

Continuing along this chain of thought, a critical rent in the fabric of national stability will occur when the conservative nature embodied in cultural elements and social institutions is overwhelmed by change, particularly, change in the areas of technology and interconnection to the rest of the world. Modern nations already have a favorable predilection towards change, contrasting with traditional or preliterate nations and their highly conservative, change averse attitudes towards change. Man is inherently an adaptive organism, and on the whole has done well in adapting to millions of years of change. However, it appears that there is a limit to the rate of change that can be tolerated by individuals and societies. The rate and intensity of change is determined by the many situational variables and the individuals involved. If this rate of change is exceeded, men react individually or collectively in ways to re-establish some form of manageable equilibrium. History has many examples of change outstripping the specific cultural ability to absorb the change, but perhaps this theory is most clearly illustrated in events in Iran during the late 1970's.

Iranian Experience

Rather than review in depth the development of the Iranian people as a nation in depth, the interested reader may verify these observations with the cited reference.(37:70) One would be safe in assessing that Iran in the late 1940's to be a traditional society rather than modern. The Iranian culture emphasised nomadic desert life, was founded largely on the foundations of a strong Islamic religious infrastructure, and emphasized loyalty towards the preservation of the status-quo. Iran was on the whole a depressed nation economically and relatively isolated from the impositions of the interconnected world. The British influence was largely limited to superficial, governmental changes, and life continued on relatively unhampered with little outside influence.

The discovery and exploitation of the oil resource started a gradual path of development and transition into supplier relations with a well connected world. Needless to say, the intensity of these relationships to the outside interconnected world intensified, with early contact through a relative handful of oil company employees concentrated in small enclaves. As the intensity of moderniztion increased through the late 1960's and early 1970's under the direction of Shah's regime, so did the tension of change versus traditional elements. It is conceivable that the Shah was quite insensitive to the building tension as he himself was the product of Western educational systems and had spent many of his formative years immersed in the interconnected Western world system. Signs of this building tension can be clearly seen in retrospect with the sporadic resistance to the Shah's regime (which was met with violent repression by the SAVAK), and in intensified vocalness of various religious elements calling for a return to past ways of "purity." and for purges of the "western devils" now occupying their homeland. This reaction does not seem surprising when one looks at the magnitude of change that the Shah had attempted to impose in a short period of time.

Culturally, the Iranians had advanced to a western equivalent of the early 1800's when compared to the interconnected Western world during the late 1950's. The government attempted a growth schedule of catching up some 150 years of technology and interconnection in a period of 30 years. However, as a nation, Iran lacked the physical and cultural infrastructure for such dramatic change. The technological sophistication of the Iranians required to absorb Western weapons, mores, and the physical infrastructure being built for them by westerners simply did not exist. Indeed, it is probable that many Iranians saw the vast numbers western technicians living alongside the growing facilities a vital threat to the safety of the culture and very way of life of the Iranian people.

In this context, it appears that the rise of the Ayatollah Kohlmeni and the ouster of the Shah satisfied the societal need to return to a level of equilibrium in which change could be coped with, and managed. Arms transfers played a large role in this process of destabilization because, 1) the Iranian people generally lacked the technical sophistication to use and support the weapons without external intervention, 2) the infrastructure to support such weapons, such as roads, hospitals, and military bases was based on technology not necessarily suited to or designed in response to the unique needs of the people, (31:124) and 3) arms forced elders seeking to continue the status-quo to assure that their impressionable young held to the ways of the old despite their intensive interactions with westerners during training to use the new weapons. Both situational variables and absolute values of change elements precipitated the backlash to return to an equilibrium and stability situation.

In contrast to this argument, George Ball echoes traditional economic thought and has put forth the thesis that arms purchases diverted scarce funds from the civilian sector to the military sector, depriving individuals of goods and services. The lack of attention to the civil sector eventually led to the revolution. However, George Lenczowski refutes this by pointing out that Iran enjoyed oil revenues of some $20 billion per year prior to the revolution, and that at no time did arms purchases exceed $6 billion per year. This seems to indicate that at least $14 billion was available for substantial development activities. (23:239) Neuman points out that there has been "little disaggreement among analysts, ..., that the development process itself somehow contributed to the political instability in Iran."(23)

Summary of Major Thought

At this juncture, it would be beneficial to recap and attempt to clarify major tenents supporting the design of the model. These observations and assertions stem from underlying arguments of many different authors, and as such are not necessarily stated, by rather can be derived by inference from a vast body of literature. The model development at this point rests on refutationist argument, and will develop from these points with a rationalist bent. The primary points advanced by this thesis are:

1. The interconnected nature of the world system has evolved through time and has resulted in the currently observable situation of high degrees of interconnection and interdependence. Current arms transfers are both a result and an instrument of this system.

2. Analyzing arms transfers apart from the underlying system can be of value in assesing individual nation actions, however it provides little insight into the effects of arms transfers on regional and national stability.

3. Change is endemic to the very nature of the world system. Various cultures and nations have adopted methods for dealing with change ranging from isolationism and radical conservatism to expansionism and change-seeking innovative behaviors. The nature of this reaction to change allows sociologists and cultural geographers to categorize nations and cultures on a scale from traditional to modern as relative extrema. Change by itself must be taken in context with the various situational variables to assess its impact on the system.

4. Arms transfers are a means and method of change, and as such interact with cultural elements to impact on the society as a whole, to include the notion of stability. Stability can be assessed in both relative and absolute terms. In relative terms, one can compare respective rates of change in the cultual adaptive mechanisms and the rate of technological and interconnection advancement. Rapid change in a nation of high traditional orientation leads to incresed instability. In absolute terms, a high level of technology and interconnection in a traditional society indicates possible colonial style of domination leading to possible instability with developing awareness and cultural advancement.

Primary Sectors

The dynamic nature of nations implies the interaction of complex forces beyond those apparent on the surface. Gomez identified a series of distinct characteristics representing the essential nature of a nation, its people, and its functions. In particular, he focused on elements that would help to define the degree of "moderness" of the national entity. In his model, the dynamic interplay of interconnection, technology, and culture determine the level of moderness. Additionally, and due in part to his background as a geographer, he placed heavy emphasis on definition of place and "effective earth environment" as limiting situation variables in developing a comprehensive systems view of a nation.(11)

Green refers to similar indices also in developing a comprehensive sociological model of the modern world. He differs in his approach in that he attempts to explain human behaviors in light of structural elements, where Gomez was simply attempting to find a comprehensive frame of reference for categorization and classification. In particular, Green examined the universality and variability of culture, the impact of technology and interconnection as elements of social change and formed a substantial theory pointing to human elements that determine the final composition of a nation. (12)

This model borrows heavily from both Gomez and Green in an attempt to identify critical system elements that have a direct impact on the arms transfer process and the resulting measurement of stability. Specifically, this model uses a combination of surrogate and artificial structures to describe degree of interconnection to a larger world system, the level of technological sophistication embodied within individuals and the goods they produce, and the degree of cultural "moderness" of the social systems internal to the nation. In developing three sectors, interconnection, technology and cultural moderness, and causing them to interact in a dynamic manner within the model, relative rates of change observed under arms transfer behavior provide a index for assessing national stability. Stability assessment can be accomplished as outlined in the previous section, that is by comparing internal rates of change in the cultural sector to the rate of change of technology and by comparing absolute levels of technology and cultural moderness.

Further development of this model using the methodlogy of system dynamics must depart from the sole use of words to explain the intricacies of a functioning system. The next section introduces specific causal diagrams to initially identify causal relationships found in the system and conceptualize specific dynamic behavior of the system. Furthermore, these diagrams introduce a common symbolic language in an attempt to otherwise clarify the subtle inaccuracies of the written word, and express the essential elements of the research model in this symbolic language.

<u>Development of Causal Loops</u>

The methodlogy of causal loop diagramming is by design simple to understand, yet it provides a great depth of information about the behavior of a complex system. The emphasis in identifying basic loop structures is to identify "loops of interconnection identifications--loops of cause and effect."(29:4) Characteristically, these loops will represent feedback loops: "a closed sequence of causes and effects, a closed path of action and information." (29:4) In forming the causal loop diagram, relationships existing between elements of the system are taken two at a time. Arrows directed between any two variables imply relationships, with the use of a "+" or "-" sign indicating the nature of the relationship. As an example observe, the following diagram.

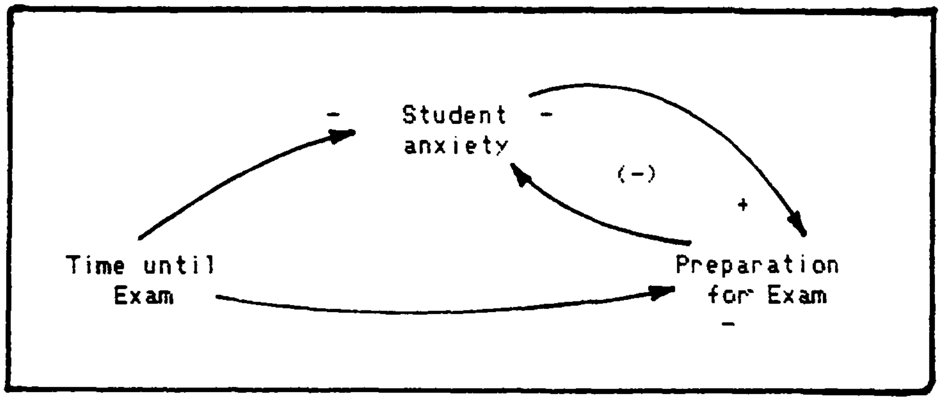

FIGURE 2.1 - SAMPLE CAUSAL LOOP DIAGRAM

The independent variable of this system is time remaining until the exam, and as such is not effected by changes of variables in the system. The plus sign on an arrowhead indicates that the direction of change in the variables is the same, as indicated the by the relationship between student anxiety and preparation for the exam. This structure represents that as student anxiety increases, efforts in preparation for the exam will also increase. The minus sign on the arc from preparation for the exam to student anxiety indicates opposite direction of change in the two variables. In this case, increases in student preparation decreases student anxiety.

In addition to observing the single effects of change on a variable, the polarity of a completed feedback loop provides additional insight into system behavior. Loops with positive polarity are self reinforcing, that is any change of a single variable contained in a complete loop will continue throughout the loop in the same direction, and causing further change as it completes the cycle. Unless the loop is acted on by some external link, the result is either exponential decay or exponential growth. Conversely, loops with a negative polarity strive to control and stabilize. To determine the polarity of a given loop, simply count the number of negative (-) causal links. The feed-back loop is negative, thus stabilizing, if the number of links is odd; positive and destabilizing, if the number of negative links is even or zero. In the example above, the completed loop between student anxiety and exam preparation has a negative polarity. This implies a stable system, with a limit being reached on student preparation and anxiety.

A causal loop diagram is a useful tool to develop a view of the system in feedback terms. Images and words that are otherwise ambiguous and imprecise take on a more precise relational meaning when viewed from this perspective, and expected behavior can be explored through loop polarity analysis . From this exercise, lets turn to the larger task of describing the system model of arms transfer impacts.

System Causal Loops

The development of causal loops takes place on a national level, with aggregation of key indices taking place in the computerization sector of the model development. During the development of theory, we saw that changes in cultural "moderness" had an impact on national stability. We intuitively observed that overwhelming change in the technological sophistication with respect to cultural "moderness" causes instability, as does grave imbalances of high technology in a largely traditional "preliterate" nation. In figure 2.2, this relationship is explicitly stated, and another factor added.

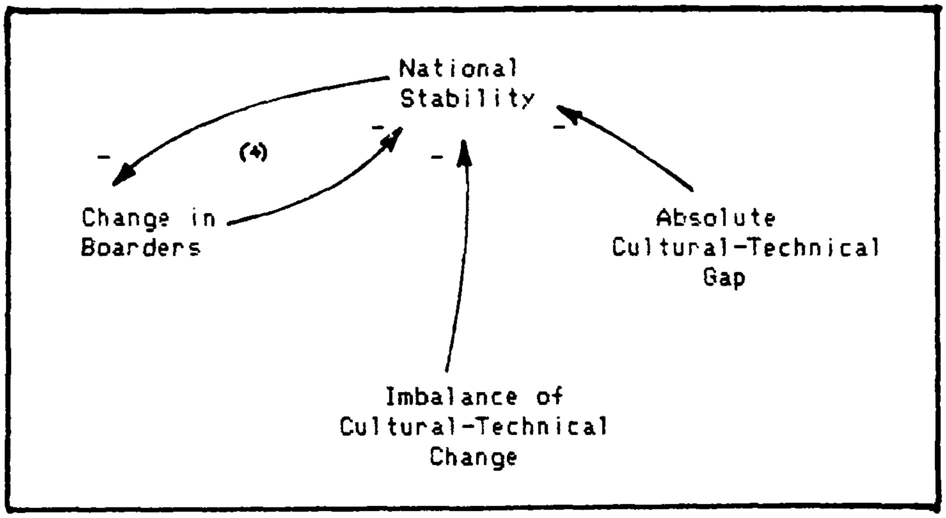

FIGURE 2.2 STABILITY ASSESSMENT CAUSAL DIAGRAM

Specifically, this model hypothesizes decrease in national stability due to increases in cultural-technical gap, imbalances in cultural technical change, and changes in boarder structure. It is important that stability itself in a national setting is a dynamic concept. One may take point estimations of stability at any given time, however since it is a dynamic abstract concept, artificialities need to be introduced for the sake of the model. Nowhere in the literature is there reference to units of stability, but rather stability is expressed as a balance of dynamic and often confliciting forces of social systems. As an artificiality, this model presents stability units, but merely as a methodolgy of assessing direction and magnitude of change form an equilibrium position.

The inclusion of the boarder change loop reflects the geographical aspects of a nation discussed by Gomez. He defines a nation in terms of the land occupied by a particular group of people conducting ongoing life processes (11). To deprive a people of the land they occupy is in fact to deprive them of their national status. In this model the change in landmass has a direct negative impact on national stability. Similarly, enlarging the area of a nation inevitably introduces new cultural elements and compounds the complexity of internal interactions diminishing the status quo, and disturbing the equilibrium of the national system. Similarly, stability has a negative impact on boarder change. A stable national system will not seek to expand its frontiers, and its very lack of substantial threat to its neighbors will not encourage their adventurism.

As described earlier, cultural- technological gap represented as either a contrast in rates of change or in absolute terms of the differences of technology and culture sectors might be an appropriate measure to assess stability. When the rates of change for either the cultural or technological sectors are outstripped by the other, people will tend to behave in conservative manners to restore a sense of equilibrium to the system, and restoring stability.

A similar behavior is found in situations where the absolute differences in of cultural level and technology, are grossly unequal. For example if a preliterate, traditional society were to acquire modern telecommunications equipment, only those portions of the technology that were appropriate to the enviroment and useful to maintaining vital processes would be adopted. They might find that the wires forming the cords of the telephones make great bowstrings and that the bells ward off evil spirits (and birds) in the agricultural cycle. If some authority replete with the requisite force were to insist that this equipment be used in the way it was designed to be used, conflict might arise in the acceptance of the new technology. If the cultural mores identified voices coming out of handsets to be supernatural, and evil in origin, internal cultural change would be required to allow this level of technology to be used. Although the same degree of contrast may not be present in the transfer of arms, the same basic mechanisms may be at work, and leading to instability. The key to the response in stability is likely to be the intensity of change required in cultural elements to accept new thinking underlying new technology.

Elements of Technological Change

Attempting to find a measure of technology is quite similar to the problem of finding a measure of stability. For purposes of this model, technology refers to

> ...the application of knowledge for practical ends... the sum of the ways in which a social group provide themselves with the material object of their civilization. (36:1349)

However, this model focuses more on the dynamics of change in technology, as it the hypothesis of the model that instability results from the overall conflict of cultural change and technological change. How then can one measure the technology of a nation and its dynamic behavior?

Technology and its effects on a national system have been explored with some depth and with great interest by both sociologists and economists. Nicholson begins his study of the effects of technical progress (growth in technology) with the observation that output per labor-hour has risen rapidly in the past 200 years. A portion of this growth can be attributed to increasing capital investment in the means of production, but a greater portion "must be ascribed to the development of better productive techniques." Solow analyzed increases in production in the U.S. economy over the period of 1909-1949, and after deducting for increases in capital and labor, reached the conclusion that technology advanced at a rate of 1.5% a year. Furthermore, he claimed more than one half of the growth of real output can be attributed to technical change rather than in growth in the physical quantities of the factors of production. (24:213) Denison in his study of the American economy concluded that 40% of the previously unexplained residual in the growth of the Gross National Product could be explained by improvements in in the quality of the labor force. This indicated the strong role played by education in the growth process. His work became much of the basis of future studies of the "embodied" nature of techical progress. (7:231)

The "embodiment hypothesis" of technical progress starts with the observation that the stock of machinery in use in a nation is a collection of equipment of various ages. Each piece of equipment embodies a portion of the technology available at the time of its production. Individuals espousing the embodiment hypothesis argue that

> ...technological advances are manifested only in the latest additions to the capital stock and that the productivity of old machines remains more or less

> constant.... Solow found that new capital equipment improves at the surprising rate of 5% per year, meaning that machines introduced during the current year are 5% more effective than machines produced the previous year.... Solow concludes that most of the unexplained growth in output found in earlier studies can be attributed to the embodiment of improved technology in latest additions to capital stock. (24:215)

Nicholson advances the proposition that the same should be true of the labor force as well, and that if incoming workers to the labor force are equipped with better skills than those already at work, then technical progress is embodied in these new workers. At this juncture it is important to note that economists in general hold to the concept that technology not employed in productive enterprises is not to be counted as part of the national technology. Books on library shelves or data in computers do no good until employed.

Nicholson's idea of technology embodied in a labor force is echoed by Green's concept of human capital. He notes that the traditional arguments for American supremacy in production based on the concept of capital invested in machines fall short particularly when identical machinery in other economies results in lesser output. He cites the lack of "human capital that is capable of adapting , modifying, and using technology," and points to the Scandanavian experience of high production despite relatively small domestic markets for consumption. (12:467) He further notes that "sociological research has shown that, among other factors, the disruption of established habit patterns is a necessary prelude to economic production of a high order."(12:468)

Three causes of technical progress are discussed by Nicholson. The distinction between invention, innovation,and the spread of innovation points to two factors determined in part by the stock of human capital available in a given economy and the third factor determined by interconnection to a larger information system. The first use of innovative technology represents a sizable risk to the innovator and may result in rather marginal returns. However, with the success of an innovation, "several authors have found that the diffusion of innovation can be pictured as an S-shaped curve (logistic function)." (24:217) Research has shown that since knowledge is more or less available to all firms, the spread of innovation is related more to the interconnectedness to a global economy of the local economy. Nations taking advantage of their interconnection typically demonstrate real economic growth due to spread of innovation much sooner than do nations of relative isolation. (24:218)

Economic growth and increased production apparently result from increases in capital and labor inputs, from increases in embodied technology in machines, from growth of embodied technology in labor (human capital), and from the spread of innovation. Changes in technology apparently can be registered by noting changes in production, education of workers, and in the degree of interconnection to a global system. If this is true and after subtracting for increases in capital and labor we should have a fair representation of the level of technology embodied in a nation whose dynamic response could be tracked over time. The model advances this theory in figure 2.3 below.

This model implies that a nation can expect continuous growth in the development of technology due to the positive polarity and reinforcing nature of the three feedback loops. However, this loop diagram does not exist in isolation. There exist a number of other mechanisms inherent to nation systems that impact on these three variables, damping

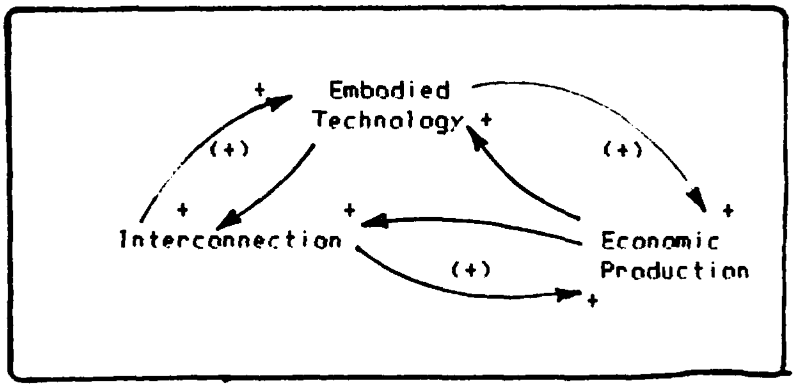

FIGURE 2.3 TECHNOLOGY CAUSAL STRUCTURE

and otherwise diminishing the reinforcing responses of the loop.

<u>Change in the Cultural Sector</u>

The cultural sector in most societies is a conservative force, cushioning the blows of technological advances and leaps in interconnectedness, and providing a relatively constant framework in which people deal with one another. For purposes of definition, this model considers culture as

> ...the sum total of ways of living built up by a group of human beings and transmitted from one generation to another. (36:325)

However, at the insistence of men for progress and change, many of the stabilizing cultural elements found in a nation system may erode in insidious ways. The dichotomy of change versus maintenance of status quo discussed earlier in this chapter illuminated some of the structures generally found internal to all national cultural sectors and that are critical for a nation of people to maintain some semblance of cultural legacy. Green identifies structures such as religious institutions, moral codes, family structure, and education systems as determinants of a culture. Traditional information and verbal history flows intergenerationally through family structures, is reinforced and shaped by societal moral codes and religious training, and is modified or disrupted by processes of formal education systems (12:607-633).

Culture and the legacy of the past derives strength from an older population due in part to the conservativeness of age and the establishment of life patterns that seemingly work appropriately in the surrounding situation. A younger population may be still attempting to define itself in terms of the old, tried methods handed down, and employing newer methods yet untried that may be more effective in dealing with life situations. As such, a younger population will tend to be more adventurous in trying new methodologies, and is more susceptible to external pressures that might attempt to otherwise influence perceptions and expectations. Interconnectedness of the national system likely determines the intensity of influence from other than traditional sources, as will the intensity of formal education processes, however on a much more gradual process. It takes years to shape minds in a schooling process, yet opinion can be steered in mere days through media processes. The impact of a large immigrant population will have a diluting effect on the essential elements of legacy, mores, and tradition as new methodologies supplant and in cases replace the established.

The precepts of a dynamic cultural sector are embodied in the following loop diagram.

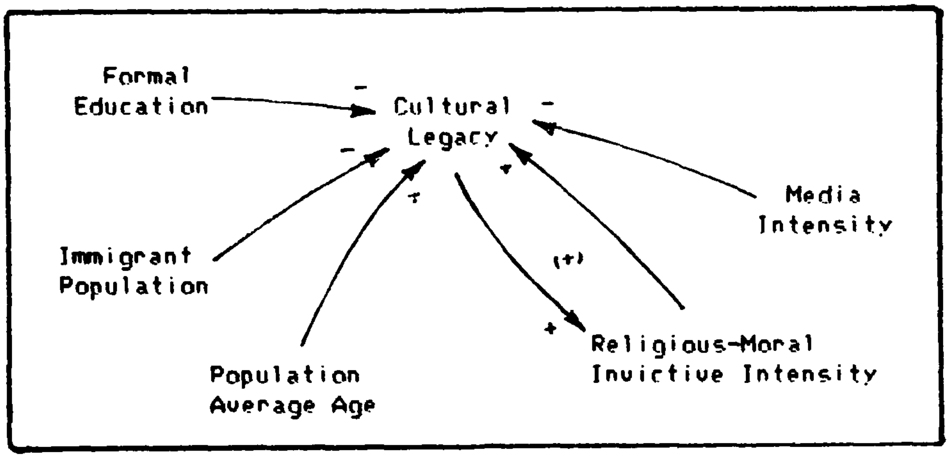

FIGURE 2.4 CULTURE CHANGE CAUSAL STRUCTURE

The measurement of cultural legacy reflects the traditional orientation of a nation. A high degree of cultural legacy, that is an intense social system of rigid social mores and stratified relationships, focused on the past rather than the present, reflects the traditional nation's social system. The measurement of cultural legacy cannot logically depend solely on any one variable, any more than can one assess the motivation in any one individual with a single observable measure.

The measurement of cultural legacy borrows from behavioral scientists who have tried to estimate motivation by combining several measures such as tardiness, absenteeism, and error rates into a surrogate, artificially scaled variable. (2:252) Although it is generally recognized that it is infeasible to determine the exact amount of motivation that a person has, one can still get a reasonable estimate of motivation in these contrived "motivation units", if nothing else on a comparative scale. The same rationale is applied to the model's measurement of cultural legacy. Although, one might have difficulty in directly observing cultural legacy, one could easily observe the number of people employed in direct agriculture, or the per capita income, or even the literacy rate of a nation. A combination of these observable measures to form a cultural legacy measure, therefore, is quite logical and consistent with recognized practices.

Economic Production and Human Capital.

As detailed in the technology change sector, economic production and human capital are the national embodiment of technology. Nations demonstrating high per capita productivity are normally considered among the modern world, and are not agrarian, labor intensive in their production schemes.

Traditionally, economists identify capital and labor as the essential inputs to any production function. Capital is not limited solely to financial resources, but can be seen in the machinery used for production and the raw material consumed in the process of production. As a simplification of the production process, this model ignores invested capital as a sunk cost in assessing the impact of production on technological growth, and trade growth. As capital investment in new technology occurs, production itself increases, indicating a concurrent growth in embodied technology. Standard measures of production include value of raw material processed for use in secondary production and export, dollar value of agricultural primary production, value of energy and energy products produced, and dollar value of secondary, manufactured products designated for internal consumption and export. Human capital value is considerably more difficult to assess due to a lack of traditional economic indicators as found in economic production. However, by assigning a surrogate measure that stems from annual capital investment in education processes and predominant level of literacy, an approximation of the value of human capital can be assessed. The following causal loop diagram states the essential relationships in this sector. There exists a number of feedback mechanisms that are not depicted in this diagram. As an example, increases in energy production will lead to increases in expenditures for education, but through an indirect route that includes growth in technology and population. At this point of model development, it would be neither instructional nor helpful to laying out the basic components and relationships of the national system to include such detail.

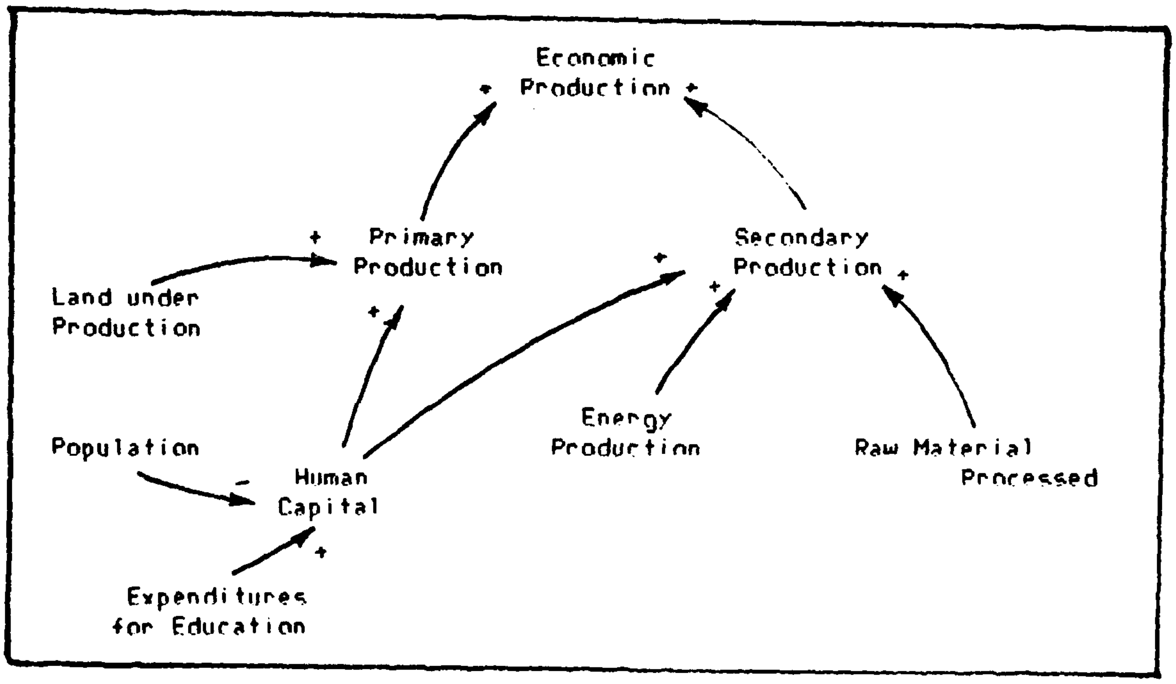

FIGURE 2.5 ECONOMIC PRODUCTION AND HUMAN CAPITAL DEVELOPMENT CAUSAL STRUCTURE

In this production subsector of the larger technology sector, one observes that human capital, a measure of the education and technical sophistication embodied in a population, is increased through increases in educational expenditures. Similarly, primary production or agriculture and other organic growth oriented production is increased by growth in land under production and human capital. The production of energy, predominantly fossil fuels, and extraction and processing of raw materials, such as iron, contributes directly to the level of secondary production and to levels available for export. A simple additive relationship of primary production, secondary production, and the exportable portion of fossil fuel and raw material production, all taken on a per capita basis provides a rough measure of total capital production. Positive changes in this production when applied to the embodied technology indicates an underlying appreciation and increase in the national technology.

Interconnection

Interconnection and interdependence are hallmarks of the current world structure. As seen in the technology development sector, interconnection through the transfer of innovation is among the causes of the development of technology. However, in its purest form, innovation transfer is nothing more than the transfer of the embodied technology from one society to another, a process that we call trade. Trade itself takes place through well defined transportation networks, but the processes of trade find other media. Telephones, radio, and television are media used to promote trade, and in themselves have a reinforcing effect on the degree of interconnection present in any nation.

Innovation transfer is not solely limited to the transfer of goods, but also includes people with ideas in their heads and innovative skills that become a part of the innovation transfer process. People move in a relatively few modes of transportation, and the nature of the network available to them limits their ability to take part in the transfer process. The process of innovation transfer is essentially the process of information transfer, but additionally includes the notion of implementation of this information into production. The mechanisms we have developed for transfer of information limit both the quantity and quality of information transferred.

Take for example the information transfer network available to an early settler of the western United States. In this period of time the information transfer network was relatively primitive. The settler himself had few roads laid out in front of him, and even fewer accurate maps of the course in front of him. He learned of new areas through spoken words passed between fellow settlers and from information that might be available in the form of pamphlets and newspapers (if he could read, that is). His means of transportation were limited to a scarce few commercial coach lines, private hauling using wagons and animals, horseback, or even foot. Movements of more than twenty miles in a day were rare. Trade of goods took place at the country store, and innovation and invention by the individual dominated the the growth of technology. Formal education was not a prerequisite to survival, and as such had little impact. The U.S. government's influence on the settlers life was minimal, except for the occasional encounter with a marshall or Army outpost. This is in sharp contrast to the information transfer network available today.

In observing the information transfer network available today, perhaps the most striking characteristic is that of its immediacy. The Atlantic Ocean is routinely traversed in a matter of hours. Information of happenings in all corners of the world is transmitted mere moments from its occurence. Newspapers, books, and periodicals offering in depth information are readily available to those a part of the interconnected world. It only seems reasonable to attempt to measure the intensity of interconnection through measures of trade intensity, transportation networks availability, media presence, and government intervention in national life. In taking this view, the act of arms transfers is in itself a means of transferring of innovation usually through a government device, and could be seen as a means of interconnection within a world environment. Using this framework the following causal loop diagram was constructed.

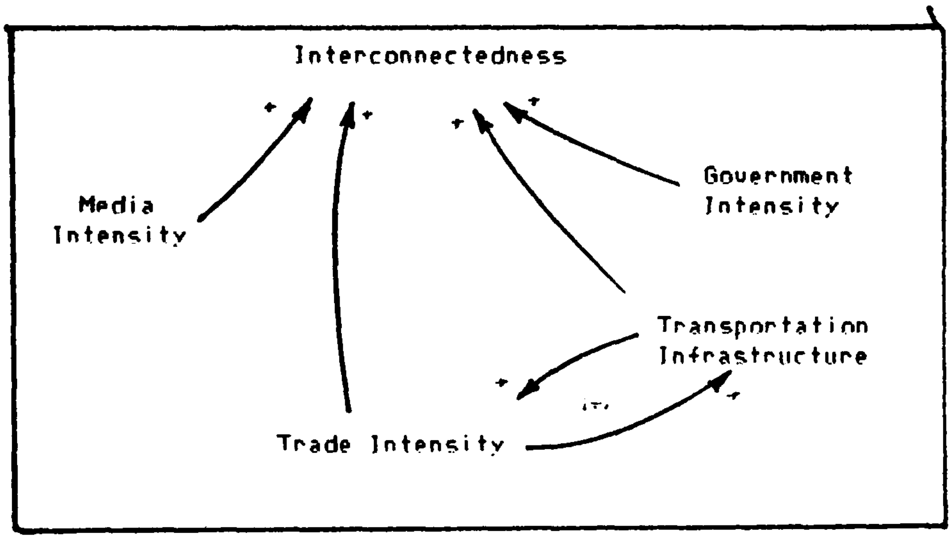

FIGURE 2.6 - INTERCONNECTION CAUSAL STRUCTURE

This loop diagram implies continuous growth of technology, behavior which is consistent with observations of the current world situation. This phenomena will likely continue due to the massive information cascade that is taking place from the modern nations to the developing ntions. Limits to growth will be likely to be found in social structures, depending in part on the degree of cultural legacy present in the national structure.

Trade Intensity

People of every corner of the world exchange goods and services as a matter of routine business. In fact, trade has traditionally been the cornerstone cited by sociologists for the development of sophisticated, interconnected societies. It is a reasonable assumption that life as we know it today could not exist without the scale and scope of trade now witnessed. The effects of trade are pervasive and often nearly overwhelming. For example, the multinational corporation dealing in an international commodity may have a budget larger than many small nations, and have impacts in the world system far beyond the boundaries of mere trade.

Analyzing the nature of trade among nations and internal to nations is a momentous undertaking, employing legions of executives, bookkeepers, and accountants in the task. However this model will not attempt to analyze trade in a great amount of detail. In assessing the impact of arms trade on a the stability of a regional and national system, trade mechanisms are a conduit for arms, yet the arms seldom affect the nature or the intensity of trade in substantial ways during the short run. Recall that trade and its changing intensity in this model reflect an increasing level of embodied technology as a result of innovation transfer. It is the measure of trade both internal to the nation and with external partners that provides an assessment of the degree of interconnectedness and the speed with which transfer of innovation and embodied technology takes place. Figure 2.7 illustrates these concepts.

Increase in exportation and importation increase this intensity of connection with the outside world, while the level of internal consumption of goods indicates the level of internal trade. Some nations, due to political policies, consciously restrict trade with other nations. Because of their nearly self-sufficient nature, they still demonstrate a high trade intensity and enjoy a good standard of living. By simple summation of the value of exports, imports, and internal consumption on a per capita basis, one can derive a relatively accurate measure of trade intensity. This measure applied initially provides an element of

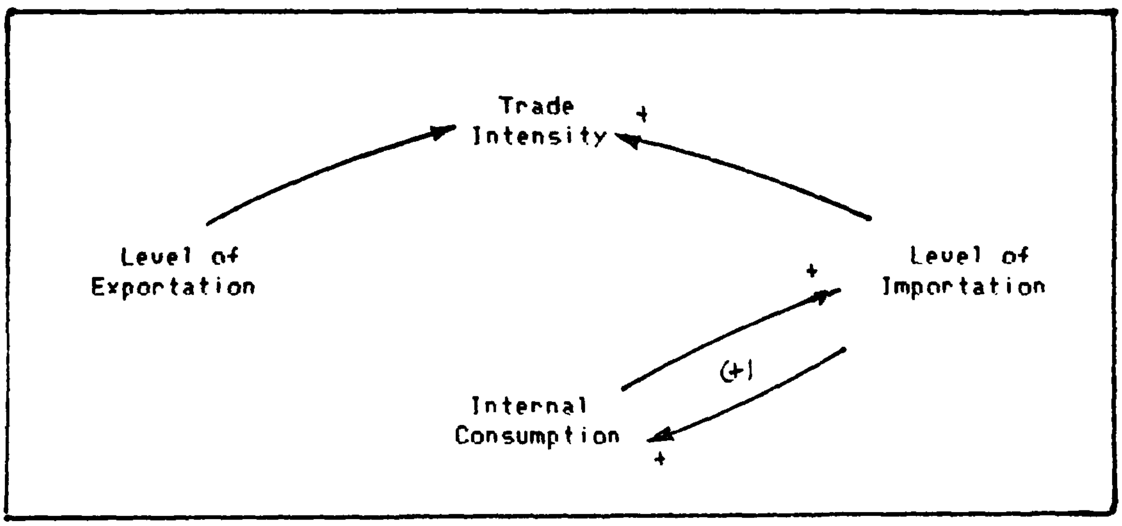

FIGURE 2.7 TRADE INTENSITY CAUSAL STRUCTURE

the degree of interconnectedness present in the national system, and by gauging its rate of change with respect to time, this measure indicates the changes encountered in the dynamics of the system.

Transportation Infrastructure Intensity

As seen in the trade intensity sector, interconnectedness depends on the transfer of goods and services either internally or with the external world. Transportation infrastructure indicates the ability of the nation to transfer goods and services, and as such is another indicator of the degree of interconnectedness of a national system. In assesing the nature of the transportation structure of any given nation, one should consider the size of the nation, the types of transportation media available, the practicality of selecting any mode for use, and the capital requirements of maintaining a particular transportation system. A nation of extensive mountains might find the cost of connecting many small mountain villages with railroad to be prohibitive in both initial outlay and in terms of continuing operation. As an alternative , these nations might chose to use a rudimentary road system, supplemented with aircraft for high speed transport. As noted in the trade sector, unless goods and people can make ready passage into nearly all areas of a nation, the transfer of innovation and technology will be slow.

For the purpose of this model, internal transportation devices are used to get goods to markets for either distribution internally or exportation to the larger world system. Railroads, inland waterways, and roads exemplify internal transportation networks. It appears that external transportation links rely predominantly on the presence of port facilities for goods, and large airports for the transfer of people. Other mechanisms may be present for the transfer of innovative technology, and may include crossovers of domestic and international facilities, however, they are assumed to be a minor factor, and as such are not included. The causal structure below details this sector.

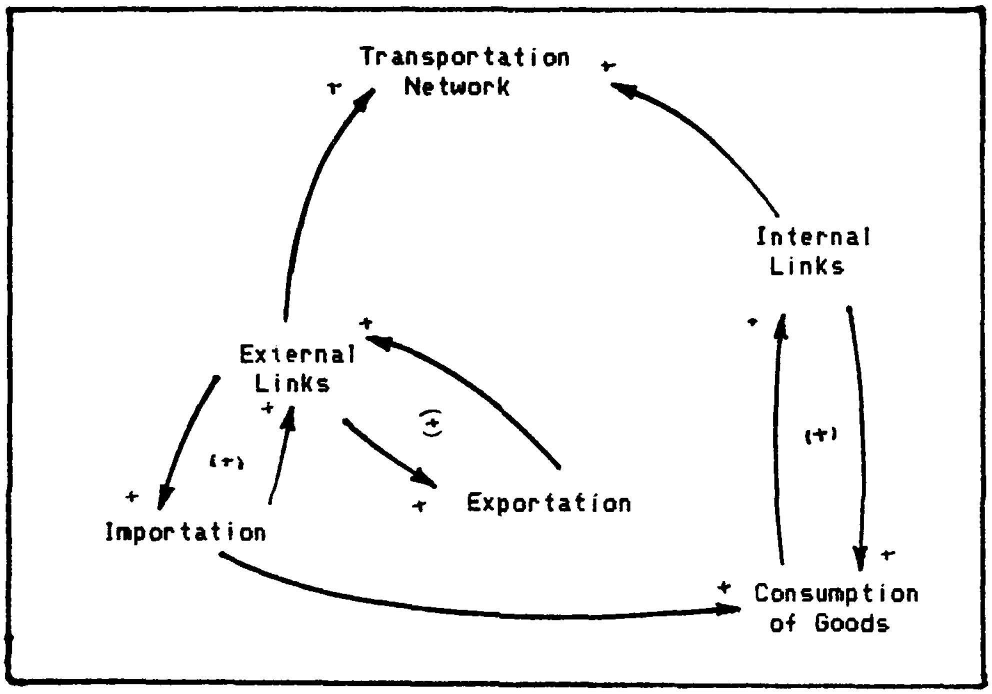

FIGURE 4.8 TRANSPORTATION NETWORK CAUSAL STRUCTURE

Increases in imports and exports from the trade sector increase the number of external linking facilities over time which, in turn, increases the level of imports and exports. The internal links and internal consumption measures are similar in model construction, showing similar interaction over time. The impact of increases in the transportation infrastructure serve to intensify the interconnectedness of the nation in a world system. Furthermore, the positive polarity of all feedback loops implies continual intensification of interconnection. Implications of this trend include increasing loss of privacy for the individual, greater government involvement in the life of a nation, increasing ease of movement to any place in the world, and development of a larger global economy. The actual impact of these trends will again depend on the prevailing social climate and how individuals react to new initiatives to increase interconnection.

Media Intensity

Media intensity, for the purpose of this model, includes the means of mass communication available in a national setting , and includes such devices as radio, television, books, magazines, newspapers, and telephone networks. The mechanisms of the mass media, and the convenience of telephone enable the rapid transfer of information and hence the transfer of technology. As such, media and the transfer of information using this means is perhaps the most volatile element of change in any national system. The information transferred in the electronic and printed conduits is a powerful shaper of perceptions and opinions, in part due to the nature of the transfer,and the isolation of the recipient from the sender of the information. The recipient cannot directly challenge the bias of information sources or the moral codes portrayed by actors, and as such often accepts the messages transmitted without question. Green states :

> Any medium which depicts human beings talking, planning, and striving is instructive. It holds up models of character and transmits standard of conduct. Beyond that, such instruction builds habits

> of expectation and response. It determines what the mass audience wants as much as the mass audience wants determines ... that which they are supplied. (13:597)

In many nations, the media is the predominant link with the interconnected world. World events entering an otherwise traditional society on an daily if not hourly basis through television and radio. The subtle selection of broadcast news events shapes many perceptions, and that which is not said can be more important than that which is said. The influence of media on the young is particularly strong as many expectations are shaped by the plethora of goods and services offered, and behavior norms expressed by actors before them become roles for their behavior. Distinct cultural values degrade in the light of continuous exposure to an interconnected world.

Media deals heavily in accentuation and time compression of change. The power of media lies in part with this time scale alteration and its ability to seemingly move the user to any time period from the future of <u>Star Trek</u> to the past of the <u>Flintstones</u>. Expectations become further altered by this time scale distortion. Americans sit in front of television sets watching events unfold in Central America and feel a sense of frustration in the time required to bring a conflict to its termination. Important issues are expected to be solved in minutes much as crisis is dealt with and resolved during any one of their favorite television shows.

This model treats media intensity as a negative effect on cultural legacy, and a strong indicator of interconnectedness. In this role, media can reshape the thinking of a nation, redefine acceptable mores,

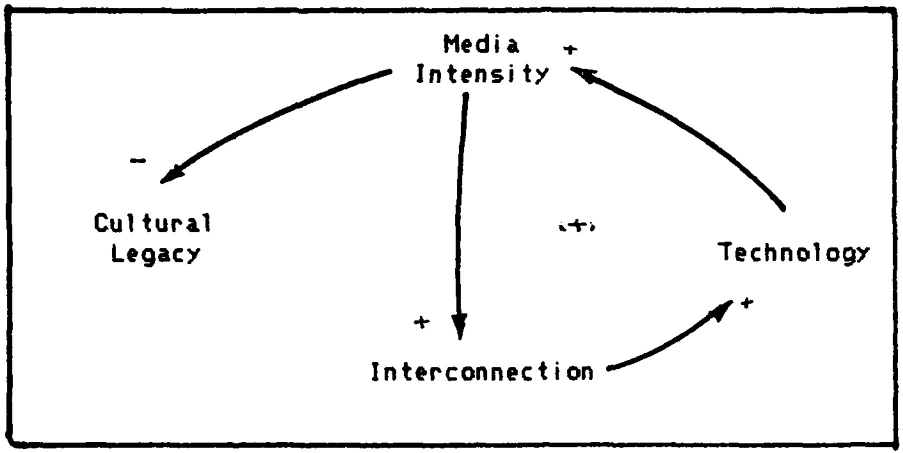

FIGURE 4.9 MEDIA INTENSITY CAUSAL STRUCTURE

and become an agent of change. The implications and expected results of continuing increases in media intensity are yet unexplored, due in part to the recentness of the electronic media elements. Media intensity is limited by the underlying technical sophistication of the nation, yet has the power to increase interconnection and thus the embodied technology of a nation.

Government Intensity

Government in any nation provides a unifying force, and as such can be assessed as largely a mechanism dealing with communication and interconnection factors. According to Max Weber:

> the state is an association that claims the monopoly of the legitimate use of violence, and cannot be defined in any other manner. (13:494)

Green proposes,

> the state arise when centralized political power manages and <u>integrates</u> (my emphasis) the defined public interests of all the citizens of a nation, when this power is legitimized in the eyes of the majority of the ruled, and when they come to regard their nation's sovereignty as the supreme collective need in the midst of a permanent condition of war and threat of war. (13:494)

In theory, government derives its legitimacy from those being governed. This legitimacy can be forced at the point of a gun; it may be surrendered through apathy; or it can be granted through established political processes laid out in substantive law. The means of acquiring legitamacy depends highly on control structures and the collective will of individuals for justice and equity. In a nation of people in which an intense involvement of government is tolerated or desired, control structures will be manifest, leading to a forced level of interconnectedness through the government sector. In nations in which personal freedom is preferred to strong control, structures of control will be considerably less prevalent, and the role of the government as an integrating factor less intense. This model envisions the presence of control structures such as police, professional civil service, nationalized industry, collectivized agriculture, income redistribution processes, and national defense predicated on the degree of control desired by the inhabitants of a nation. Government intensity is then a measure of internal interconnectedness, and in that interconnectedness, another measure of the technology innovation transfer capability of the nation.

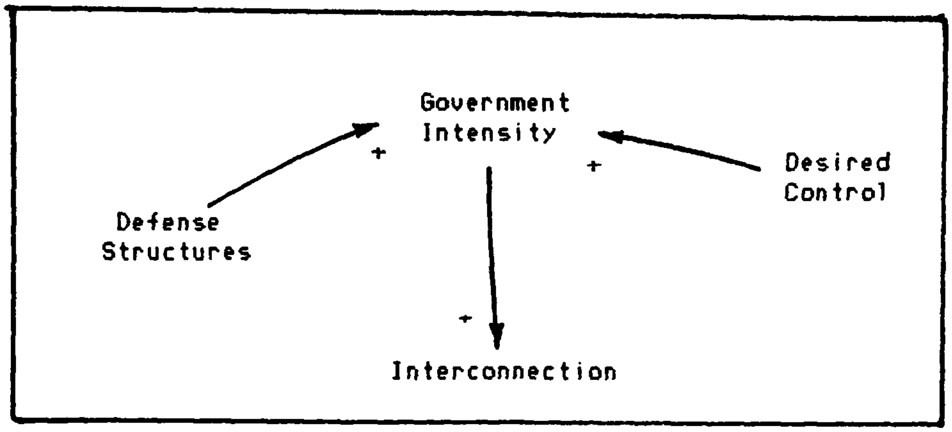

FIGURE 4-10 GOVERNMENT INTENSITY CAUSAL STRUCTURE

In this sector, an exogenous variable factor of desired control is determined by the type of government currently in place, and is based on an assumption that the degree of expressed control desired by the population depends on the number of years the nation has maintained its national status. In general, this assumption states that a "democratic" style of participative government will desire less control over internal national affairs during its early years, and will gradually increase control over time of internal functions based on the arguments of "common good" and "equity." Conversely, governmental structures initiated under the rule of a few, will relinquish control whether intentionally or unintentionally under the load of running a complex system, thus decreasing its absolute integrating impact on the overall society.

This model does not deal with such classical economic and political debates concerning efficiencies of scale, or with the aspects of efficiencies in maintaining control through integrating mechanisms. Instead, the focus is on determining the impact of government as a integrating mechanism, and its impact on increasing embodied technology. Additionally, since in theory government flows from the people being governed,

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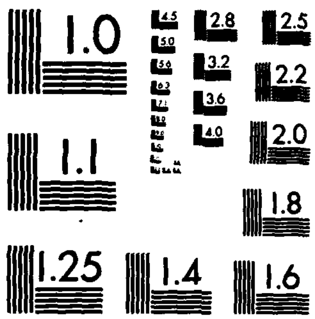

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

and ostensibly is an outgrowth of the nation's cultural legacy, its impact on culture is negligible and will not be examined.

As a legitimate function of government, and the central theme of this study, defense structure and the process of arms transfers is treated as an element of increasing, enforcing, or maintaining existing interconnection. Additionally, through the mechanisms of education which builds human capital and direct transfer arms and their embodied technology which builds capital stock (defense equipment is a portion of a nation's capital, as is training to adequately operate this equipment), arms transfers can possibly increase the technology of a nation. The immediate influence may be imperceptible, and spread over a long period of time, but the military influence is a rather pervasive and perhaps important mechanism of growth.(23) Defense structure and the use of arms will be discussed in greater detail in the next section.

Defense Structure

Whenever any group of people assemble in a nation and occupy certain spaces, there tends to be other groups of individuals arising to oppose such organization. To assure continued existance, to maintain a semblance of distinct cultural legacy, and to post a sign to others wishing to occupy this particular place, nations organize defense structures. The relative sophistication of this effort is in part determined by cultural as well as technological considerations. (26:6;31:126) Historically, nations of traditional orientation, that is those nations that are technically unsophisticated and rely on labor intensive methods of production, organize simple self-defense forces. In defending the nation, use of technology adequate to make occupation of the land by an intruder costly enough to retreat from the endeavor is sufficient. (39:254) Those nations highly oriented towards the interconnected world, as a rule, attempt to acquire or develop technology beyond the basic needs of simple defense. The proliferation of sophisticated conventional arms throughout the Third World and the intensity of production by those leading the modern world seems to bear witness to this phenomena. From a point of reason of armed forces being defensive in nature, this activity seems to be rather counterproductive and speaks in strong overtones of aggressive intentions.

Despite the intentions of individual governments conducting business for a nation, defense structures are nominally initiated in response to a perceived threat. This perceived threat is based on terms of immediacy and relationship to vested interests. For example, India would perceive a greater threat from Pakistan if the Soviet Union were to transfer 50 MiG-23 fighter bombers today than it would from Israel receiving an equivalent number of M-1 battle tanks from the United States two years hence. This perception may be formed irrespective of the actual capability of Pakistan in terms of infrastructure absorbtive capacity. Without the underlying elements of well developed lines of communication, an organized goal-oriented leadership, adequate human capital development to use these machines, and a basic technology that supports the repair of broken components, sophisticated weapons are little more effective in effecting defense than would be simple handguns. Nevertheless, India may still perceive a threat from Pakistan, and attempt to increase if nothing else the stock of arms, whether they could be used or not.

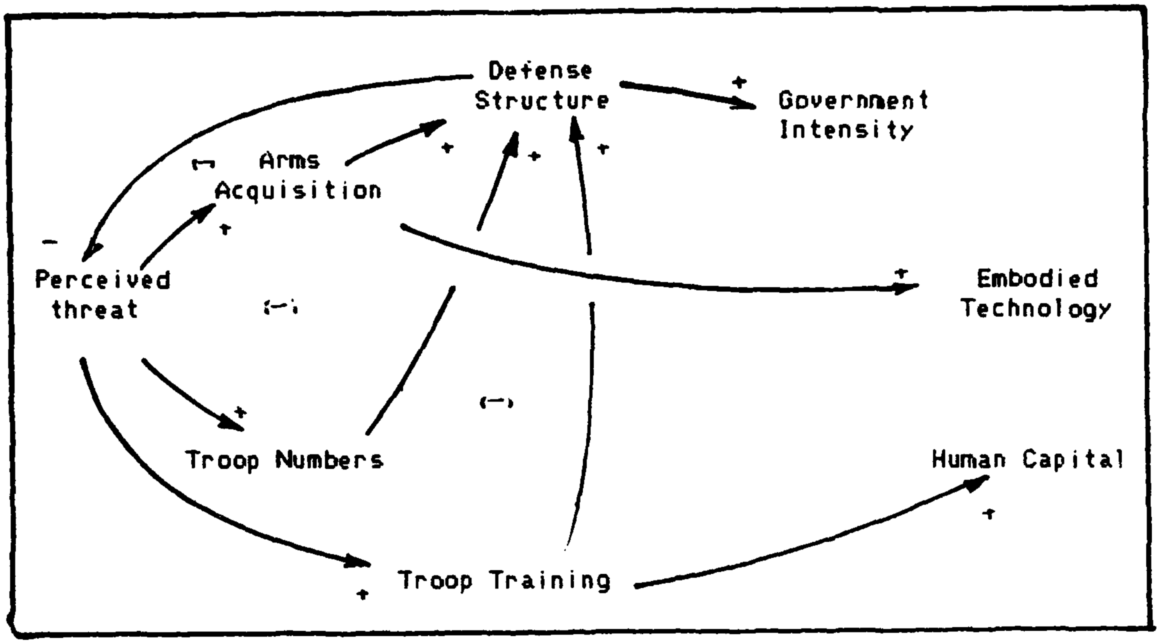

FIGURE 2.11 DEFENSE STRUCTURE CAUSAL DIAGRAM

Due to this phenomena, this model represents defense structure in terms of arms sophistication and quantity and troop quality and quantity. The level of defense seeks the lowest common factor, much like the chain that is only as strong as its weakest link.

The actual intensity of the defense structure is increased upon perceptions of threat, a measure derived by summing the defense intensities of all other nations in the region, and observing the smoothed level of change. Increases in threat cause a nation to exert pressure to increase any of the variables comprising the defense structure, that is by seeking additional arms or improving the quality of these arms, or by increasing its troop strength or quality. If defense structure is seen as appropriate to meet the threat, perceived threat is decreased as is defense seeking behavior. For purposes of this model defense structure is the independent variable that will be varied by nation to observe the impact of arms transfers on both national and regional stability. These experiments will be explained in greater detail in Chapter Five.

Summary

There exist few simple solutions or mechanisms by which we can establish or even gauge stability in a nation and regional setting. This model has proposed a break with convention by attempting to measure stability by focusing on societal conflict of advancement of technology with desire to maintain traditional ways of life as a measure of stability. To accomplish this, theory dealing with the dynamic nature of the national setting for arms transfers has been developed by borrowing in an eclectic manner from many sources in many disciplines. From this theory, causal structures detailing many hypothesized relationships and laid a framework for further development using flow diagrams and corresponding DYNAMO computer code. A completed picture of these interactions in a causal loop diagram are found in figure 2.12.

In particular, *technology embodied* in a nation can be gauged using measures of economic capital production, human capital, and interconnection with a larger world. The desire to retain old patterns of living has been captured in a composite measure of cultural legacy, using such measures as immigrant population, literacy, age of the population, and participation in organized religion. The impact of arms transfers reflects through measures of interconnection. Armed forces, being an instrument of the government, promote interconnection both internal to the national system, and within the larger regional and global systems.

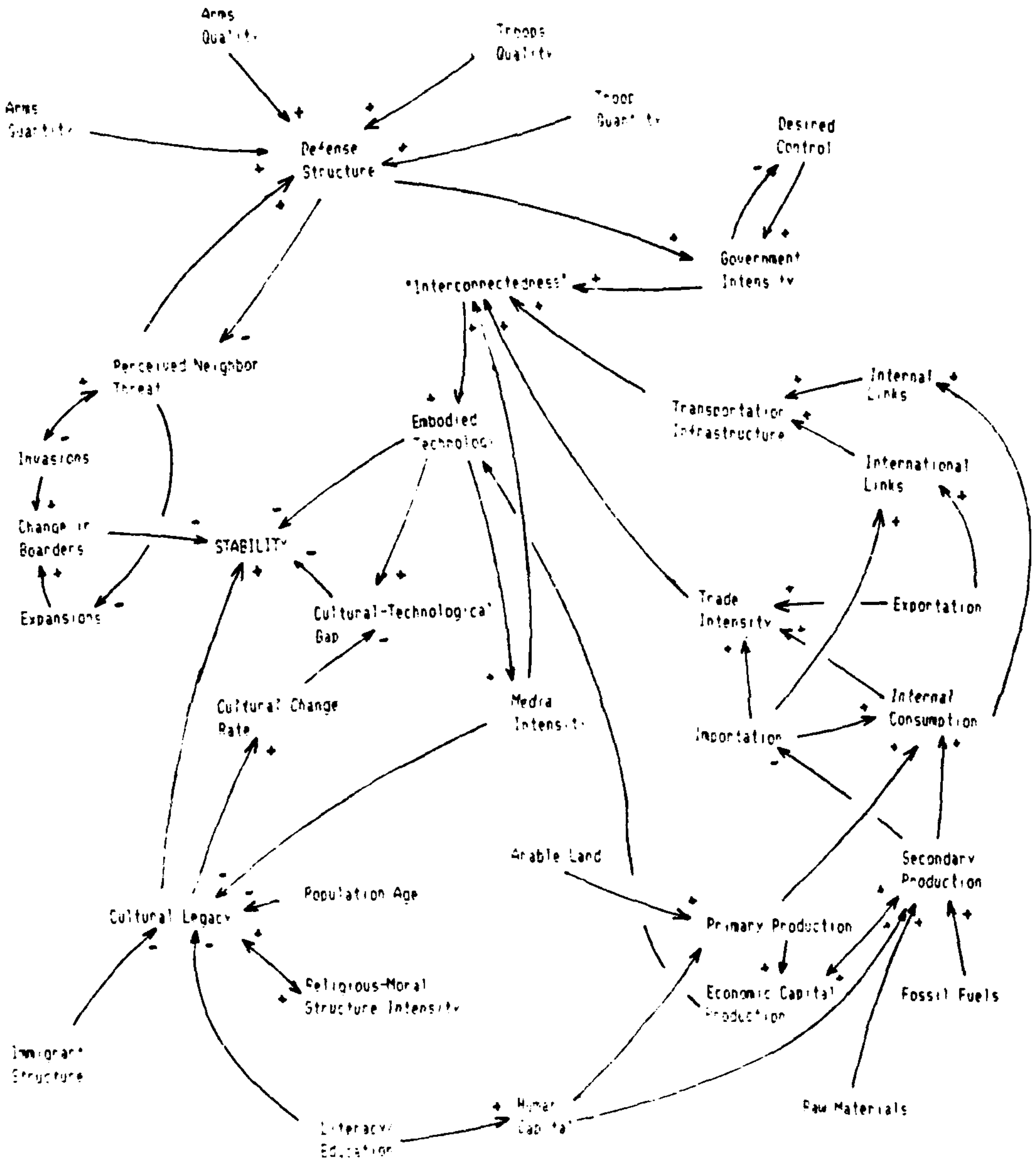

FIGURE 2.12 NATIONAL STABILITY ASSESSMENT FLOW DIAGRAM

Stability can be assessed in two ways, 1) by taking the absolute difference of cultural legacy and technology, or 2) by comparing the relative rates of change in technology and cultural legacy. Primary social conflict resulting in instability in the system results when either technology advancement outstrips cultural legacy decay, or technology is much further adanced than the underlying cultural mechanisms to deal with the technology. Additional instability can be induced through mechanisms of invasion by neigbor states, or through expansion of geographical boundaries.

Nations interact in this model through the measurement of perceived neighbor threat, which in part determines defensive actions taken by the government. The feedback mechanism employed in this loop limit arms buildup to the degree of threat perceived, yet allows for the phenomena of arms wars without war.

Chapter Four will take the causal relationships developed and convert them to System Dynamics flow diagrams and DYNAMO computer code. Chapter Five will report on validation and verification of the developed model, and Chapter Six reports the design and results of a number of experiments conducted using the developed model. The concluding chapter reviews the accomplishment of research objectives, and includes personal reflections that would be useful for the interested researcher that might continue on this thesis' line of inquiry.

CHAPTER III

Model Computerization

Introduction

As discussed in Chapter I, the methodology for computerization of the developed model is that of System Dynamics. In Chapter I, the problem of lack of a quantifiable measure or assessment of stability was identified, and a research plan identified. Chapter II introduced a detailed model of the nature of the interconnected world system with respect to arms transfers. The critical factors identified in this model included the human cultural factors of cultural legacy, change response in an interconnected system, the contrast of response of a modern society to the response of a traditional society, and the impact of arms transfers on change rates.

The cultural factors leading to national and regional stability were identified and developed in last chapter's flow diagrams. System Dynamics methodology then leads to the development of a detailed computer model expressing the intricacies of both the theory and the developed causal loop diagrams. This chapter develops the critical flow diagrams and their supporting computer codes that express the model. Due in part to the size and complexity of the model, model flow diagrams are developed in sectors, with each sector describing processes and flows. In addition, DYNAMO equations accompany the flow diagram, explicitly stating hypothesized relationships.*

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* For a review/introduction of the DYNAMO equation structure, flow diagrams, and methodology of DYANMO, see Richardson and Pugh (29).

Overview

Development of the model starts with a discussion of each major sector, followed by an in-depth explanation of interconnections and interrelationsips of believed significant variables of the sector. As an aid and in keeping with the methodology of system dynamics, explanations focus on stylized flow diagrams, explaining assumptions, simplifications, and surrogate measures. DYNAMO computer code follows the flow diagram and any specialized adaptations or mechanisms explained. In sectors that composite surrogate measures are required, starting value nomograms are provided, accompanied by a brief discussion of the derivation and use of the aid.

Initial development starts in the cultural legacy sector and progresses to the embodied technology sector. This sector is broken into its major components of capital production and interconnection, with interconnection further resolved into transportation, trade, media and goverment intensity subsectors. Although a part of the government subsector, defense and the effects of arms transfers are described in a separate section, with additional explanation of the threat, and boarder change due to war variables provided. As a final sector, the development of stability indices concludes develpment of the model. A summary recaps the essetial features of the computerized model and sets the stage for Chapter IV, Validation and Verification.

Cultural Legacy Sector

As discussed in Chapter II, instability in a social system can result from rates of change in the social system differing significantly from rates of change in technology and interconnection, which may be due in part to arms transfers. To illustrate the concept of social system changes, this model uses a composite measure that has no readily measurable counterpart in a real world system, the notion of cultural legacy. People relating in social system tend to exhibit conservative behavior that continues ongoing relationships and techniques simply because it works. When a majority, or a well defined minority exhibits certain relationships, or characteristics in these relationships, one can easily identify that social grouping as a distinct culture. Culture presents a role model, a "blueprint for conduct"(12:363), however the relationships are not necessarily etched in stone. As an example, social systems rooted in a male dominated hierarchy, value expressed in terms of land holdings, predominance of the Roman Catholic religion, and the predominant use of the Spanish language are strong indentifiers of a Central American "Latin" culture.

In part, the ability of a nation to deal with change stems from its cultural legacy, or lack thereof. A traditional society tends to shun change, whereas a modern society will tend to embrace change. If a society displaying a high degree of cultural legacy experiences rapid increases in technology, this model envisions an increase in the tendancy towards instability. Specific discussion of the determination of the value of cultural legacy for any specific system will be addressed later. However, as a point of reference for upcoming discussion, the value of cultural legacy is initially set between 1 and 10, and will vary from this initial value through dynamic interactions.

Modeling Change in National Systems

In the model of the national system, one primary focus is on change, specifically change in cultural legacy and technology. In many dynamic systems one observes concurrent change in interacting systems. As an example, an observer might notice that decreases in working population coincides with decreases in production. One might propose a causal structure between these two variables displaying a feedback loop of positive polarity, and attempt rudimentary analysis. Often it is difficult to find a starting point for analysis due to the "chicken-egg" paradox. Does decreased working populaion cause decreased production or does the converse apply? To avoid problems of this nature, the model starts with the assumption that one can observe behavior of a system over a short period of time. As a result of the observation one can develop both a rate change diagram reflecting a portion of existing dynamics, and at the termination of observatons take a snapshot of the operating system measuring key variables that appear to be vital in the operation of the system. To accurately simulate the operating system, one should reflect both the dynamics of the system and a snapshot of current status of the system, and implement these findings in a structural model of the system that reflects vital flows of information and material.

A continuous flow feedback model can operate under two premises. One can assume that discrete levels of information and material control the other levels in the system and model the system accordingly. Alternately, one can assume from observations that rates of change of specific material or information accumulations determines the behavior of other system components. This model asumes the latter. The former methodolology works well in dealing with well quantifiable variables, such as stock on hand in a production process, and is particualrly effective in implementing decision structures based on discrete levels. However, the nature of a national and regional system demands a different approach. Discrete decision rules are seldom discernable in a functioning social system. Individual actions in a complex system are difficult to trace, and attributing specific system responses to any single action may exceed the information handling capabilities of the model.

The relationship in modeling here is somewhat like the relationship of microeconomics and macroeconomics. Microeconomics models the behavior of the individual based on rules of rationality, and marginal utility, and is similar to the first method of modeling. Macroeconomics, in contrast, models the operation of economic systems, using tools that examine the behavior of economies rather than the individual, and is seldom based on the use of decision criteria. Similarly, this nation model examines behavior of interacting systems, in which individual actions "at the margin" will have an effect on overall system behavior, but overall the cumulative and synergistic combinations of the dynamic system elements that determines overall performance. To deal with the macro nature of this model, and elimnate the need to quantify nation specific decision criteria, this model relies on the measurement of change in system elements. To assess change of any measured variable, a simple fractional change formula embodied in a user function (MACRO PCTCHG) is used.

The development of MACRO PCTCHG allows the modeler to use specific rates of change in variables in either a singular or aggregate manner to control or modify levels in other related, aggregated variables. Additionally, this provides the modeler the capability to test assumptions of interelatedness in various sectors without explicitly having to trace the intricate impacts of information or material flows throughout the system, particularly in validation of model structures.

Specifically, the structure of the MACRO is as follows:

```
MACRO PCTCHG(LEV.K,LLEV.K)
A PCTCHG.K=(LEV.K-LLEV.K)/SWITCH(.0000001,
X MAX(-LLEV.K,LLEV.K),LLEV.K)
MEND
```

where
LEV.K = the current value of the variable
LLEV.K = the prior value of the variable

The use of the MAX function in the denominator of PCTCHG auxilliary equation functions as a means of taking the absolute value of LLEV and assuring the integrity of sign in change values. By convention, a negative valued change indicates a decrease. Additionally, the SWITCH function prevents division by zero causing a computer mode failure, by setting the denominator to a very small number. Although this use of SWITCH prevents mode failures, there still exists the possibility of unrealistic values for percent change when the prior value is indeed equal to zero. To help prevent this occurence, all variables that use MACRO PCTCHG are initialized to non-zero values.

Cultural Legacy Flow Diagram.

This model represents cultural legacy as a level or quantity, degraded by influences of immigration, media, and changes in the underlying religious-moral structure and average age of the population. The flow diagram for the Cultural Legacy Sector is seen in figure 3-1.

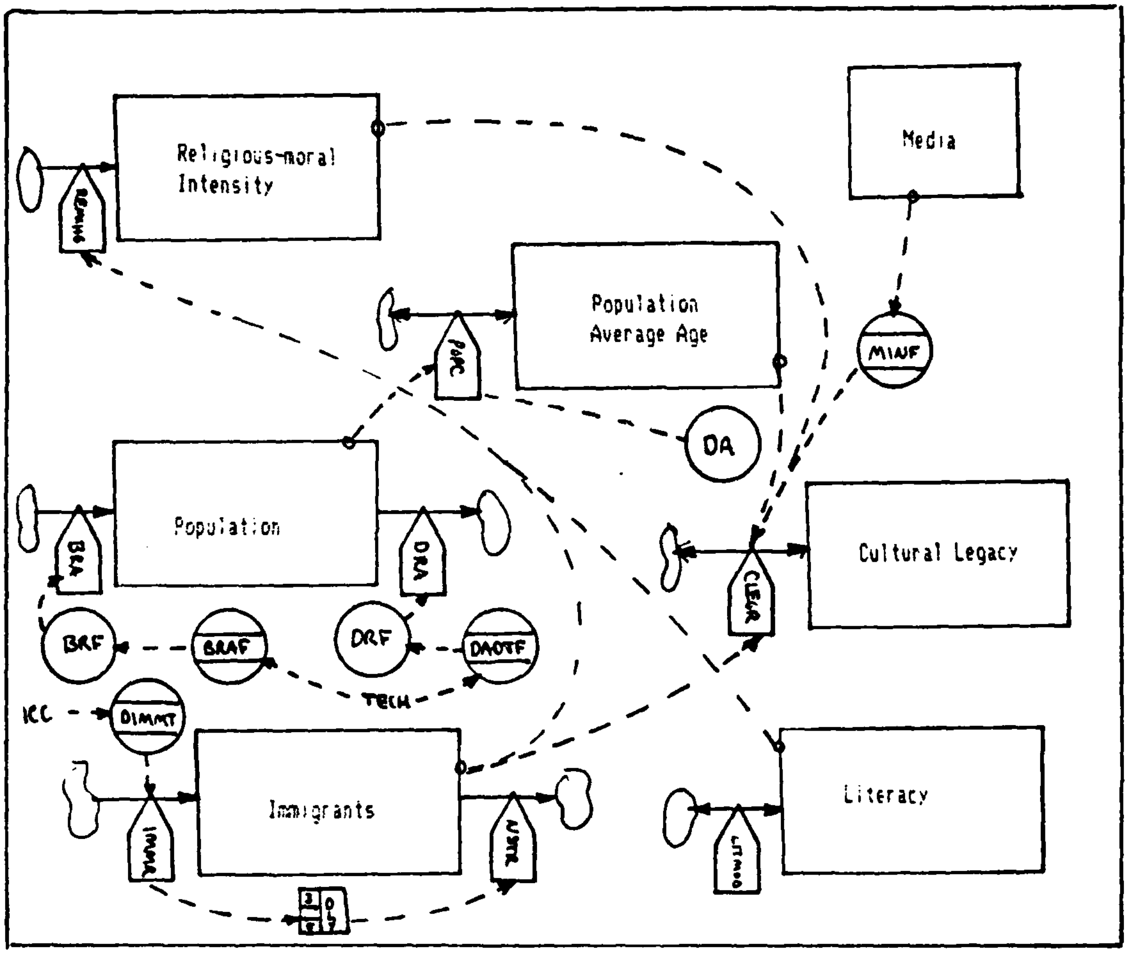

FIGURE 3.1

CULTURAL LEGACY SECTOR FLOW DIAGRAM

From the diagram, cultural legacy is added to or detracted from by media influences (MINF), smoothed change in the religious-moral structure (REMORS), and changes in the percentage of the population that are yet immigrants (IMMCHG). As population age (POPAGE) is important to the influence of media and education processes, this auxilliary variable is derived through the use of a population level variable (POP), and a years of age pooled level variable (POPAV), both controlled by technology adjusted birth rates (BRA), death rates (DRA), and a feedback induced through average age of the population (AGF). The level of immigrant members of a population effects the composition of the cultural legacy, and as such is included as a level in this sector. Immigration (IMM) is controlled by a government affected immigration rate (IMMR) and the population of immigrants loses their immigrant status over time as they become part of the culture and obtain national status (NSR). The slowest moving level in any culture are the religious and moral mores (moral norms) that govern behavior. These are profound beliefs and patterns for behavior.(13:92)

> Out of our mores ... come our religious dogmas, and our definitions of what the age groupings, races, occupational superior and inferior, and sexes owe one another. Out of the mores come our profound convictions of right and wrong, convictions that transcend argument and "rational" demonstration. ... They change more rapidly in civilization than in preliterate society. Perhaps they are changing more rapidly in modern America than in any other civilization. (13:92)

Mores tend to evolve slowly over time under the natural progression of generations, however, since this model focuses more on an intermediate time frame of 15-20 years in the future, the only major influences on mores in this time span can be the smoothed effect of institutionalized education (LITCHGS), and a major influx of immigrants (IMMCHG) bringing with them their own particular structure of mores.

DYNAMO Code

The System Dynamics technique now calls for the translation of these flow diagrams into actual computer code for simulation. DYNAMO code for the levels in this sector are as follows:

Cultural legacy -

```
L LCLEG.K(I)=CLEG.J(I)
N LCLEG(I)=LCLEGI(I)
T LCLEGI(*)=8.001/8.001/8.001
L CLEG.K(I)=MAX(.00001,(CLEG.J(I)+DT*(CLEGR.JK(I))))
N CLEG(I)=CLEGI(I)
T CLEGI(*)=8/8/8
R CLEGR.KL(I)=CLEG.K(I)*(REMORS.K(I)-MINF.K(I)-IMMCHG.K(I))/3
A MINF.K(I)=TABLE(MEDT,POPAGE.K(I),0,1,.1)
T MEDT=.05/.04/.03/.025/.02/.015/.01/.005/0/0/0
```

LCLEG - Level of cultural legacy in last period
CLEG - Level of cultural legacy
CLEGR - rate of change of CLEG
MINF - Level of media influence, as determined by population age, on table function
MEDT - Table of media influence (%)
IMMCHG - Change in immigrant fraction of populaton (%)
REMORS - Time smoothed change in Religious-moral structures (%)

To prevent cultural legacy from dropping to a negative level, making no intuitive sense, the MAX function stops CLEG from taking a value less than .0001. The table MEDT displays the hypothesized decreasing influence of media on an older population, and is illustrated below.

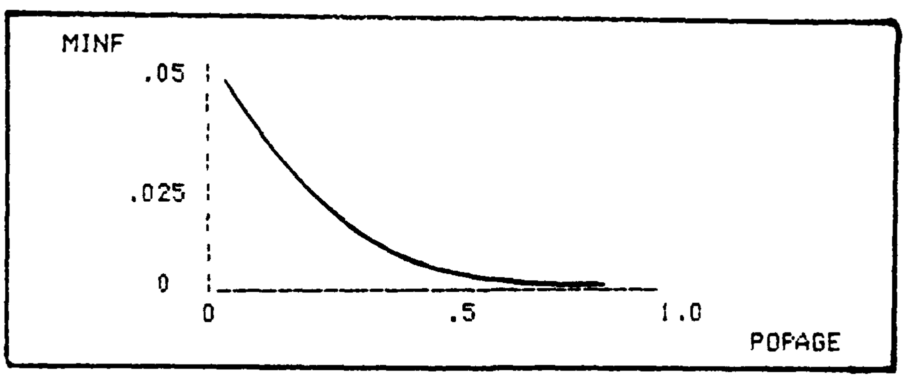

FIGURE 3.2 MEDIA INFLUENCE VS. POPULATION AGE FRACTION

Further detailed discussion on the influence of media on a national system is included in the MEDIA sector of interconnection mesurement.

As a labeling convention, use of "L" as a prefix indicates the last period level, and is used in conjunction with MACRO PCTCHG. Similarly, use of "I" as a suffix indicates initial values of various levels for individual nations under evaluation, and "S" as a suffix indicates a smoothed value. Variables stemming from direct evaluation under MACRO PCTCHG will contain either "CH" or "CHG", and as such indicate rates of change of levels in the model.

Immigrant population -

```
L LIMM.K(I)=IMM.J(I)
N LIMM(I)=LIMMI(I)
T LIMMI(*)=.049/.049/.049
L IMM.K(I)=MAX(.0001,(IMM.J(I)+DT*(IMMR.JK(I)-NSTR.JK(I))))
N IMM(I)=IMMI(I)
T IMMI(*)=.05/.05/.05
R IMMR.KL(I)=IMM.K(I)*DIMM.K(I)
A DIMM.K(I)=TABLE(DIMMT,ICC.K(I),0,10,1)
T DIMMT=-.02/-.015/0/.015/.03/.05/.065/.08/.097/.09/.082
R NSTR.KL(I)=DELAY3(IMM.K(I),10)
```

LIMM - Last period value of immigrant population (% of total pop)
IMM - Current value of immigrant population (% total population)
IMMR - Rate of change in immigration population
DIMM - Desire to immigrate based on national interconnection
NSTR - National status attainment rate

The national status attainment rate uses a DELAY3 function to allow for some individuals integrating into the population more rapidly than others. The desire to immigrate table displays the underlying assumption that individuals won't necessarily desire to immigrate to a nation unless it is accessible, and that the nation is known about by the potential immigrant, both of which depend on the interconnection to the rest of the world by the gaining nation. This table is illustrated in

Figure 3.3.

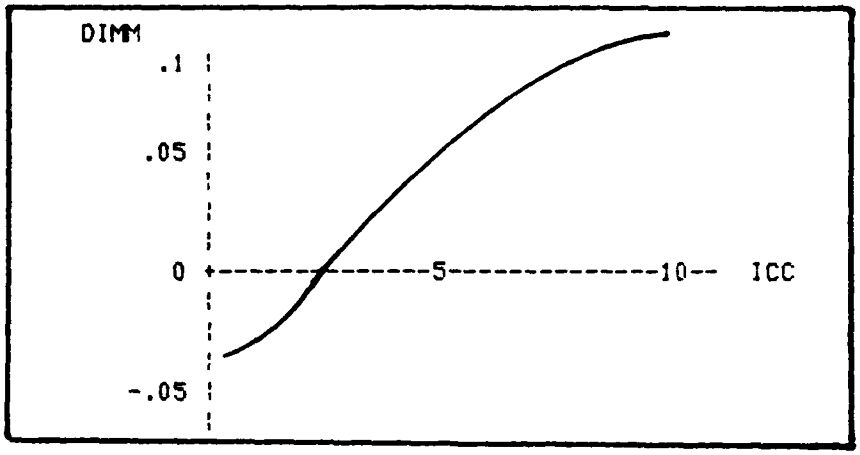

FIGURE 3.3 DESIRE TO IMMIGRATE VERSUS INTERCONNECTION

Population -

```
L LPOP.K(I)=POP.J(I)
N LPOP(I)=LPOPI(I)
T LPOPI(*)=19.8/19.8/19.8
L POP.K(I)=POP.J(I)+(DT*(BRA.JK(I)-DRA.JK(I))*POP.J(I))
N POP(I)=POPI(I)
T POPI(*)=20/20/20
R BRA.KL(I)=(BRF.K(I)*BR)-(TABLE(AGF,POPAV.K(I),10,25,5)*BR)
C BR=.06
T AGF=.94/.65/.30/0
A BRF.K(I)=TABLE(BRAF,TECH.K(I),0,10,1)
T BRAF=1.1/1.07/1.055/1.04/1.03/1.01/1.0/.98/.96/.95/.925
R DRA.KL(I)=DRF.K(I)*DR
C DR=.03
A DRF.K(I)=TABLE(DADJF,TECH.K(I),0,10,1)
T DADJF=1.2/1.18/1.16/1.13/1.1/1.05/1.0/.95/.90/.85/.8
```

POPAGE - Population age factor expressing relative age of population (dimensionless)
LPOP - Population level in the last period (million people)
POP - Population level (millions of people)
BR - Raw, unadjusted birth rate (%)
BRA - Birth rate adjusted for technology, and population average age (%)
DR - Raw, unadjusted death rate (%)
DR - Death rate adjusted for technology (%)
BRF,DRF - Birth rate, death rate adjustment factors
AGF - Age Factor adjustment to birth rate

Birth rate and death rates show the influence of technology on them. Implicit to the death rate factor is the assumption that death rate decreases rapidly at first due to the improvements in medical, and sanitation facilities that tend to decrease death rates in the young in particular, however that these improvements are not as dramatic when a high level of technology is reached. Adjustments to the birth rate occur with increases in technology with the introduction of contraceptive means in relatively sophisticated societies. Additionally, birth rates are adjusted downward dramatically in the short run through an age function (AGF) if the population average age indicates a loss of individuals in the prime reproductive years, or if the very young (under 10 years) become a predominant portion of the population.

Population age:

```
A POPAGE.K(I)=POPAV.K(I)/(MAGE*MAGEF.K(I))
L POPAV.K(I)=(((POPAV.J(I)*POP.J(I))-(DRA.JK(I)*DT*POP.J(I)
X *DA.J(I))+(BRA.JK(I)*DT*POP.J(I)))/POP.J(I))+DT
N POPAV(I)=POPAVI(I)
T POPAVI(*)=26.5/26.5/26.5
A DA.K(I)=(LOGN(RAND.K(I)))/((-1)/(MAGE*MAGEF.K(I)))
A RAND.K(I)=MAX(RND.K(I),(-RND.K(I)))
A RND.K(I)=NOISE()*2
A MAGEF.K(I)=TABLE(MAGFT,TECH.K(I),0,10,1)
T MAGFT=.70/.74/.80/.90/1.0/1.15/1.25/1.28/1.29/1.3/1.34
C MAGE=45
```

POPAGE - Population age as fraction of average mortality age
POPAV - Average age of population (years)
DA - Death age averaged (years)
MAGEF - Mortality age factor modifying average mortality age
MAGE - Mortality age (average life expectancy)

The average age of a population is treated as a years pool, with individual ages lost in the pool. Accordingly the demographics of the society are ignored and individual age grouping characteristics such as mortality rates are ignored. This lack of detail distorts the death age somewhat,however through the simplifying assumption that human populations follow an exponential distribution over time creates a seemingly reasonable approximation. Meadows used a similar approach however disaggregated a population into 4 demographic groups, and used the same exponential distribution to generate deaths in the population and obtained better estimates, but at the cost of an additional 50 lines of code.(19:139) Specifically, the probability of death in any period expressed in terms of the expontial probability density function is:

$$P(death) = 1 - e^{-at}$$

where

a= 1/mean death age, and
t= time (years).

Simple algebraic manipulation of the formula yields the DYANMO formulation and is as follows:

$$Death\ age = \ln\ (P(death)/\ {}^{-1}/_{mean\ death\ age}$$

Assuming that the probability of death for any one individual in the population is a uniformly distributed random event, the probability of death is generated using a 0-1 uniform random number generator. From this death age figure, the period age pool loss comes from subtracting the product of death age and the number of individuals that died in the period.

Religious- Moral Level:

```
L LREMOR.K(I)=REMOR.J(I)
N LREMOR(I)=IREMOR(I)
T IREMOR(*)=8.01/8.01/8.01
L REMOR.K(I)=REMOR.J(I)+DT*REMCHG.JK(I)
N REMOR(I)=REMORI(I)
T REMORI(*)=8/8/8
R REMCHG.KL(I)=REMOR.K(I)*((IMMCHG.K(I)+LITCHGS.K(I))/(-2))
```

LREMOR - Level of mores in last period
REMOR - Current state of mores
REMCHG - Change in mores (%)
IMMCHG - Change in immigrant fraction (%)
LITCHGS - Smoothed change in literacy (%)

Change in the the level of religious- moral mores depends directly on the last period change in immigrants and the smoothed change in educational infrastructure as represented by literacy rate. Decreases in change rates or retrenchment serve to strengthen and build mores.

Initialization

As many of the values in this sector are subjective at best, the individual using the model needs to start using values reflecting a realistic state of affairs. Without realistic values, the model will demonstrate startup transients that may not reflect reality or totally distort the measures of stability. In particular, the model has been designed to be sensitive to the changes of variables in the interrelated, interconnected system variables as is the world system, and any major deviation from those values will cause the model to react unrealistically. Rather than having to guess on the initial levels to be selected for any individual country, a nomogram is used to specify a starting value. A nomogram is

> a graph,usually containing three parallel scales graduated for differnt variables so that when a straight line connects values of any two, the related value may be read directly from the third at the point intersected by the line. (36:903)

All nomograms used in this model are constructed with the outer two axis using common statistical information, and the inner single axis describing the contrived measures of the model.

The construction of the nomogram scales has been contrived and rather subjective. Using extreme values on the two outer scales representing the extremes observed in a world system, an inner scale was constructed to reflect believed relative relationships. For example, if one believes that Ethiopia, with 56% of its population in direct agriculuture and a per capita income of $86 is the most traditional nation in the world, then the intersection of these two values should intesect somewhere on the high end of the CLEG scale. The construction of the nomogram follows no set procedure, but rather should reflect recognized measures of the variable being determined, and when possible use the same uniform set of scales for surrogate variables. Rather arbitrarily the scale of 0-10 was chosen for initial level determination, however, any other reasonable scale is acceptable, as a primary focus is on change in variables rather than actual variable value itself.* To use the nomograms, first obtain the statistical measures found on the outer two axis' for the nations of the region under investigation. Using a straightedge, connect those two values, and read the value for constructed value off the center axis as a starting value for the model.

------

* Using other scales would reqire an adjustment of many of the table functions found in the model, as most of them are based on either 0-10, or 0-1 scales.

For example using figure 3.4, Chad has a per capita income of $180, and has 54% of the labor population involved in agriculture. The low per capita income and high involvement in basically subsistance agriculture indicates a highly traditional society high in cultural legacy, which is reflected by the center axis CLEG value of 8.2. Similar procedures would be employed for initialization of other surrogate variables using the appropriate nomograms.

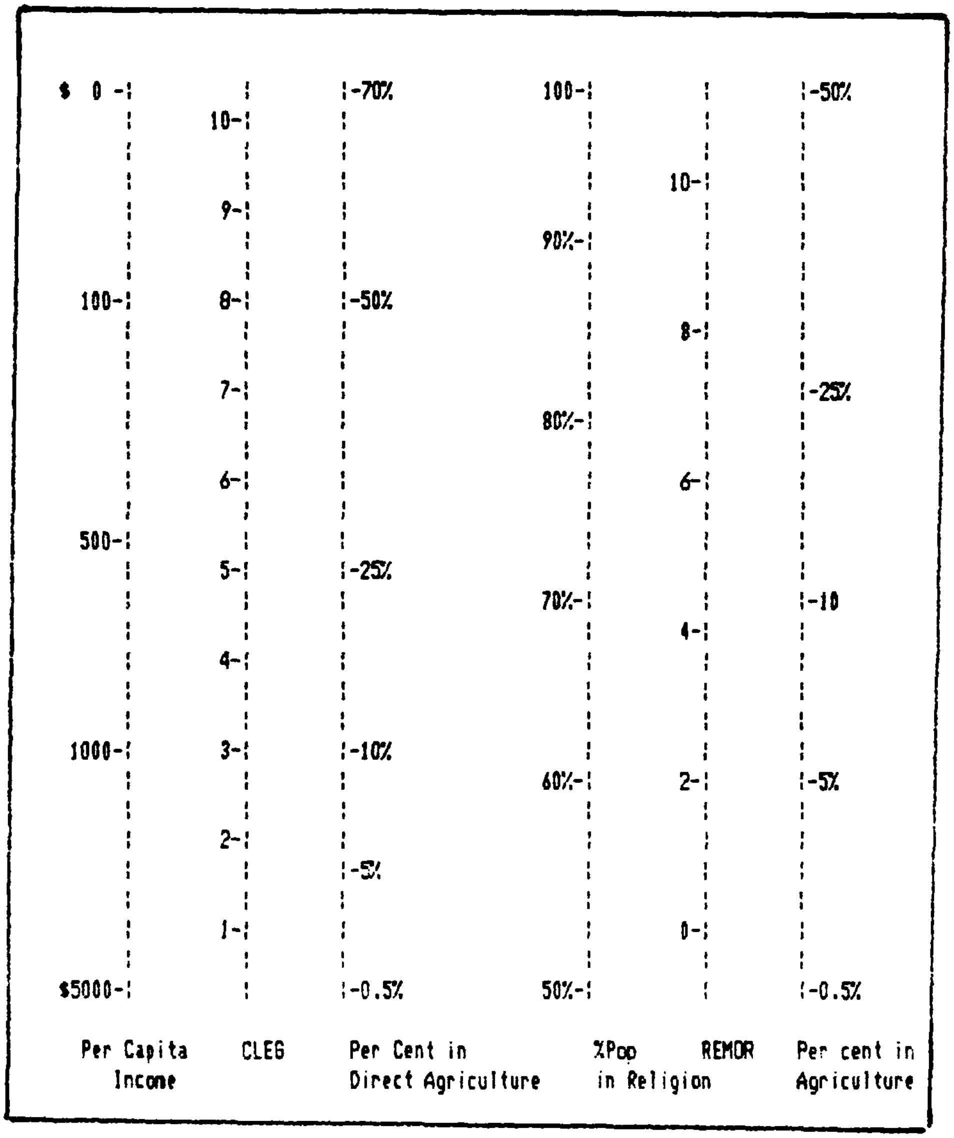

FIGURE 3.4 CULTURAL SECTOR INITIALIZATION NOMOGRAMS

Technology Sector

Within this model, the measure of technological sophistication depends on two factors, the level of capital production and the level of interconnectedness. Gomez identifies high per capita GNP as a key measure of "moderness", which includes the concept of connection to the rest of the world, as well the characteristic of a progressive cultural attitude towards change.(11) As discussed in the previous chapters, conflict resulting in internal instability can arise if rates of change in the technology sector far outstrip change in the cultural sector. Additional instability can result if the absolute difference of cultural ability to absorb technology is far less than the level of technology being imposed on the culture. Technology is most successfully integrated into all aspects of a nation if it evolves from needs originating from the lowest common levels of a society rather than being imposed from the top downward. Maggee in Megatrends identifies movements from the super-structure downward as "fads", which are likely to have little lasting impact on a society, and contrasts them with "trends" that originate from within the infrastructure which have lasting impact.(28) Similar forces can be observed with respect to technology in many developing nation. Those aspects of technology that can be implemented into the cultural fabric over time tend to endure and often find valuable uses in ways other than originally intended.

The level of technology embodied in the national structure (hereby referred to as simply "technology") can be directly observed in modes and means of interconnection with the outside world, in the product sophistication ("embodied technology") of products or services produced for trade, and in the labor intensity required to produce these goods.

In this model, the measurement of technology is developed using the concepts of capital production and interconnection as modifiers. As seen in the flow diagram figure 3.4, technology (TECH) level is controlled solely by changes in capital production (CAPCHG) and changes in interconnection. Although the actual amount of change in technology may not always equal the same change in either of these two measures, technology covaries directly with changes in these measures. Experience has shown that it is virtually impossible for either capital production or interconnection to consistently display a greater rate of growth than the underlying technology.

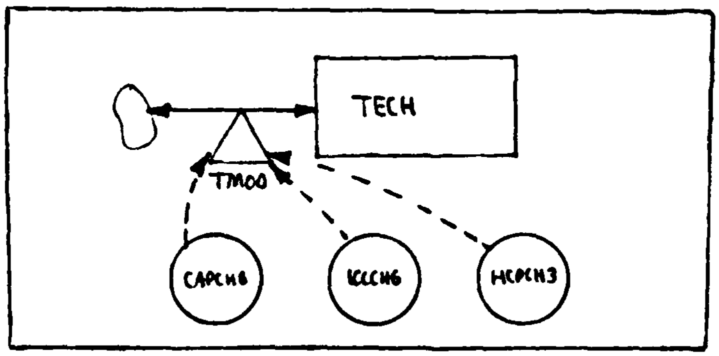

FIGURE 3.5 TECHNOLOGY SECTOR FLOW DIAGRAM

DYNAMO Code

Translation of flow diagrams of the technology measure from pictoral images to DYNAMO code is shown below.

Technology -

```
L LTECH.K(I)=TECH.J(I)
```

```
N LTECH(I)=LTECHI(I)
T LTECHI(*)=4.94/4.94/4.94
L TECH.K I)=TECH.J(I)+DT*TMOD.JK(I)
N TECH(I)=TECHI(I)
T TECHI(*)=5/5/5
R TMOD.KL(I)=TECH.K(I)*(MIN(ICCCHG.K(I),
X .6*CAPCHG.K(I))+MIN(HCPCH3.K(I),.4*CAPCHG.K(I))
```

LTECH - Level of technology in the last period
TECH - Current level of technology
TMOD - Technology modifier
ICCCHG - Change in interconnection to world system (%)
CAPCHG - Change in capital production (%)
HCPCH3 - Human capital change on 3rd order information delay

Technology is treated as a continuously variable level, with specific advances in sophistication lost in a general pool. This level of technology is used in other sectors in a feedback loop structure controlling rates of change in other level variables. As discussed in Chapter II, changes in technical capability stem from invention, innovation, or transfer of innovation.

Dennison attributed 40% of the increases in production in the United States from 1919-1957, above that resulting from increase in raw inputs of labor and capital, to an increase in the quality of the labor force. If his findings are correct, it could imply that increases in human capital were responsible for at least 40% of the increase in production. Using Nichlson's model that identifies innovation, invention, and transfer of technology as the three sources of technical growth, one might group invention and innovation together as results of increases in human capital. The remaining source, transfer of innovation can be envisioned as stemming from interconnection in the system, and with a larger world system.

From these assumptions, this model assigns causality for growth of technology as follows:

1) 40% of the growth in technology stems from increases in invention and innovation. The resulting growth in technology is assigned to the minimum rate of increase of either human capital or 40% of the rate of increase in capital production above increases in inputs.

2) 60% of the growth in technology results from inovation transfer. Change in technology is assigned by the minimum of change of interconnection or 60% of the growth in capital production above increases in inputs.

Summation of growth attributed to innovation and invention with growth attributed to innovation transfer should indicate actual growth in technology embodied in the nation. Notice that this total increase in technology will not exceed the fraction of capital production increase not attributed to growth of inputs.

Initialization

Initialization of the technology measure once again uses the notion of a nomogram, with per capita fossil fuel use and percent of population involved directly in agriculture as entering variables in figure 4-4. The assumed level of technology in the nation is then read off the center scale for input into TECHI and LTECHI. To obtain a reasonable measure for LTECHI, when possible use per capita GNP growth rates as an indicator of actual change in technology and discount TECHI by one time period to indicate this growth rate already in progress. (The user will also want to keep this value in mind as another variable, technological change (TECCHG) will use this same initial change value.)

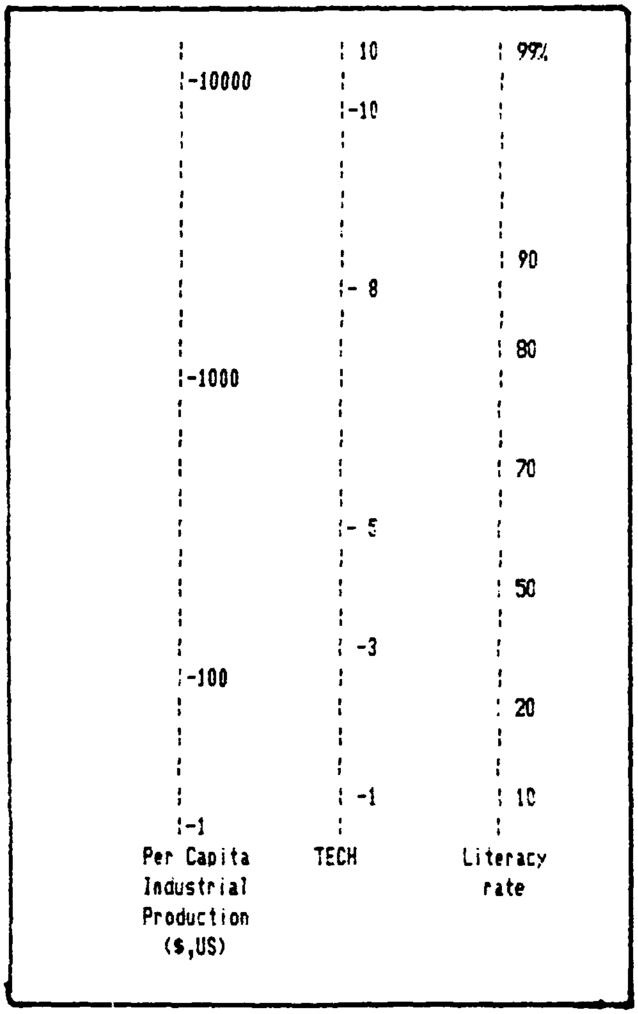

FIGURE 3.6 TECHNOLOGY LEVEL INITIALIZATION NOMOGRAM

Capital Production Sector

Capital production in nearly all nations is the very stuff that fuels growth, progress, and prevents stagnation. Preliterate, tradional societies produce a minimum of usable capital; the food they consume and the rudimentary tools used for production are the virtual limits their capital production. Labor, and the very sweat of the brow are signs of production, however these elements disappear at the very next meal. In these cultures, producing items other than those required for bare subsistence appears frivolous and even a threat to the overall cultural stability. Modern nations in contrast subscribe to the "bigger and better" concepts of capital production. Both industry and individuals measure progress in volume of goods produced, and even more so in the amount of goods consumed. Labor is not the essential element of these goods, but rather it is the composites of knowledge and information making up the sophisticated society that becomes embodied in the goods. (28: 98)

The nature of goods produced reflects the nature of the technology embedded in the producing society. The level of technological sophistication is measured in the information embodied in the goods produced, rather than the goods physical content. Consider two economy cars currently marketed in the United States, the Honda Accord, and the Chevrolet Chevette. Both automobiles have nearly the same amount of raw materials used in their structure, require virtually identical amounts of time to assemble, and have nearly identical production costs. However, the Honda holds a greater amount of information in its components,and is generally recognized as the more sophisticated automobile and as such demands a higher price on the marketplace. (29:46)

This sophistication of information is not held in the books stored in libraries, nor in the data held by massive digital computers, nor even in the sophisticated and specialized industrial robots on an assembly line, but rather in the human element of a population. Only individuals, with all their accumulated knowledge and life experiences can recognize and solve novel problems.(28:108) Many economists and sociologists have recognized this element and have characterized the unique contributions of people as being a nation's stock of human capital. James Fallows discussed this element with respect to the recent trends in United States immigration as follows:

> This economic approach pays little attention to how many immigrants arrive. It concentrates instead on the economic behavior of those who survive the process of immigration. This view... place(s) great stress on "human capital," the mixtures of talents and cultural incentives that make Germany economically different from England and Hong Kong from Macao. From this perspective, the ingenuity and perseverence that immigrants posess can make an economy richer... (8:49)

It appears obvious that human capital is important to the creation of capital goods, and in turn helps determine the level of technology embodied within a nation. Ultimately, this human capital is critical in assessing the capabilities of a nation in absorbing and using arms that may be transferred into the system.

Human capital is developed in many ways, however like trends, it must develop from the ground level up. In most societies, the capacity for critical thinking is developed in formal educational structures, over a period of time. The young learn from elders and peers, and the nature of the lessons in part determines the outcomes. Their method of learning is pedagogic, and they learn despite their inclinations towards the subject matter, or even the setting. An older person behaves differently in the learning environment; he must have an internal motivation before instruction takes root. A conscientiously developed educational system in a society with a high level of human capital will tend to increase the stock of human capital with the education of the young.

However, human capital is not perpetual; human capital depreciates over time. People get old, their memories fail, and they eventually die taking the sum of their life experiences and wisdom with them.

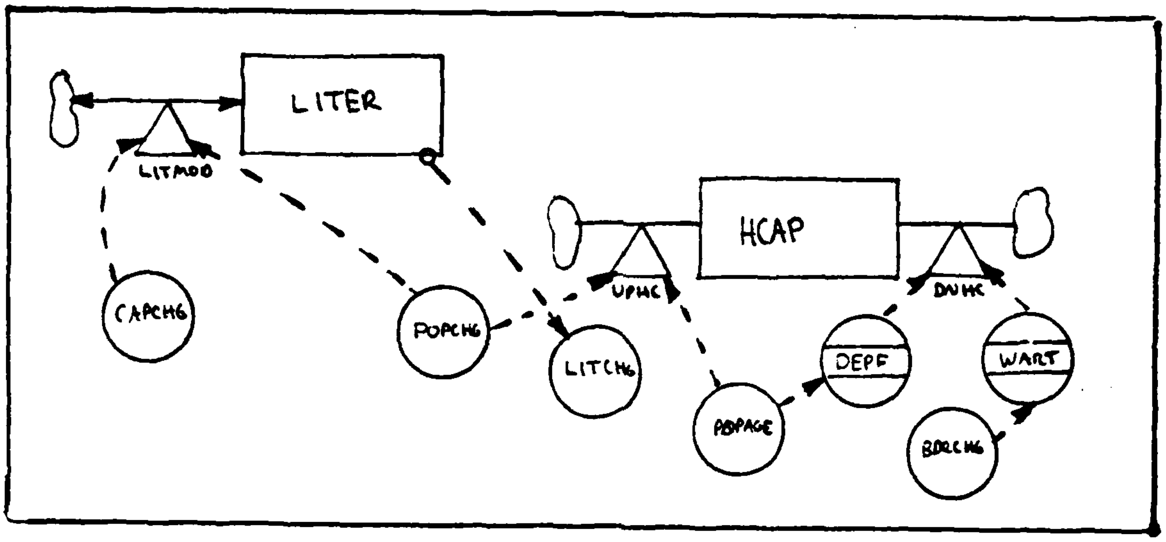

FIGURE 3.7 HUMAN CAPITAL FLOW DIAGRAM

In the flow diagram describing the human capital development (figure 3.7), one observes two major levels, the national literacy level, representing the intensity of an education infrastructure and human capital. Literacy development is driven by increases in capital production yet diluted similar increases of the total population. Human capital investment is initially determined by taking the per capita government expenditure for education and determining that effectiveness by multiplying it by the literacy rate. Increasing literacy increases the value of human capital. In this model, the national literacy rate is taken directly from readily available statistics, as is the initial average annual growth of literacy used to start the model. Again in this sector, it has been necessary to form the human capital (HUMCAP) value surrogate. There are estimates of the value of a humam labor over a period of his lifetime, however estimates of this sort are lacking for most underdeveloped nations.

Educational Infrastructure :

```
L LLITER.K(I)=LITER.J(I)
N LLITER(I)=ILLITER(I)
T ILLITER(*)=.85/.85/.85
L LITER.K(I)=LITER.J(I)+DT*(LITMOD.JK(I))
N LITER(I)=ILITER(I)
T ILITER(*)=.84/.84/.84
R LITMOD.KL(I)=MAX(0,CAPCHG.K(I)-POPCHG.K(I))
```

LLITER - Last period literacy rate (%)
LITER - Literacy Rate (%)
LITMOD - Literacy modification (%)
CAPCHG - Change in capital production (%)
POPCHG - Population change (%)

These equations embody the assumption of continuing increase in national literacy as a result in rising economic production. The incremental increases in literacy however will be degraded by excessive growth in population, and accordingly the population growth is subtracted from growth in production. Traditionally, educational structures are slow to change in part due to their pedantic methodology and due to the manner that new ideas are introduced by infrequent influx of new instructors. Societies with a low level of technological sophistication will be limited in their ability to increase their education infrastructure, and may not be willing to develop this due to their traditional orientation.

Human Capital :

```
L LHMCAP.K(I)=HUMCAP.J(I)
N LHMCAP(I)=(IHMCAP(I)/LPOP(I))*LITER(I)
T IHMCAP(*)=4.82/4.82/4.82    MILLIONS OF DOLLARS
L HUMCAP.K(I)=HUMCAP.J(I)+DT*(UPHC.JK(I)-DNHC.JK(I))
N HUMCAP(I)=(HUMCAI(I)/POP(I))*LITER(I)
T HUMCAI(*)=5/5/5             MILLIONS OF DOLLARS
R UPHC.KL(I)=(LITCHGS.K(I)*HUMCAP.K(I))
R DNHC.KL(I)=((WAR.K(I)+DEPF.K(I)+MAX(0,POPCHG.K(I)))/3)*HUMCAP.K(I)
A WAR.K(I)=TABLE(WART,BDRCHG.K(I),0,1,.1)
T WART=0/.08/.15/.17/.20/.25/.30/.36/.42/.46/.5
A DEPF.K(I)=TABLE(DPT,POPAGE.K(I),0,1,.1)
T DPT=0/.002/.004/.006/.008/.01/.015/.025/.033/.040/.05
```

LHMCAP - Last period level of human capital (dimensionless)
HUMCAP - Level of human capital development (dimensionless)
UPHC - Increase in human capacity rate
DNHC - Decrease in human capacity rate
LITCHGSs - Change in national literacy (smoothed)
BDRCHG - Change in landmass (boarder change - %)
WAR - War loss variable
WART - Table of war loss
DEPF - Depreciation factor
DEPT - Depreciation table

Human capital increases with similar growth in the educational infrastructure and technology, yet smoothed over a three year period to show the time that it takes for societal penetration. Decreases result from an average of population growth (dilution factor), war loses (expressed by WART with respect to level of boarder change), and depreciation due to aging of the population. The WART and DEPT can be modified for national fine tuning to express nation predilection towards war, and attitudes towards the elderly in the population.

Primary Production

Capital development in all nations starts in the production of agricultural and other primary products. Green notes that

> ... usually, the village has historically risen upon the economic base of settled agriculture. Unlike the band, the agricultural village requires a permanent location and a rudimentary division of labor that includes trade. (12:62)

From this initial specialization, societal mechanisms of increased complexity evolved, centering around trade mechanisms and the common need for goods and services. However, many nations trace their economic roots back to their agricultural sectors.

The sophistication and efficiency of primary production varies greatly with the embodied technology in the society. A nation of low technological sophistication tends to use labor intensive methods of agriculture, categorically demonstrate low yields in production, and be generally inefficient in terms of labor investment. Traditionally, agricultural goods fetch a lower price than do manufactured goods when compared with respect to labor investment in production, and those nations depending solely on primary production for their economic well-being demonstrate lower per capita earnings.

Primary production is traditionally increased in two ways; the first, increasing land under production, and the second, increasing technology used in production. Land reclamation, terracing, and expansion are prime examples of the first methodology, whereas chemical fertilization, irrigation, supergrains, and mechanization are examples of increasing technology. Increasing technology usually results in greater efficiencies in production and usually higher yields for every acre of land under production, whereas increasing the stock of arable land does not necessarily portend any increases in efficiency or level of production. This model treats this primary production sector simply as seen in figure 3-8.

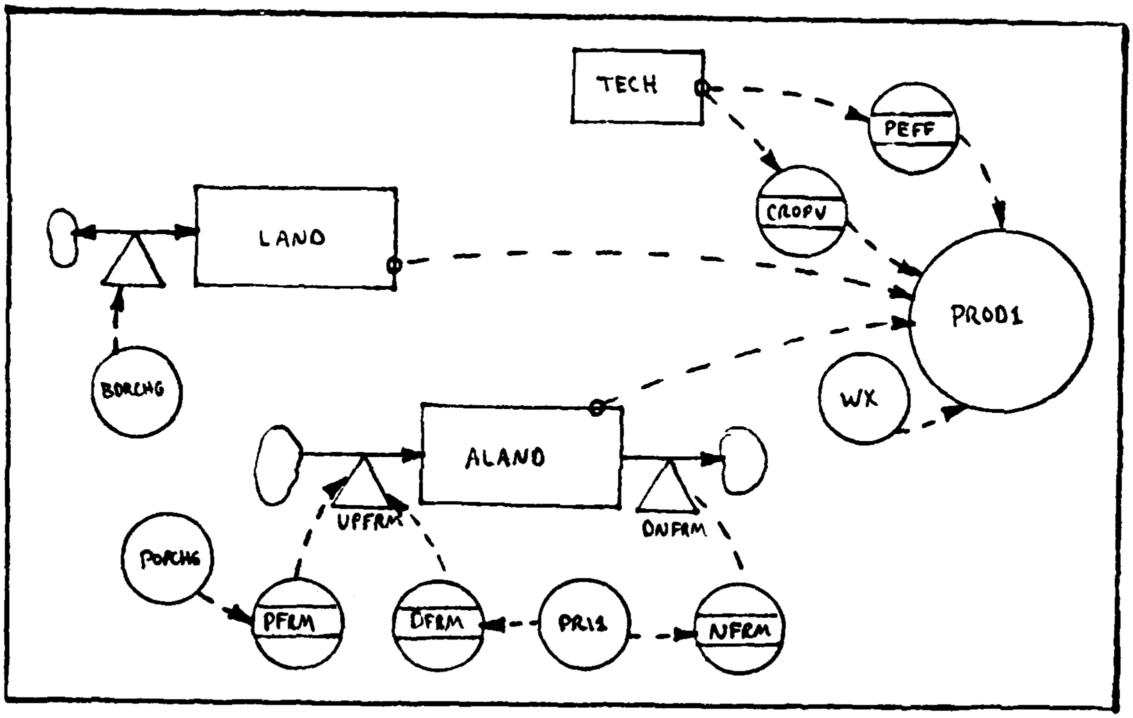

FIGURE 3-8

PRIMARY PRODUCTION FLOW DIAGRAM

The auxilliary treatment of the primary production stems from the observation that primary production is not so much a continuing process that depends on prior levels of production, but rather a discrete process that depends on the level of national technology and arable land, with a random factor of weather often determining the outcome of attempted production. Arable land under production reflects the number of acres started into production each year. Factors of price expected for goods produced and demands based on population changes result in increases or decreases in price modifying production attempted. The differing effects of price changes on arable land reflect the observation that land is taken out of production much more slowly when prices fall than it is brought into production when prices rise. The DYNAMO equations follow:

Arable land :

```
L LLAND.K(I)=LAND.J(I)
N LLAND(I)=LLANDI(I)
T LLANDI(*)=25.0/25.0/25.0
L LAND.K(I)=LAND.J(I)+(DT*BDRCHG.J(I)*LAND.J(I))
N LAND(I)=LANDI(I)
T LANDI(*)=25.0/25.0/25.0
L ARLAND.K(I)=ARLAND.J(I)+DT*(UPFRM.JK(A)-DNFRM.JK(I))
N ARLAND(I)=ARLANI(I)
T ARLANI(*)=.50/.5/.5
R UPFRM.KL(I)=(TABLE(PFRM,POPCHG.K(I),-1,1,.2)+
X TABLE(DFRM,PRI1.K(I),0,10,1))/2
T PFRM=-.008/-.0075/-.006/-.005/-.002/0/.002/.005/.007/.009/.01
T DFRM=0/.01/.015/.02/.025/.032/.040/.052/.067/.08/.1
R DNFRM.KL(I)=TABLE(NFRM,PRI1.K(I),0,10,1)
T NFRM=.01/.009/.008/.007/.006/.005/.004/.003/.002/.001/0
L PRI1.K(I)=PRI1.J(I)+(DT*(.02+(NOISE()/5)))
N PRI1(I)=IPRI1(I)
T IPRI1(*)=5.0/5/5
```

LLAND - Last period level of land (Thousands of sq miles)
LAND - Amount of land held by the nation (Thousands of sq miles)
ARLAND - Arable land under production (% of total land)
UPFRM - Rate of increase in farmed land (%)
DNFRM - Rate of decrease in farmed land(%)
PRFRM - Pressure to farm due to increases in population
DFRM - Desire to farm due to changes in price
NFRM - Action to not farm due to price changes
PRI1 - Price of primary goods on the market ($)

As a gross simplification, the price of primary goods is a steadily increasing function of time, with a random noise generator used to display market changes about a central value. The tables NFRM and DFRM are used to reflect the effects of price on production undertaken, whereas the PFRM table reflects societal pressures due to increases in population to increase land under production. The actual land resource owned by a nation depends on its fortunes in war as reflected by the boarder change (BDRCHG) variable.

The actual value of primary production depends on the level of land under production, production efficiency, and value of the crops undertaken. The assumptions of greater labor efficiency and greater value of crops with increasing technology are advanced with little additional support. Weather plays a crucial part in any primary production scheme, often seeming capricious and totally unpredictable. However, weather effects appear to display a random normal distribution over time, with a fairly well defined mean value and variance. The model level of primary production is adjusted for these weather effects. The DYNAMO code follows:

Primary Production :

```
L LPROD1.K(I)=PROD1.J(I)
N LPROD1(I)=IPROD1(I)
T IPROD1(*)=13.0/13/13
A PROD1.K(I)=CROPV.K(I)*(ARLAND.K(I)*LAND.K(I))*PEFF.K(I)*WX.K(I)
A PEFF.K(I)=TABLE(PEFT,TECH.K(I),0,10,1)
T PEFT=.2/.3/.35/.40/.42/.46/.55/.62/.70/.73/.76
A WX.K(I)=NORMRN(1.0,.15)
A CROPV.K(I)=TABLE(CVALT,TECH.K(I),0,10,1)
T CVALT=1/2/3/4/5/6/7/8/9/10/11
```

LPROD1 - Last period primary production (Million US $)
PROD1 - Primary production (million US $)

PEFF - Labor production efficiency based on technology level
PEFT - Production efficiency table
WX - Random weather effect
CROPV - Crop value (million $ per 1000 sq miles)
CVALT - Crop value table

Weather effect is normally distributed with a mean of 1 with standard deviation of .15. The table CVALT is easily accessible to alternative pricing schemes for any nation based on the actual types of crops produced.

PEFF - Labor production efficiency based on technology level
PEFT - Production efficiency table
WX - Random weather effect
CROPV - Crop value (million $ per 1000 sq miles)
CVALT - Crop value table

Weather effect is normally distributed with a mean of 1 with standard deviation of .15. The table CVALT is easily accessible to alternative pricing schemes for any nation based on the actual types of crops produced.

Secondary Production

In the last section, primary production was defined as including all types of human productive activity that derives direct value from goods produced from the tillage and cultivation of land. The notion of secondary production includes those activities not included in the category of primary production that produce products of value. Secondary production does not include services such as banking and finance, but rather involves the production of goods from raw materials using whatever sources of energy or capital suited to the production of a finshed or intermediate product. In particular, the notion of capital production in the secondary sector involves the procurement of the raw materials and energy sources essential to production of goods and the appropriate application of human talents to complete the production of a product.

As noted in the previous section, the concept of specialization sprung from the formation of villages of individuals involved in agricultural pursuits, in which individuals with particualr talents pursued the production of specialized products other than those of agricultural production. Other individuals of the community found value in the products fashioned and were willing to trade goods with these specialists in very rudimentary forms. Without the specialized talents of the individual, the raw materials used in the production of the good were singularly of no real value in the trading community. The utility and supply of the goods caused certain market demand, and caused alteration of the value scheme from a singularly individualistic concept to a collective notion. Capital formation in any trading society stems from the basic concept of providing value for value.(28:56) The source of the value is unimportant; the demand for the value is important.

This model subsumes the existence of a trading society and the development of mechanisms appropriate to the society to conduct trade. Value schemes are implicitly aggregated into three major categories of production. These categories are energy production, raw material extractions and production, and manufactured/processed goods production. Furthermore, this model simply assumes the production of manufactured/processed goods relies solely on the national production of energy and raw materials. It is clearly apparent that this assumption fails to hold in light of an interconnected, trading nation, with the capability to import the required precursors for manufactured production. Althought much of the world community has resources for trade and capital acquisition in the world marketplace are able to develop a complex manufacturing scheme for extensive secondary production. (Trade concepts will be treated in more depth in the next sector.) From these simplifications, a rudimetary secondary production of capital system can be developed, and is depictied in figure 3.9 below.

The production of secondary goods depends in part on the level of raw material available. The conversion of raw materials to finished goods is one of the keystones of orgaized society and forms one of the key links in trade. Without the existence of these precursors, modern production is impossible. This model treats raw materials as relatively inexhaustible in the period of concern, and as being a homogeneous whole. There is no differentiation of ores, raw lumber, or fish.* The collection and processing of these resources are a production scheme in forest is of no value until employed unless there is an offsetting which value is added to otherwise worthless resources. (A tree in the opportunity cost in not leaving it in its setting.) The act of gathering for further production processes adds some capital value to the good gathered and is the basis for assigning raw material production as an integral part of capital production. Raw material production is an observable phenomena in all trading societies.

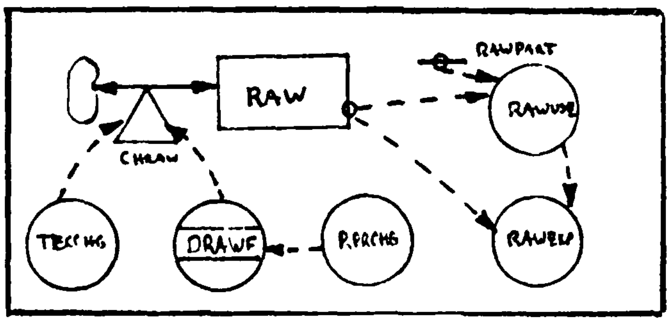

Figure 3.10. RAW MATERIAL PRODUCTION FLOW DIAGRAM

Raw material production increases as a result of increases in technology embodied in the society, its people and its machines, or due

----

* In the traditional sense, trees are not cultivated, nor are any other otherwise naturally occurring live resources such as game or fish. The use of these resources follows a gathering scheme rather than a planned production scheme.

to increased demand for the product as seen in market price. Producers of raw materials will similarly refrain from producing the good if there is insufficient value attached to their labors. The DYNAMO code below explicitly states these relationships.

Raw Material Production :

```
L LRAW.K(I)=RAW.J(I)
N LRAW(I)=LRAWI(I)
T LRAWI(*)=49.8/49.8/49.8
L RAW.K(I)=RAW.J(I)+(DT*CHRAW.JK(I))
N RAW(I)=RAWI(I)
T RAWI(*)=50.0/50/50
R CHRAW.KL(I)=(TECCHG.K(I)+DRAWF.K(I))*RAW.K(I)
A DRAWF.K(I)=TABLE(DRAW,RPRCHG.K(I),-.1,.1,.02)
T DRAW=-.1/-.08/-.06/-.04/-.02/0/.04/.06/.1/.12/.24
A RPRCHG.K(I)=NOISE()/5
A RAWUSE.K(I)=PROD2.K(I)*RAWPART
C RAWPART=.4
A RAWEXP.K(I)=RAW.K(I)-RAWUSE.K(I)
```

LRAW - Level of Raw Material production last period (Million US $)
RAW - Level of raw material production (million U.S. $)
CHRAW - Change in raw material production (million U.S. $)
DRAWF - Desire to produce raw materials factor (dimensionless)
DRAW - Desire to produce raw maerials w.r.t. to price table (dimensionless)
RPRCHG - Raw price change (%)
RAWUSE - Portion of raw materials consumed by domestic industrial production (million U.S. $)
RAWPART - Portion of raw production consumed by industry
RAWEXP - Portion of raw production exported

Fossil Fuel Production.

Fossil fuel production and its concurrent per capita growth is one of the most accurate indicators of a modern nation.(11) As a source of energy for production, fossil fuels can be transported to nearly every corner of nation. Its use in transportation systems allows people of a nation flexible movement. In agriculture, it frees labor for other tasks and increases labor efficiency in production. Fossil fuels provide nearly all the energy for industrial production in a majority of nations of the world, even though it is a non-renewable resource, and faces depletion in the next century. However, in the absense of a readily transportable alternate energy source, fossil fuels should reasonably continue to be the energy source of choice for the period of the model.

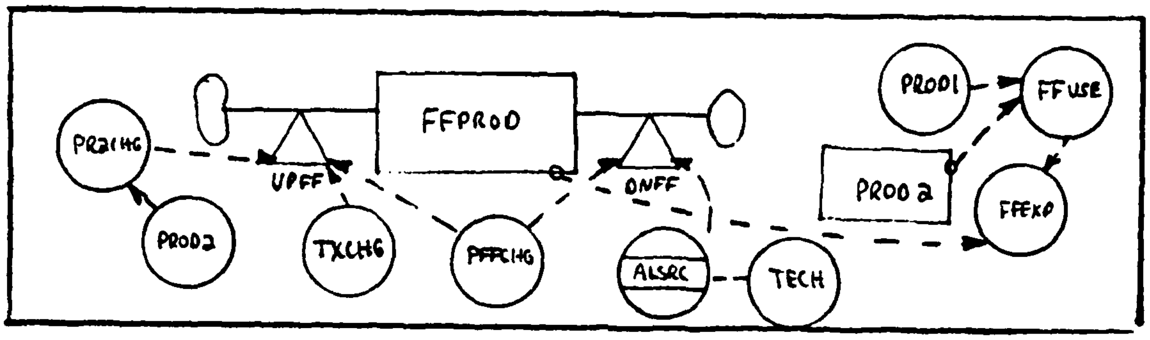

FIGURE 3.9 FOSSIL FUEL PRODUCTION FLOW DIAGRAM

In this model, the assumption of a soley domestic source of fossil fuel production is a point of departure from reality. However, rather than dealing with the intricacies of the world fossil fuel trade, another major project in itself, a permanently decreasing use function is included the rate control "Down Fossil Fuel" (DNFF), indicating the decrease in use as a primary energy source due to the drastic increase in prices. As an example, Brazil has developed an extensive agricultural product alcohol production capacity, in part to isolate the nation from major fossil fuel price increases, and currently supplies 80% of the domestic transportation fuel requirements. Other lesser developed nations are developing similar mechanisms to wean themselves from the tyranny of price in importing fossil fuels. Additionally, nations that had previously found it uneconomical to develop their own known fossil fuel reserves have turned to exxtracting these resources rather than import. A major trend of attempting to break the imported fossil fuel constraint has developed and is gaining strength.

Pressure to increase fossil fuel production comes increases in transportation infrastructure increases or due to increases in price of manufactured goods. Decreases in fossil fuel production come from the development of alternate energy sources with increases in national embodied technology.

Fossil Fuel Production:

```
L LFFPRO.K(I)=FFPROD.J(I)
N LFFPRO(I)=IFFPRO(I)
T IFFPRO(*)=75.0/75/75
L FFPROD.K(I)=FFPROD.J(I)+DT*(UPFF.JK(I)-DNFF.JK(I))
N FFPROD(I)=FFPROI(I)
T FFPROI(*)=75.1/75.1/75.1
R UPFF.KL(I)=MIN((TXCHG.K(I)+(2*PR2CHG.K(I))/3),
X PFFCHG.K(I))*FFPROD.K(I)
A PFFCH.K(I)=MAX(-(NOISE()/10),(NOISE()/10))
R DNFF.KL(I)=TABLE(ALSRC,(TECH.K(I)+PFFCHG.K(I))/2,0,10,1)
X *FFPROD.K(I)
T ALSRC=.02/.017/.01/.006/.0057/.0055/.0057/.0065/.0075/.009/.01
A FFUSE.K(I)=(PROD2.K(I)*INDFF(I))+(PROD1.K(I)*AGFF(I))+
X (.5*FFPROD.K(I))
A FFEXP.K(I)=FFPROD.K(I)-FFUSE.K(I)
```

LFFPRO - Fossil Fuel Production in last period ($ U.S., millions)
FFPRO - Fossil Fuel Production ($ U.S., millions)
UPFF - Increase Rate of Fossil Fuel production
DNFF - Decrease Rate of Fossil Fuel production
PFFCHG - Change in Price of Fossil Fuel
ALSRC - Alternate Source development
FFUSE - Domestic use of fossil fuels
INDFF - Portion of industrial production inputs accounted for by fossil fuel use
AGFF - Portion of agricultural production inputs accounted for by fossil fuel use

FFEXP - Exported portion of fossil fuel production

In operation, this code demonstrates an increasing use of alternate sources with increasing technology and prices of fossil fuels. An assumption that 50% of fossil fuel production on the average is used domestically, may not be realistic on an individual nation such as Libya that is regarded as an energy producer. However, Meadows (19:96) indicates that this is a reasonable assumption in a majority of nations investigated and used this figure in his WORLD III model.

Secondary Production

Recalling that secondary production improvement comes from two sources, increases in input of capial and labor, and increases in technical efficiency, this portion of the model attempts to capture the market forces, and underlying increases in inputs to determine levels of industrially based secondary production. Unfortunately, in most nations the influence of free market price mechanisms on production is not present. Instead a council of "experts" set production goals and attempt to justify at the end of the period why goals were not met. As discussed in previous sections, growth of embodied technology results in part from increases of efficiency in capital production and the concurrent increases in production. The flow diagram of the secondary production level below details these relationships.

Secondary production is modified by price changes in raw materials in capitalistic free economy situations, and a combination of the lowest common change in price for finished product, change in availability of fossil fuels and raw material , and quality of the labor force

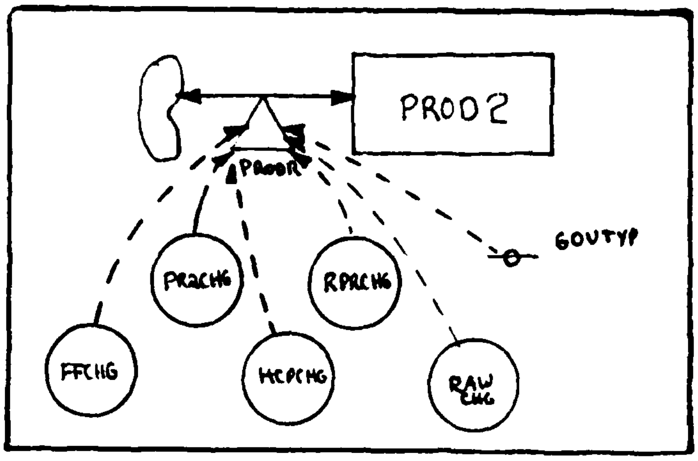

FIGURE 3.10 SECONDARY PRODUCTION FLOW DIAGRAM

The absence of free market competition and a profit motive, due to either protection or regulation, resulting in generally lower production gains, appears to be a reasonable assumption. As seen in the experience of controlled economy societies, and in the United States experience with federally regulated transportation industries, the lack of profit motive may stifle inventiveness and innovation, and the resulting capital gains.

Secondary Production -

```
L LPROD2.K(I)=PROD2.J(I)
N LPROD2(I)=LPRO2I(I)
T LPRO2I(*)=74.8/74.8/74.8
L PROD2.K(I)=PROD2.J(I)+DT*(PRODR.JK(I))
N PROD2(I)=PROD2I(I)
T PROD2I(*)=75.0/75/75
R PRODR.KL(I)=((RPRCHG.K(I)*GOVTYP)+MIN(((PR2CHG.K(I)+FFCHG.K(I)+
X HCPCHG.K(I))),RAWCHG.K(I)))*PROD2.K(I)
T GOVTYP(*)=1/1/1          --- IF = 0 IMPLIES NON - CAPITALIST ---
```

LPROD2 - Secondary production in the last period ($ U.S.,millions)
PROD2 - Secondary production ($ U.S.,millions)
PRODR - Production modification rate (%)
RPRCHG - Raw material price change (%)
PR2CHG - Change in production in last period (%)
FFCHG - Change in fossil fuel availability (%)
HCPCHG - Change in human capital (%)
RAWCHG - Change in raw material production (%)
GOVTYP - Type of economy present (1 - free market, 0 - controlled)

Reflecting the conservative bent again, increases in secondary production come from the minimum of the average increase in production across last period production (PR2CHG),change in energy availabilty (FFCHG), and change in labor capability (HCPCHG); and the increase in raw material availability. Profit motive is allowed in free economy societies available to increase production

Total Capital Production

As a final statement of production in a society, total capital production is the summation of all outputs in the society, including agricultural output, raw material outputs, fossil fuel outputs, and secondary production. The reader may notice the lack of a pure service sector in this capital production model. Although increases in technology may result from increases in service provided, few economic texts treat service production as a concrete output of the economy, and as such does not necessarily increase embodied technology. However, in constructing the model, the service sector should be included, but there exist few measures of this output of any sort. Inclusion of a grossly inaccurate measure may not be to the benefit of the policymaker in examining the impact of arms transfers, and as such has been excluded from the model.

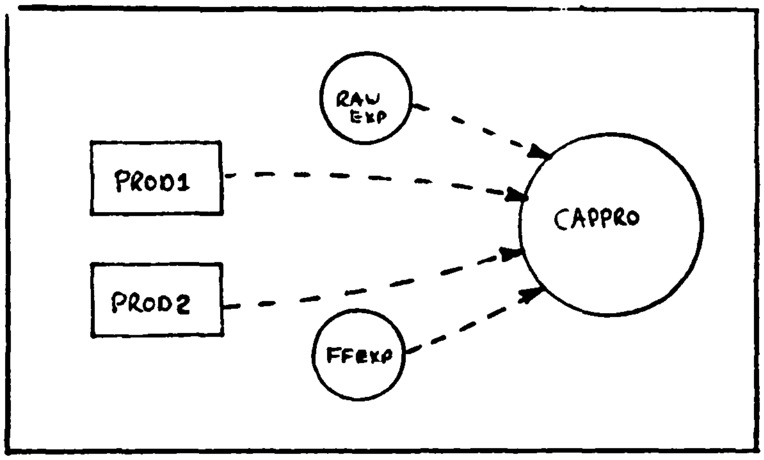

FIGURE 3.11 TOTAL CAPITAL PRODUCTION FLOW DIAGRAM

The internal relationship of capital production is purely additive in nature.

Capital Production -

```
L LCAPRO.K(I)=CAPPRO.J(I)
N LCAPRO(I)=ICAPRO(I)
T ICAPRO(*)=400.0/400/400
A CAPPRO.K(I)=(PROD1.K(I)+PROD2.K(I)+RAWEXP.K(I)+FFEXP.K(I))
X )/POP.K(I)
```

LCAPRO - Last period per capita Capital Production (\$ U.S.)
CAPRO - Capital Production (per capita) (\$ U.S.)
PROD1 - Primary production (\$ US, million)
PROD2 - Secondary production (\$ US, million)
FFEXP - Fossil exports (\$ US, million)
RAWEXP - Raw material exports (\$ US, million)

Interconnection Measurement

In Chapter II, transfer of innovation was cited as one of the three major sources of technological growth. During preliminary causal structures formulation it was observed that one could gain some determination of national interconnectedness by observing the trade structures and mechanisms, the means and pervasiveness of transportation networks, the availability of different types of media, and the control exerted by government over the governed population. Recall that technological growth due to innovation transfer is largely a transfer of information. This information for growth may be embodied in the products transfered, in people moving in and out of the national system, or in pure information channels, such as books, journals, and technical manuals.

In this model, information transfer is subsumed if the channel for transmission is available. This means that if international airports are available, professionals with expert information may enter into the national system and transfer their innovative information to others permanently occupying the system, or build the necessary structures that make use of the special information and become a part of the capital of the nation. If roads are available for the movement of goods from the point of production to the users, then when such an action takes place, information and the technology embodied in the good is transfered. Although it is recognized that an undeveloped nation with an economy built heavily on a tourist trade may not actually use the information embodied in visitors, or even understand the intricacies of the transportation network that brought the visitor, the potential for the transfer still exists. Mere contact, in even a social sense, has a broadening effect on the society being visited, and over time information appropriate to the environment will be transferred. Although it would be beneficial in terms of the model to be able to assess the actual transfer of innovation, the task is nearly impossible. Particularly in the case of innovation, a germ seed can be planted, but it may take time to come to fruition as a technical improvement in production. As the task of equating innovation transfer to any meaningful index is sadly lacking, this model takes the view that interconnection leading to transfers changes at the average rate of change of all elements contributing to the surrogate measure of interconnection. Interconnection is an artificial, surrogate variable that ebbs and flows with the changes in its constituent elements.

Arms transfers and the accompanying transfer of technology through training, support agreements, and construction of infrastructure to support their use, is captured nearly exclusively in the government sector. All legitimate defense activities for a nation are the result of specific policy measures taken by government officials empowered by the government and acting in an official capacity. As such, transfer of

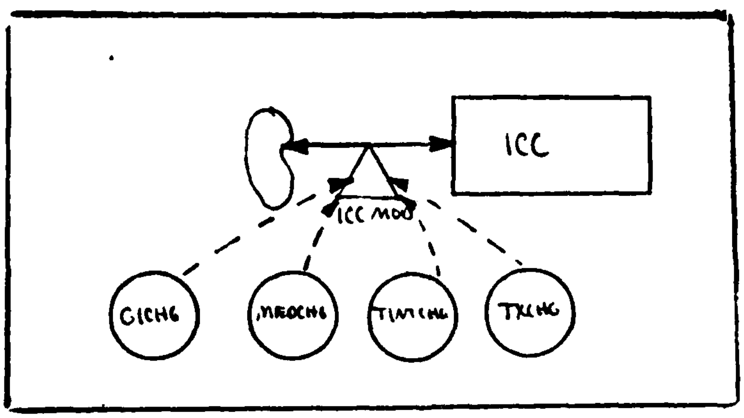

FIGURE 3.13 INTERCONNECTION FLOW DIAGRAM

arms and the resulting intensity of the defense sector of a nation is captured in the government sector of the model.

An additional limitation is imposed on interconnection in that it does not allow for revolutionary changes in the nature of the system. It explicitly excludes revolutionary government changes, introduction of new railroad networks, the creation of a new product that creates a great surge in trade due to demands, or other changes in information/innovation transfer that reflect other than evolutionary, incremental change in efficiency or effectiveness. The DYNAMO code below details these relationships.

Interconnection Measurement:

```
 **************** INTERCONNECTION INDEX ***************
L LICC.K(I)=ICC.J(I)
N LICC(I)=LICCI(I)
T LICCI(*)=4.45/4.45/4.45
L ICC.K(I)=ICC.J(I)+DT*ICCMOD.JK(I)
N ICC(I)=ICCI(I)
T ICCI(*)=4.5/4.5/4.5
R ICCMOD.KL(I)=ICC.K*(TXCHG.K(I)+TINTCH.K(I)+
X MEDCHG.K(I)+GICHG.K(I))/4
```

LICC - Last period level of Interconnection (dimensionless)
ICC - Interconnection index (dimensionless)
ICCMOD - Change of interconnection (dimensionless)
TXCHG - Change in transportation availability (%)
TINTCHG - Change in trade intensity (%)
MEDCHG - Change in media intensity (%)
GICHG - Change in government involvement (%)

The average of increase in ICCMOD is a ready point of modification for testing alternate hypothesis on the behavior of interconnection with respect to its input variables.

Initialization of Interconnection Index.

Gomez suggests that one measure of national interconnection to the larger global environment can be found in per capita annual imports. (11) Close examination of this measure appears to indicate that a level of imports is positively correlated to the physical distribution system available to a nation, to levels of trade undertaken with the world economy, and to activity of the domestic economy.

This author suggests an additional measure of interconnection is per capita consumption of petroleum products. Petroleum products are still the most important portable source of consumable energy; their use is a strong indicator of a good domestic and international transportation facilities; and their limited nature leads to development of sophisticated import mechanisms and transfer facilities. Using these two measures of interconnection, the following nomograms provide initial values for ICC and LICC variables.

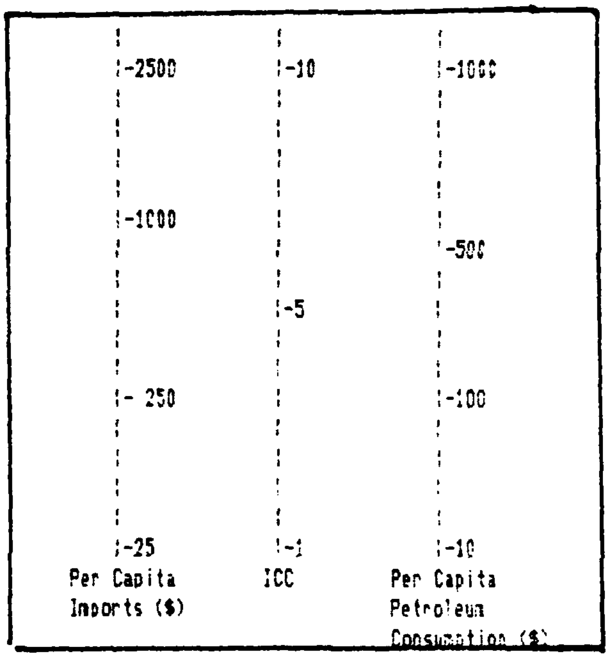

FIGURE 3.14 INTERCONNECTION INDEX INITIALIZATION NOMOGRAM

Trade Structures

Trade takes place in two distinct ways in a national system, at the system boundaries through importation and exportation, and internal to the system in a myriad of wholesale and retail relationships. Measurement of trade allows a decisionmaker to gauge an number of internal and external economic functions, and has traditionally been used to that purpose. In particular, the critical balance of import to export value has resulted in policy decisions leading to protectionist legislation and the restraint of free trade, intense negotiation between nations to prevent economic inspired war, and the incorporation of multinational corporations to legally circumvent the restrictions of politically inspired sanctions. This model recognizes these mechanisms as important and incorporates them as a restriction to trade, however, the model of this sector has more interest in the change of patterns of trade, and the resulting change in transfer of innovation.

Trade of goods on an open global market depends on the demand for a particular type of good, the price charged for the good as determined by its rarity and utility, and the mechanisms available to get the good to market. Often before the good is entered onto a world market, a demand must be created, marketing strategies developed, transportation networks identified and contracted with, and vendors of the product recruited.(40:43) All of these actions lead to greater interconnection and spur the transfer of appropriate technology to support the trade.

Importation.

Quite often, the importation of goods into a new market proves to fraught with the complications of government protection and regulation. If the nation as a whole has been running a deficit in international trade, importing more than exporting, or has an implicit goal of becoming self-sufficient in a particular commodity or class of commodities, then it is reasonable to expect restraint of trade.

The experience of Jamaica of government-perpetrated protectionism is nearly the same as dozens of other Third World nations, and exemplifies the paradoxical responses found in the restriction of trade, and then later opening trade to all comers. Under the rule of Michael Manley, "who had sought to build socialism at home and a new world economic order abroad," Jamaica underwent a severe decline in its economy, and found many social programs foundering. He had based the government on popular precepts, but leaned heavily towards socialist concepts of

> an economy 'more independent of foreign control and more responsive to the needs of the majority of the people at home,' and an 'egalitarian society' in which 'people felt that they were of equal worth and value.' This (plan of government) was to be accomplished by reducing foreign ownership of industry and agriculture, reigning in the local oligarchy, increasing state control of the economy, and fostering grass-roots participation in national decision-making. (18:41)

The experiment was indeed grand and as a leader Manley had wide popular support until economic disaster due in part to the collapse of world demand for bauxite, dramatic increases in the price of oil, and a general world recession led to general dissatisfaction. Jamaica's economy, having been based heavily on the booming export of bauxite during the 1960's, had failed to develop adequate food production capability prior to the collapse, found itself with a product of limited demand, and a hungry population. Political opponent, Edward Seaga attacked his opponent and promised a return to prosperity with his election in 1980. (18)

Winning the election, Seaga opened the gates to foreign investment and aggressively sought out modernization assistance. To deal with the staggering debt left by Manley for the multitudinous social programs in place, Seaga sought the help of the World Bank and the IMF, for both modernization and a financial bail-out. With the aid from the IMF and later the United States, a number of large multinational industries were persuaded to enter the Jamaican scene with promises of an open trade structure for both imports and exports, with the Jamaicans becoming a large labor pool. However, this modernization and opening of trade flooded the market with imported goods and rapidly led to the demise of the few sheltered industries that managed to survive under Manley, leaving the Jamaicans with no substantial domestically controlled industry. Because of the substantial tax breaks granted to multinational industries to woo them to Jamaica, revenues from exportation left the nation along with the products produced there. There are more people at work in nation in the industrial sector, however there have been no dramatic improvements in the agricultural sector production, and despite being one of the most fertile nations in the world, Jamaica must import over half its food from other sources. Things might have a brighter outlook except that along with the aid from the World Bank and IMF, were stringent demands for structural readjustment in the economy. This led to Seaga's pronouncement of a new austerity program of "tough measures for tough times." (18:37-56) including the termination of popular income redistribution plans and cutoff of funds for agricultural development.

To state that the problems of Jamaica are flow strictly from either Manley's or Seaga's policies, or from the meddling of the multinational industries would be simplistic and naive. Instead it is instructive to note the effects of protectionism on undeveloped nation industries and balance that with competition on a world market.

From these discussions and observations, the importance of importation to the state of a nations economy as well as to the transfer of embodied technology should be apparent. Too much importation can lead to instability in developing industries as goods compete for markets; too much protection leaves the nation without the benefits of efficiency spurred by market competition. This model assumes that increases in imports come from either increases in embodied technology or from increases in media penetration. Media penetration is a precursor for mass marketed products oriented towards the consumer. Without knowledge of the product, demand will be spotty and future sales will rely more on informal information chains spreading news of the product. Importers tend to increase above initial stock levels only upon confirmation of a building new market. Business leaders also rely heavily on media information in specific channels for the improvement of capital resources.

Increases in embodied technology in a national setting lead to increases of importation in a circular manner. Take for example the importation of automobiles. After the automobile itself is purchased from an outside source, continued support and maintenance depends on the further import of parts, technical manuals, specialized tools, and training from the original supplier. Gasoline and other POL products may need importation, and the effect cascades across the entire spectrum of an economy, assuming that sufficient demand for automobiles continues.

Decreases in imports tends to follow somewhat different mechanisms. In general, market pressures have little to do with decreases, as other vendors will find surrogate items to replace or supplant originally imported goods. In the case of petroleum products and crude oil, most of the decrease in importation came as a result of specific government mandate rather than through market intervention. Certainly the rate of increase of demand decreased, however the quantity demanded remains relatively static. To discourage imports, governmental agencies often affix prohibitive import tariffs, legislate restrictions to the numbers of a particular product that may enter the economy, or prohibit possession by citizens. Most of this behavior appears to stem from policy maker use of statistics citing trade imbalances either in export-import absolute figures, or in terms of percentage of imported goods sold in a domestic market. Referred to commonly as "balance of trade" or "foreign share of the market", these figures have been the source of much protective behavior in recent years, and as such are likely to be a fair indicator of expected decreases in importation.

The flow diagram, Figure 3.15, illustrates the mechanisms controlling imports and the transfer of innovation from external sources. The measure of market penetration is determined by comparing total imports to domestic consumption, and balance of trade by comparing total imports to total exports with respect to total domestic consumption.

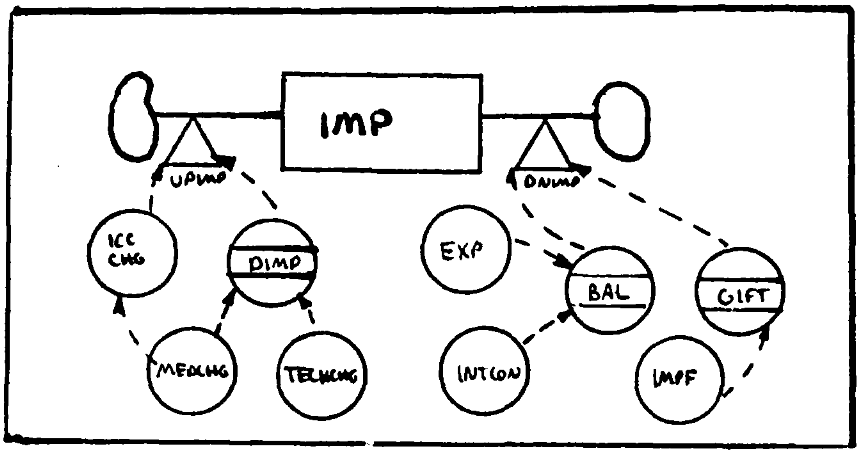

FIGURE 3.15 IMPORT STRUCTURES FLOW DIAGRAM

Code detailing these relationships is given below:

Import Structure:

```
L LIMP.K(I)=IMP.J(I)
N LIMP(I)=LIMPI(I)
T LIMPI(*)=39.9/39.9/39.9      MILLION DOLLARS
L IMP.K(I)=IMP.J(I)+DT*(UPIMP.JK(I)-DNIMP.JK(I))
N IMP(I)=IMPI(I)
T IMPI(*)=40.0/40/40           MILLION DOLLARS
R UPIMP.KL(I)=(ICCCHG.K(I)+DIMP.K(I))*IMP.K(I)
A DIMP.K(I)=(MEDCHG.K(I)+TECCHG.K(I))/2
R DNIMP.KL(I)=IMP.K(I)*MAX(GIF.K(I),BALF.K(I))
A IMPF.K(I)=IMP.K(I)/INTCON.K(I)
A GIF.K(I)=TABLE(GIFT,IMPF.K(I),0,1,.1)
T GIFT=0/.05/.08/.2/.5/.65/.75/.80/.82/.90/1.0
A BAL.K(I)=(EXPO.K(I)-IMP.K(I))/INTCON.K(I)
A BALF.K(I)=TABLE(BALT,BAL.K(I),-.4,1,.2)
T BALT=0/0/.05/.18/.35/.70/.92/1.0
```

LIMP - Import value last period ($ US, million)
IMP - Import value ($ US, million)
UPIMP - Period increase in import value ($ US, million)
ICCCHG - change in national interconnection (%)
DIMP - Desire to import (%)
MEDCHG - change in media intensity (%)

TECCHG - change in national embodied technology
DNIMP - Period decrease in import value ($ US, million)
GIF - Government intervention factor (%)
BALF - Trade Balance Factor
IMPF - Import Fraction of total national consumption
INTCON - Internal consumption ($ US, million)
BAL - Trade Balance (fraction of internal consumption)

Both BALT and GIFT tables reflect increasingly stiff opposition by government to increasing imports above 20% of the total domestic consumption and or having a trade deficit that exceeds 5% of the total domestic consumption. When these factors kick in, imports are slowed dramatically, demonstrating the conservative bent of many Third World nations. Initial growth/retrenchment patterns are set to currently observed levels before being modified by these mechanisms.

Exportation

The mechanisms of exportation of goods is by far a simpler process than importation when viewed from the internal perspective of a nation. The nation must only find buyers for goods, hoping that their owm protective measures have not alienated prospective importers. Exportation depends heavily on satisfactory connection with the global marketplace, skillful marketing, and competitive pricing. For the purposes of this model, the chokepoint for the export of goods is centered on the degree of interconnection to the rest of the world. Without the necessary infrastructure for trade on the global marketplace, significant domestically controlled exportation is nearly impossible. Without the necessary infrastructure, the nation becomes merely a labor pool and an offshoot factory town of a large multinational corporation, much as Jamaica has become. In this model, exports increase incrementally, depending on increases in raw material production, fossil fuel production, and embodied technology.

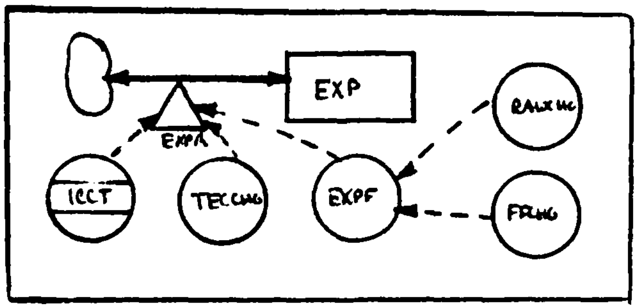

FIGURE 3.16 EXPORT FLOW DIAGRAM

This model explicitly excludes the political climate between trading nations, the type of goods being traded, or demand for particular goods on the world market. The artificialities do distort the actual conduct of trade on the export side of the market, however since the use of trade in this model is to assess the transfer of innovation into the system, as it is currently operating. Export value merely indicates roughly the scale of transfer of goods and is used as a frame of reference for determining respective balances of trade.

Export DYNAMO Code.

```
L LEXP.K(I)=EXPO.J(I)
N LEXP(I)=LEXPI(I)
T LEXPI(*)=15.0/15/15
L EXPO.K(I)=EXPO.J(I)+DT*(EXPR.JK(I))
N EXPO(I)=EXPOI(I)
T EXPOI(*)=15.05/15.05/15.05
R EXPR.KL(I)=ICCF.K(I)*((TECCHG.K(I)+EXPF.K(I))/2)
A EXPF.K(I)=(MAX(-RAWCHG.K(I),RAWCHG.K(I))+MAX(-FFCHG.K(I),
X FFCHG.K(I)))/2
A ICCF.K(I)=TABLE(ICCT,ICC.K(I),0,10,1)
T ICCT=0/.25/.45/.625/.75/.80/.85/.90/.95/1.0/1.0
```

LEXP - Value of exported goods in last period ($ US, million)
EXPO - Value of exported goods ($ US, million)
EXPR - Inremetnal increase in exported goods per period ($ US, million)
EXPF - Export factor of change in domestic production (%)
ICCF - Interconnection factor (%)

The interconnection factor (ICCF) is used to determine how much of the increase in raw material and fossil fuels can make it into the world market through export mechanisms. It implies that goods make their way into the market more readily when a nation enjoys a high level of interconnection and produces goods embodying a high level of technology.

Domestic Consumption.

As discussed earlier in this section, trade intensity can be measured in two veins, that of trade with the world external to the nation system and trade internal to the system itself. Rather than attempt to itemize or detail the processes inherent to domestic trade, this model assumes that goods imported get distributed and eventually consumed, that a portion of the raw materials get exported, and that all of the primary and secondary production is used internal to the nation.

These assumptions follow quite closely with Dennis Meadows research in his WORLD III model in which he found that across 36 nations considered to be of underdeveloped or "Third World" in orientation, consumption (including services) as a percent of GNP varied from a low of 82% to a high 92% with a mean value of 87%. Recall that this developing model explicitly excluded the services sector of all economies in all facets of trade. If indeed some 13% of the total economy is based on services, then the slack is explained, otherwise some other adjusting factor will be required. From this modeler's perspective, based on the fact that interconnection change assessment is based on a combinatorial, averaged figure derived equally from transportation infrastructure changes, changes in government intervention in the national setting, changes in media intensity, and changes in trade, the loss of a possible 13% of change in a relatively stable system of domestic consumption appeared nearly insignificant. The problems of accurately assessing total consumption from the facors used thus far in the model far outweigh its benfits for explaining instability in a national and regional system.

Similarly, the task of assessing total impact of trade intensity on interconnection comes from a simple summing of the level of imports,exports, and domestic consumption and assigning a per capita weight to this figure. Change in this measure of trade intensity, favors

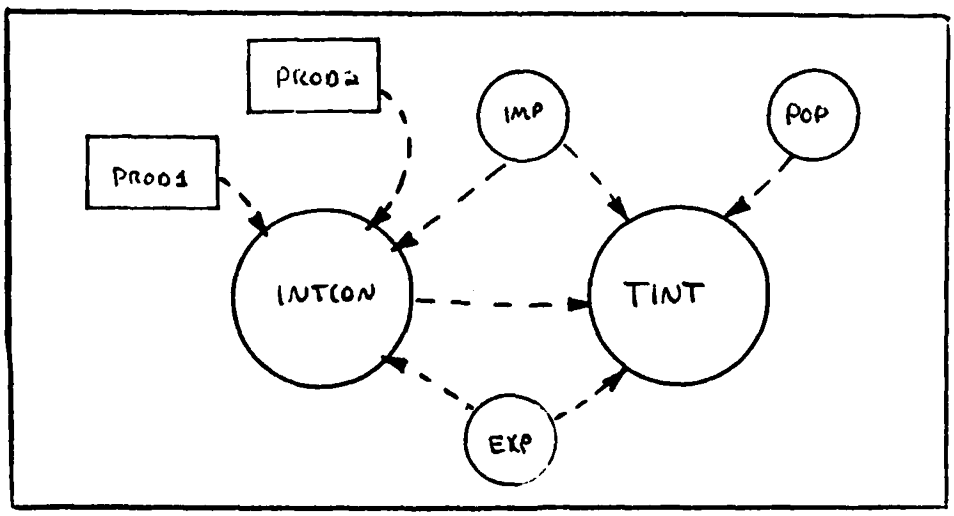

FIGURE 3.17 DOMESTIC CONSUMPTION AND TOTAL TRADE INTENSITY FLOW DIAGRAM

the increase of imports as a method of innovation transfer by counting it in twice, as a part of domestic consuption and as imports by itself. This reflects this modeler's bias towards imports as a method of technological innovation transfer.

Interconnection DYNAMO Code

```
A INTCON.K(I)=(PROD1.K(I)+PROD2.K(I))+(IMP.K(I)-EXPO.K(I))
L LTINT.K(I)=TINT.J(I)
N LTINT(I)=LTINTI(I)
T LTINTI(*)=4/4/4
A TINT.K(I)=(INTCON.K(I)+EXPO.K(I)+IMP.K(I))/POP.K(I)
```

INTCON - Internal, domestic consumption ($ US, million)
PROD1 - Primary production ($ US, million)
PROD2 - Manufactured goods production ($ US, million)
LTINT - Last period trade intensity ($ US,per capita)
TINT - Trade intensity ($ US, per capita)
POP - National population (millions)

Initializaion of the LTINT variable is accomplished with a common calculator, and initial figures gained from any reputable statistical reference.

Transportation Structure.

If trade is the life-giving economic blood of the nation, then the transportation infrastructure is the circulatory system of trade. Without a well developed transportation system, technology simply will not transfer. As innovative technology transfers through diverse means, both goods moving and people moving systems are essential. Green sees the availability of diverse transportation networks defining the cultural aspects of many nations. With ready availability of far reaching systems, individuals tend to develop a broader view of the world structure and they themselves become conduits for information transfer. Without these networks, a certain xenophobia sets in, new ideas and methodology fail to take root, and the culture becomes very self-centered, often resorting to mysticism and exclusive cultural rites. (12:138) New transportation modes often presage a new way of life. Witness the effect of the automobile on cities, and the way that modern Americans live. The automobile and the accompanying development of a good road system has provided a flexibility of movement and choice for nearly every person. The influence on social mores has been as important. The availability of an automobile has shaped courtship habits, the type of automobile owned has become a badge of status, and behavior behind the wheel a sign of innate personality traits. Cultures with different modes of transportation than perhaps the automobile tend to define many of their life patterns in terms of that transportation.

For the purpose of this model, transportation structure is a contrived, surrogate measure, designed to express the mobility of people, and the availability of goods throughout the system. A nation without the requisite infrastructure will be unable to transfer goods embodying innovation or individuals with the seeds of innovation. Rather than look at all forms of transportation, counting numbers of automobiles, or tons of rolling stock, or number of airplanes in a nation, this model focuses on the facilities supporting these transportation modes. By looking at the number of large airports, miles of roadway, miles of railway, and number of ocean ports, and comparing that to the total land mass, one can obtain a relaively good feel for the amount of transportation interconnection going on in a nation. The use of the surrogate measure helps to prevents a bias towards any one particular measure of transportation, instead directing the modeler towards examination of the adequateness of the modes of transportation for movement of goods and people. Not all nations would find themselves best served by a vast network of interstate highways, or even a large number of inland waterways. The use of a particular mode of transportation depends on many situational variables, terrain, capital intensity, expense, type and availability of energy required, and others.

The measure of transportation is divided into two distinct areas, those supporting primarily domestic movement, and those supporting international movement. Domestic transportation increases with increases in domestic consumption, reflecting the increases in distribution networks for both goods and services. However, domestic transportation structures deteriorate over time, at a rate commensurate with their pervasiveness in the nation. This assumption stems from observations that as a nation gets more transportation modes, the older methods lose their technical edge and as a result receive maintenance or improvements only to keep them in operation.

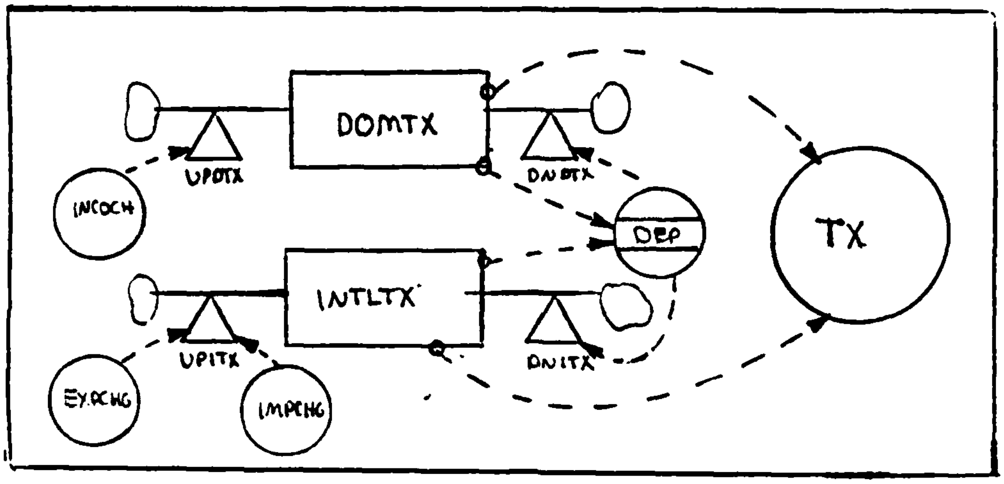

FIGURE 3.18 TRANSPORTATION STRUCTURE FLOW DIAGRAM

Similar mechanisms are in evidence in the international transportation sector. Increases in the international infrastructure are due in part to increases in foreign trade through imports and exports. Deterioration in international facilities is similar in reason and manner to the deterioration of domestic facilities. When combined together, domestic and international transportation provide a good estimate of the physical interconnection of any nation both internally and externally. Figure 3.18 illustrates the flows inherent to this subsystem.

<u>Transportation DYNAMO Code</u>.

```
L LDOMTX.K(I)=DOMTX.J(I)
N LDOMTX(I)=IDOMTX(I)
T IDOMTX(*)=5/5/5
L DOMTX.K(I)=DOMTX.J(I)+DT*(UPDTX.JK(I)-DNDTX.JK(I))
N DOMTX(I)=DOMTXI(I)
T DOMTXI(*)=6/6/6
R UPDTX.KL(I)=DOMTX.K(I)*INCOCH.K(I)
R DNDTX.KL(I)=(DEP.K(I))*DOMTX.K(I)
A DEP.K(I)=TABLE(DEPT,LDOMTX.K(I),0,10,1)/100
T DEPT=5/6/3/2.5/2.4/2.5/2.6/2.7/2.8/2.9/3.0
```

```
L LINTX.K(I)=INTLTX.J(I)
N LINTX(I)=LINTXI(I)
T LINTXI(*)=4.5/4.5/4.5
L INTLTX.K(I)=INTLTX.J(I)+DT*(UPITX.JK(I)-DNITX.JK(I))
N INTLTX(I)=INLTXI(I)
T INLTXI(*)=4.6/4.6/4.6
R UPITX.KL(I)=(IMPCHG.K(I)+EXPCHG.K(I))/2*INTLTX.K(I)
R DNITX.KL(I)=(TABLE(DEPT,INTLTX.K(I),0,10,1)/100)*INTLTX.K(I)
L LTX.K(I)=TX.J(I)
N LTX(I)=LTXI(I)
T LTXI(*)=4.5/4.5/4.5
A TX.K(I)=(DOMTX.K(I)+INTLTX.K(I))/2
```

LDOMTX - Last period Domestic Transportation (dimensionless)
DOMTX - Domestic Transportation (dimensionless)
UPDTX - Increase in Domestic Transportation
INCDCH - Change in Domestic (internal) Consumption (%)
DNDTX - Decrease in Domestic Transportation
DEP - Depreciation of Domestic Transportation Infrastructure (%)
DEPT - Depreciation Table
LINTX - Last period International Transportation (dimensionless)
INTLTX - International Transportation (dimensionless)
UPITX - Increase in International Transportation
IMPCHG - Change in Imports (%)
EXPCHG - Change in Exports (%)
DNITX - Decrease in International Transportation Infrastructure
LTX - Last period Total Transportation (dimensionless)
TX - Total Transportation (dimensionless)

The table function (DEPT) has been designed with a bathtub shaped depreciation curve. When it is used with the proper input value of last period domestic/international transportation (LDOMTX/LINTX), the relationship implied by the curve is that if a nation has few facilities of relatively low sophistication (low value INTLTX/DOMTX), then there is relatively little to lose by depreciation. An unimproved road system, or a single primative port facility lose little of their carrying capacity with wear and tear over time. Furthermore the curve implies that in moderate ranges of DOMTX/INTLTX, a country will allocate the resources necessary to maintain facilities, due in part to their recognized importance in sustaining innovation transfer. With high values of

INTLTX/DOMTX, the rate of depreciation takes a large jump. Due to saturation of the transportation system, the older systems are often left to decay, with little more than routine, perfunctory maintenance performed. New capital is seldom committed to improve or restore old systems to good working order. This phenomena is often seen in nations caught up in growth and change oriented spirals, and in particular in the United States.

Transportation Value Initialization

As discussed before, one must be careful to not bias the assessment of transportation infrastructure by using any national norm. For some nations, such as West Germany, a well developed road and railroad system of high road density per square mile is appropriate to the terrain and culture and number of the West German people. However a similar network would not serve Switzerland with the same efficiency, particularly with respect to terrain, and population density. As a result, the Swiss people have developed their rail resource more intensely, and augmented people movement with an extensive aerial tram system. To assess any transportation infrastructure, one must observe three items carefully, terrain, population density patterns, and types of interconnection. This model uses on two measures for domestic transportation, combined rail and road mileage, and population density. International transportation uses a combined statistic of number of major port and airports with improved runways over 8,000 feet, and population for an initial assessment of the infrastructure. Although this does ignore terrain factors and alternative interconnection schemes, particularly in the domestic sector, investigation shows that most nations of the world move most of their ton miles of freight and people miles using four modes of transportation, that is by water, rail, truck/personal auto, and aircraft. (40:23)

To use Figure 3.18, with Bolivia as an example, we can find that there are 2,218 miles of railroad, 23,163 miles of roads of all types (totaling ~ 25,500 miles), and a population density of 12.4 people per square mile. Entering the DOMTX nomogram, this yields a 4.5 as starting value for DOMTX. Similarly, with 5 airports with runways 8,000 feet or greater, and access to 8 major ports (Bolivia is itself landlocked), and a raw population of 5.286 million people, an INTLX starting value of 3.3 results.

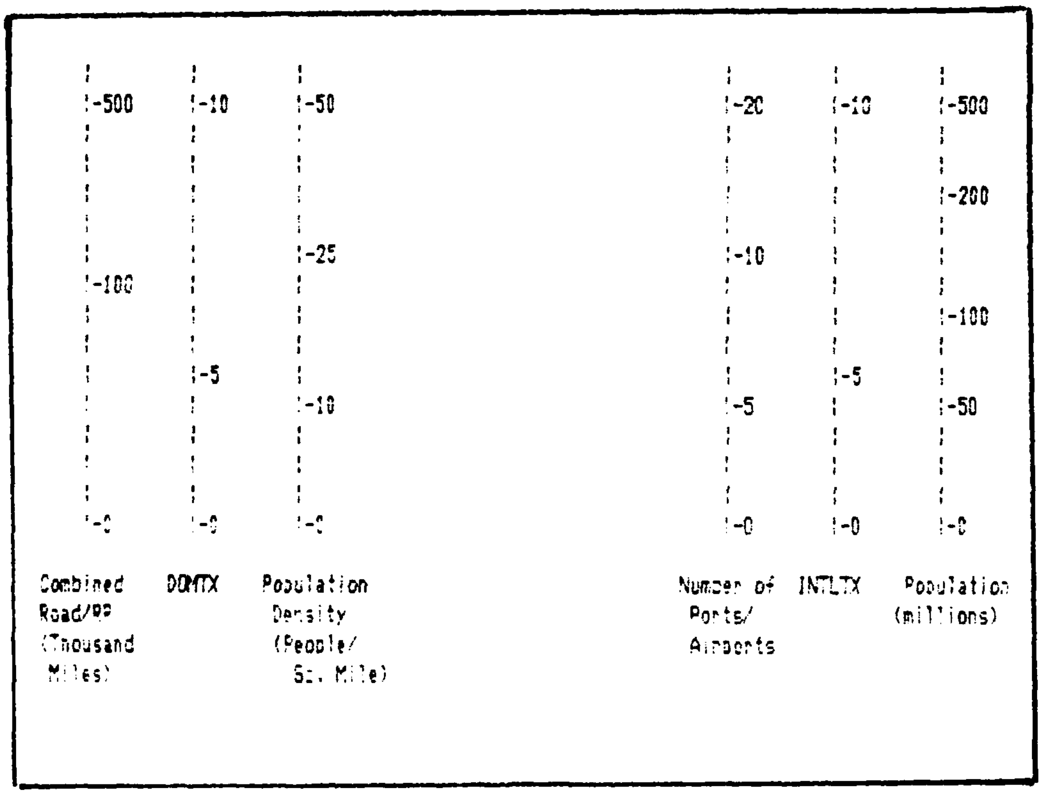

FIGURE 3.19 TRANSPORTATION INITIAL VALUE NOMOGRAM

Media and Interconnection

Media, comprised of many elements including newspapers, magazines, radio, and television, is a powerful influence in many national settings. It can be used to educate people, promulgate new ideas, and enlighten a depressed people. It also can be used to propagandize captive populations, chastise unpopular leaders and their policies, and excite a population to action. The very nature of media allows equally the potential for constructive endeavor, as well as the potential for destructive endeavor. Those that control a nation's media usually have a powerful influence on the paths of a nation.

The ready availability of the devices of media have made it popular around the world. Radio in particular has made considerable inroads into developing nations as both an entertainment and informational device. It is not uncommon to see a farmer in the Phillipines behind his caribou preparing a rice paddy for planting with a small Japanese transistor radio hung over his shoulder. Through this radio he can receive hourly news updates from sources such as the British Broadcasting Corporation, and the National Broadcasting Corporation discussing international events, mixed in with local news and information. He is at once associated to the larger global system informationally, yet still bound to the heritage of the land before him. He hears in his own tongue concepts and ideas that are at once foreign yet still familiar. The breakdown of insulation provided by a special cultural system, handed down from generation to generation starts here.

The impact of television is as intense as that of radio if not more so. Words speak loud, but not so nearly as loud as do actions. The actions of other people, combined with spoken dialogue teach powerful lessons on the nature of human interactions, mores, and values. Consider the example of "Archie Bunker." Although intended to poke fun at American bigotry and ethnocentricism, it provides a graphic example of seemingly acceptable behavior. There is a studio audience available to laugh at precise points, reinforcing perhaps unacceptable behavior with a positive response. Seldom does one see Mr. Bunker corrected for his narrow views or inappropriate, bigoted remarks, and when it does happen, the situation presented often allows him to escape as a victim of unfortunate consequences. With this message presented to the viewer, who by the nature of the medium is a passive recipient, a small part of the social veneer that discourages such behavior is chipped away. Each nation that has the capacity for independent television production has similar examples. This phenomena tends to reinforce the observation that media provides a degrading influence on the traditional social patterns of a nation, detracting from the cultural legacy, and reinforcing a new mode of behavior in its place.

This new mode of behavior is shaped by the immediacy of media. A story is presented, crises faced and resolved, and time altered, either compressed or expanded, all in the space of a 25-minute television show. The mores and behavior modes on the screen before the viewer become cataloged in the individual's reference file of human behaviors. With the young, this cataloging of information perhaps plays a greater role in shaping behavior and expectations, in part due to their limited experiences with life.

Media provides a vital link to the world outside the nation and internal to the nation itself. The transfer of information, and perhaps transfer of innovation, is nearly immediate. The content may be shaped, but nevertheless, the conduit, once in place, stays in place, with no discernable depreciation or deterioration over time.

This model conceptualizes a single surrogate measure of media, determined by the media density with respect to population, and measured in multiple modes. Media will be equivalently increased by increases in embodied technology on the assumption that improvements in technology will immediately radiate into the communications/media sector of the nation. The flow diagram depicting this realtionship is shown in figure 3.20.

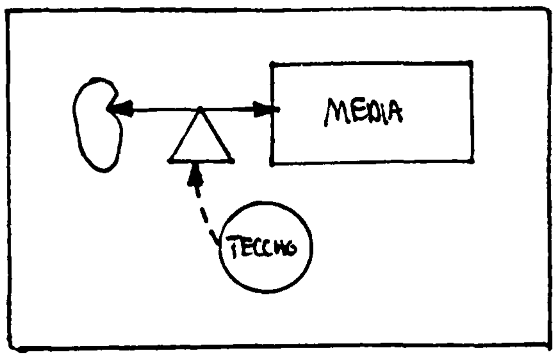

FIGURE 3.20 MEDIA FLOW DIAGRAM

The DYNAMO code implementing this structure is simple and follows with no further explanation.

```
    *************** MEDIA SECTOR ****************

L LMEDIA.K(I)=MEDIA.J(I)
N LMEDIA(I)=IMEDIA(I)
T IMEDIA(*)=4.45/4.45/4.45
L MEDIA.K(I)=MEDIA.J(I)+(DT*TECCHG.J(I)*MEDIA.J(I))
N MEDIA(I)=MEDIAI(I)
T MEDIAI(*)=4.5/4.5/4.5
```

LMEDIA - Last period Media intensity (dimensionless)
MEDIA - Media intensity (dimensionless)
TECCHG - Period Technology change (%)

Initialization

Reflecting the importance of the spoken word, and lasting impressions made by the visual scene, this surrogate measure of media uses the dual measures of per capita radios and per capita televisions as a basis. The nomogram follows:

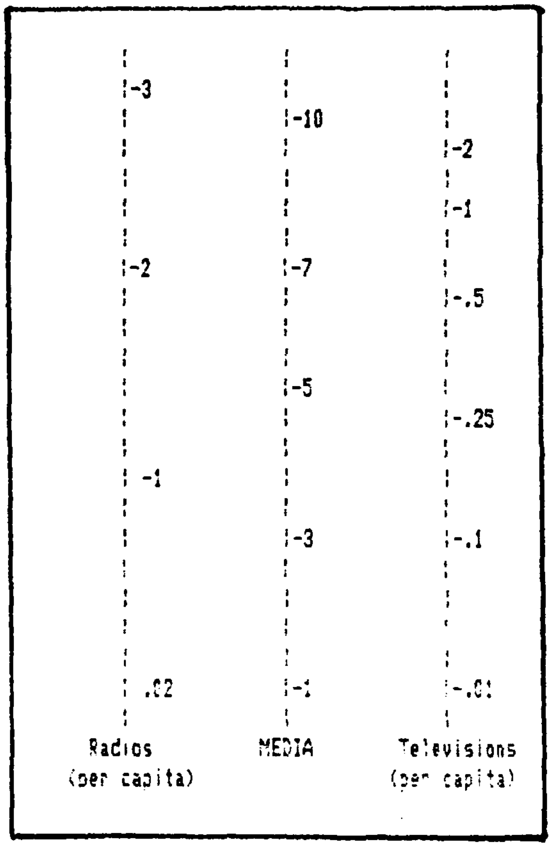

FIGURE 3.21 MEDIA INITIALIZATION NOMOGRAM

Government and Interconnection.

As discussed in Chapter II, government can be thought of as an integrating mechanism that unites individuals into a nation group. Much of the integration results directly from the power that individuals vest in the government, and the sources of power are diverse. Some governments wrest power at the point of the gun, others assume it insidiously, a step at a time, and others spring forth as a revolutionary force, full of bravado, and idealism for a new social order.

Whatever the nature of assumption of power, governments invariably develop mechanisms assuring the stable continuance of power, and the continued existance of the national group. Essentially, the nature of the mechanisms stems from the control over the population desired by the government,and the power vested in the government by the people. If the citizens of a nation perceive extreme threat, either from internal sources, or from external powers wishing to somehow interfere in national goals, they tend to allow an increased degree of control by the government structure. Some national groups, and their leaders, based on the belief that the nation is best served by a centralized structure, and guaranteeing certain benefits to the governed in return for power, develop intricate control mechanisms to assure the status quo.

The nature of the control mechanisms are in part determined by the cultural heritage of the population, previous experience with a particular control mechanism, and such intangible factors as "love of liberty", "freedom of choice",and "self-determination." Some of the more common control mechanisms found across the spectrum of all governments include police forces, civil service corps, military defense forces, taxation, power to establish currencies, establishment of substantive law, punishment within the framework of a judicial system, and control of production through nationalization and collectivization. This list is not all inclusive, but provides a rough idea of the pervasiveness of government control in most national settings.

For the purpose of this model, the essential element to be gained from the integration efforts of government in assesing interconnection is the intensity of the control in the national setting, and the way that this control is changing over time. Using a gross simplification of national government interactions and discarding the role of political processes, this model assumes that control exercised by a government is a direct function of time that the ruling government has been in power, and of essential nature of the government structure. Using a simplification based on United Nation assessment of human rights and personal freedom, nations and their corresponding government structures are classified as either "free" or "not free". Nations with little freedom tend to exhibit a great number and intensity of control mechanisms, while nations with more freedom tend to exhibit fewer control mechanisms. Individually, nations are dynamic entities with control structures being changed on a near daily basis, however, it appears that a certain trend of changes in control structures is apparent.

Over time, nations exhibiting a great intensity of control structures tend to decrease this intensity somewhat,yet generally not to the point that they might be considered free societies. Nations with few initial control structures appear to increase governmental controls with time as individuals give up their personal freedoms for government guarantees and social programs designed to decrease risks due to uncertainty, exploitation, physical violence, or external interference in the conduct of life processes. Specifically, this model does not account for revolutionary upset in government structure, nor does it allow for changes in track of personal freedom due to external forces, or internal threat. Once a nation has an established government, this form of government is assumed to remain for the duration of the run of the model.

Control focuses primarily on internal aspects of a government, and as such is only part of the whole. Recall that there are many different levels of players in the interconnected world system. The primary level of world interaction is among nation entities, using a number of differing mechanisms, including diplomatic negotiation, trade, and when necessary, armed conflict. A government's ability to interact in the connected system, and essential element in determining the degree of interconnection to the world system, lies in its armed forces. Without force, be it economic, persuasive, or armed in nature, to legitmize

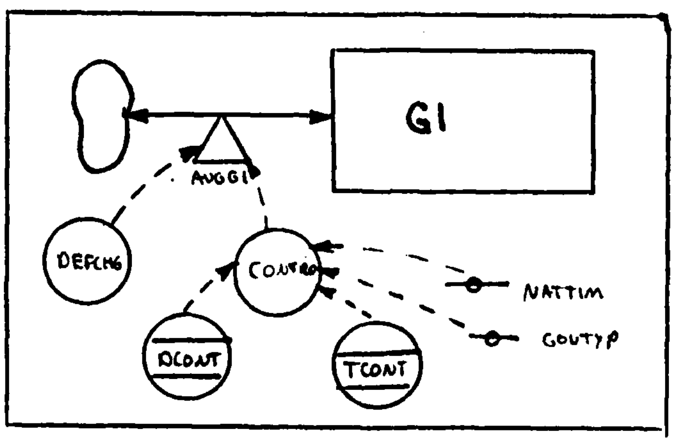

FIGURE 3.22 GOVERNMENT STRUCTURE FLOW DIAGRAM

contentions in the world system, and in the smaller regional system, a nation may cease to exist. Accordingly, nations through the development of armed forces, ostensibly organized for defensive purposes, legitimize their claims to a particular land, and in times that the political leadership deem it necessary, use these forces to enforce and define relationships with other nations. It is the added influence of the ultimate international control mechanism, armed forces, that allows a nation to maintain international legitimacy and power. It is through the combined measures of armed "defense" forces and internal control that this model determines the effect of government structures on national interconnection and innovation transfer.

<u>Government DYNAMO Code</u>.

```
L LGI.K(I)=GI.J(I)
N LGI(I)=LGII(I)
T LGII(*)=5/5/5
L GI.K(I)=GI.J(I)+DT*(AVGGI.JK(I))
N GI(I)=GII(I)
T GII(*)=5.01/5.01/5.01
R AVGGI.KL(I)=((CONTCH.K(I)+DEFCHG.K(I))/2)*GI.K(I)
L LCONT.K(I)=CONTRO.J(I)
N LCONT(I)=LCONTI(I)
T LCONTI(*)=7.0/7/7
A CONTRO.K(I)=(GOVTYP*TCONT.K(I))+((1-GOVTYP)*DCONT.K(I))
A TCONT.K(I)=TABLE(TCT,TIME.K+NATTIM,0,200,20)
T TCT=4.5/6.5/7.5/8.4/9.2/9.6/9.65/9.6/9.4/9.3/9.25
A DCONT.K(I)=TABLE(DCT,TIME.K+NATTIM,0,300,30)
T DCT=0/.5/1.0/1.5/2.0/2.8/3.4/4.6/6.0/7.0/10
T NATTIM(*)=45/120/32
```

LGI - Last period Government intensity (dimensionless)
GI - Government Intensity (dimensionless)
AVGGI - Average period change in Government Intensity (dimensionless)
CONTCH - Control Change (%)
DEFCHG - Defense Change (%)
LCONT - Last period domestic Control (dimensionless)
CONTRO - Domestic Control Intensity (dimensionless)

TCONT - Time Adjusted Control (dimensionless)
GOVTYP - Government type (0 - free, 1 - not-free)
NATIM - National political structure lifetime (years)
TCONT - Totalitarian control (dimensionless)
TCT - Totalitarian table function
DCONT - Democratic control (dimensionless)
DCT - Democratic table function

In operation, national control is a fixed function dependent only on the type of government in place (GOVTYP), and time since the government came to power (NATIM). The table functions DCT and TCT reflect assumptions and observations of actual power consolidation by governments with respect to time that the type of government has been empowered. The single variable of change, defense structure and intensity (DEFCHG), is independent of changes internal to the government structure, and responds to perceived threat from neighbors.

Defense Structure.

As discussed in development of the causal diagrams, defense capability is a function of both the quality and quantity of defense materials, and the people that conduct the operations. Rosen indicated that a force with superior quantities or quality of equipment could be defeated handily by a force of innovative individuals exploiting weaknesses in that force, or simply "fighting smarter." (31:126) This model is designed to capture the differences in quantity and quality of both arms and troops. By applying these measures of defense capablity, and assuming perfect information, construction of threat perception to neighbors becomes possible.

In most nations, defense capabilities increase as a result of political processes. Leaders may feel that a certain level of arms will enhance the national prestige on the world scene, that arms are necessary to deter potential adversaries from taking action against national interests, or that arms are necessary to complete national objectives. For the purpose of this model, the prestige factor, and expansionist desires are ignored as causal factor of arms increases. Rather than trying to identify and systematize the defense process, this model assumes an underlying increase in arms due to improvements in capital production, or perceived threat from their neighbors. Troop improvements result from training the existing troops or simply increasing the numbers of troops.

In this model, perfect information about neighbor capabilities is assumed, and that the political processes to increase defense capabilities are automatic with information of threat. Decisionmakers receive threat information from two possible venues, from formal intelligence gathering mechanisms, or from first hand experience of invasion by an adversary. Threat is taken as a cumulative index, with the defense capabilities of all neighbors assumed to be commited against the individual nation. Upon certain experimental points, when the preponderance of force favors the invasion of a country by its neighbor(s), it will be invaded, or when the nation has an overwhelming advantage over all its neighbors, it will expand, invading its neighbors. Both actions cause changes in the boarder structure, and by design of the model, increase instability in the national system, and modify perceptions of threat. Additionally, changes in actual defense capability are factored in when a nation goes to war, due to losses of men and machines in battle. Further incremental losses in arms due to an annual depreciation contribute to the decline of defense capabilities.

For purposes of experimentation and in support of the overall goal of this thesis, mechanisms to increase actual quality and quantity of both arms and troops are included. These mechanisms do not attempt to account for funds limitations, or political actions, but rather are designed to assess the impact on regional and national stability of specific arms transfers into the system. The flow diagram supporting this model is shown as Figure 3.23.

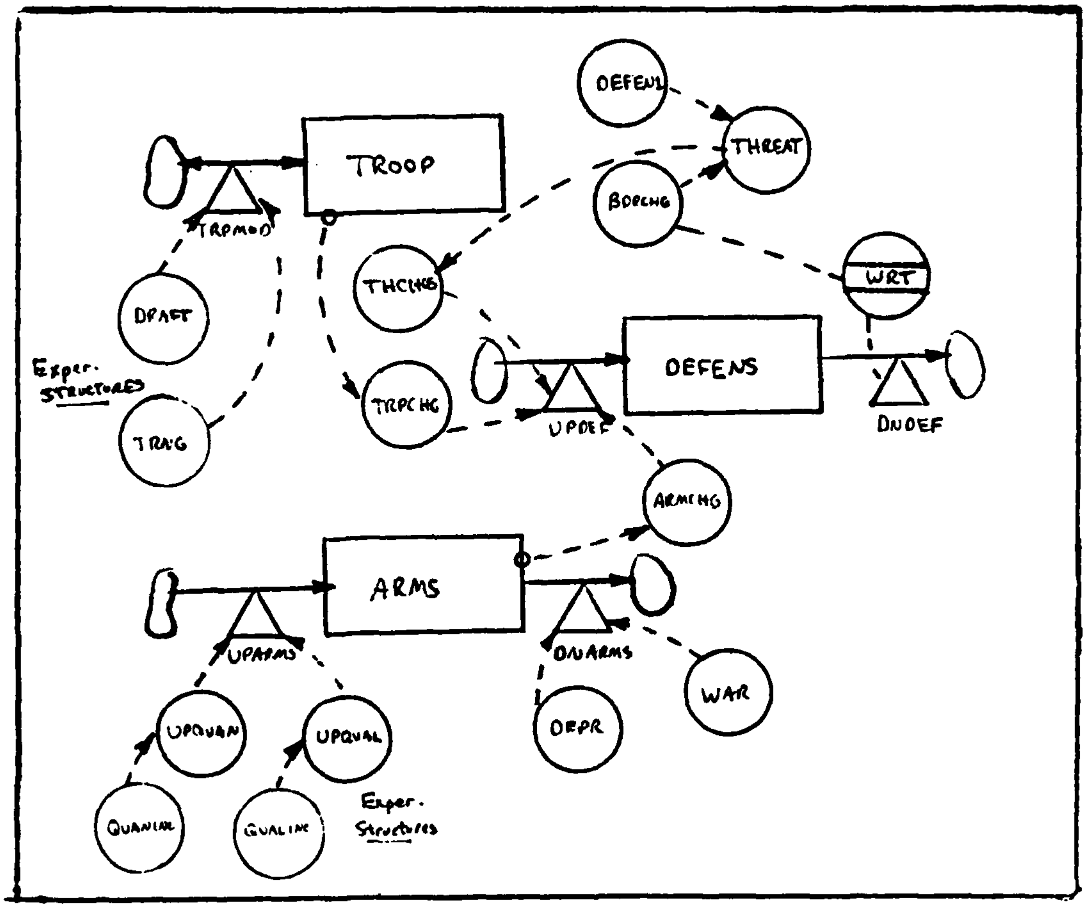

FIGURE 3.23 DEFENSE STRUCTURE FLOW DIAGRAM

Defense DYNAMO Code.

```
L LTHR.K(I)=THREAT.J(I)
N LTHR(I)=LTHRI(I)
T LTHRI(*)=5/5/5
A THREAT.K(I)=DEFEN1.K(I)+(BDRCHG.K(I)*LAND)
```

LTHR - Last period Threat perception (dimensionless)
THREAT - Threat perception (dimensionless)
BDRCHG - Change in Boarders (%)
LAND - Land area of nation (thousand sq. miles)
DEFEN1 - Total defense capabilities of neighbors (dimensionless)

```
L LARMS.K(I)=ARMS.J(I)
N LARMS(I)=LARMSI(I)
T LARMSI(*)=40/40/40
L ARMS.K(I)=ARMS.J(I)+DT*(UPARMS.JK(I)-DNARMS.JK(I))*ARMS.J(I)
N ARMS(I)=ARMSI(I)
T ARMSI(*)=40.1/40.1/40.1
R UPARMS.KL(I)=MIN(THCHGS.K(I),CAPCHG.K(I))
X +UPQUAL.K(I)+UPQUAN.K(I)        EXPERIMENTAL FACTORS
A UPQUAL.K(I)=PULSE(QUALINC(I),TIMEUP(I),999)
T QUALINC(*)=0/0/0
T TIMEUP(*)=999/999/999
A UPQUAN.K(I)=PULSE(QUANINC(I),TINCR(I),999)
T QUANINC(*)=0/0/0
T TINCR(*)=999/999/999
R DNARMS.KL(I)=(DEPR+WAR.K(I))
C DEPR=.02
```

LARMS - Last period Arms capabilities (Dimensionless)
ARMS - Arms capabilities (dimensionless)
UPARMS - Increase in arms capabilities (dimensionless)
THCHGS - Smoothed threat change (%)
CAPCHG - Change in capital production (%)
UPQUAL - Increase in arms quality (dimensionless)
UPQUAN - Increase in arms quantity (dimensionless)
QUALINC - Percent increase in arms quality (%)
TIMEUP - Experimental time for increase
QUANINC - Percent increase in Arms quantity (%)
TINCR - Experimental time for increase
DNARMS - Decrease in Arms capabilities (dimensionless)
DEPR - Depreciation rate (%)
WAR - Losses due to war (%)

Increases in the number of arms can be varied experimentally simulating a point transfer of either more arms, replacement of arms with newer arms, or a combination of both more, improved arms using the UPQUAL and UPQUAN pulsed variables, indicating how many more (%) and how much better (%) using QUANINC, and QUALINC. This will cause some reacton through the defense variable on government intensity, leading to trickle-down effects on other segments of the society. Depreciation rate is easily modified, and should be examined in light of substantive data for possible modification. The WAR variable assumes increasing losses of men and materials for defense with increases in gains or losses of territory. This assumption may need further verification, and documented evidence. The actual responsiveness to threat changes of neighbors depends on the abilities of the national intelligence gathering apparatus, and modifications in the smoothing time could be modified using a higher order delay of information, or by extending the smoothing time.

DYNAMO Code.

```
L LTROOP.K(I)=TROOP.J(I)
N LTROOP(I)=ILTRP(I)
T ILTRP(*)=6/7/8                    THOUSAND TROOPS
L TROOP.K(I)=TROOP.J(I)+DT*(TRPMCD.JK(I))
N TROOP(I)=ITRP(I)
T ITRP(*)=6/7/8
R TRPMCD.KL(I)=INCNUM.K(I)+UPTNG.K(I)    EXPERIMENTAL FACTOR
A INCNUM.K(I)=PULSE(DRAFT(I),DTIME(I),999)
T DRAFT(*)=0/0/0
T DTIME(*)=999/999/999
A UPTNG.K(I)=PULSE(TRNG(I),TRTIM(I),999)
T TRNG(*)=0/0/0
T TRTIM(*)=999/999/999
```

LTROOP - Last period troop capabilities (thousand troop equivalent)
TROOP - Troop capabilities (thousand troop equivalent)
TRPMOD - Modification to troop strength (thousand troop equivalent)
INCNUM - Increase in numbers of troops (thousand troops)
DRAFT - Number of troops added (thousand troops)
DTIME - Model time troops inserted
UPTNG - Increase in capability due to training (thousand troop equivalent)
TRNG - Equivalent troop increase due to training (thousand troop equivalent)
TRTIM - Model time training provided

In a manner similar to the transfer of arms detailed above, increases in equivalent troop numbers can be tested for system effects, by activating either conscription mechanisms (DRAFT), or by increasing the abilities of existing troops through training (TRNG). A critical factor is determining actual troop equivalent values for conscripts or additional training when using this experimental model. In some nations one may find that in adding to the military from the general public, the conscriptees are of a higher capability than are those already in service, causing a disproportionate increase in equivalent troop strength. Similarly, additional training may be ineffective in increasing effective troop strength of existing troops, because of its unsuitability (e.g., arctic training for Egyptian forces), or due to the current learning curve position of troops and their innate ability to advance to topics/ tasks of greater complexity.

```
L LDEFEN.K(I)=DEFENS.J(I)
N LDEFEN(I)=IDEFEN(I)
T IDEFEN(*)=5/5/5
L DEFENS.K(I)=DEFENS.J(I)+DT*(UPDEF.JK(I)-DNDEF.JK(I))
N DEFENS(I)=DEFENI(I)
T DEFENI(*)=5.2/5.2/5.2
R UPDEF.KL(I)=((THCHGS.K(I)+MIN(TRPCHG.K(I),ARMCHG.K(I))
```

```
X )/2)*DEFENS.K(I)
R DNDEF.KL(I)=DEFENS.K(I)*WR.K(I)
A WR.K(I)=TABLE(WRT,BDRCHG.K(I),0,1,.1)
T WRT=0/.2/.4/.6/.7/.75/.8/.83/.85/.87/.92
```

LDEFEN - Last period level of effective defense (dimensionless)
DEFENS - Effective Defense (dimensionless)
UPDEF - Period increase in effective Defense (dimensionless)
THCHGS - Time Smoothed Threat Change (%)
TRPCHG - Change in effective troop strength (%)
ARMCHG - Change in arms capabilities (%)
DNDEF - Period decrease in effective defense (dimensionless)
WR - War costs of effective defense (%)
WRT - War cost table

The culmination of both arms capabilities and troop strength is found in DEFENS. Modification of defense through direct changes in troops or arms plays a lesser role than direct increases due to perceptions of threat. When threat increases consistently and at at a substantial rate, the nation often undertakes actions in the civil sector that augment actual in-place capabilities of the standing military. Local militia and self-defense forces activate, which may not necessarily be under the control of the defense establishment, but nevertheless increase actual defensive capabilities. Actual conduct of war reflects the intensity of loss for even small gains or losses of territory (BDRCHG). The underlying table WRT can be easily manipulated to describe differing loss schedules in war based on perhaps differences in underlying technology and destructive capabilities.

Defense Sector Variable Initialization

There are many different ways of defining the defense sector capability, however no one measure appears to accomodate the many variables making up a defensive capability. The use of a composite, surrogate variable can allow one to coalesce a number of believed critical measures of defense in a given national system into a single variable for comparison with other national systems. To establish this single measure, however, one must have a good idea of rough equivalence in trade-offs. One must assess, for example, the value of one American soldier armed with an anti-tank TOW missile versus a Chinese soldier armed with a bazooka. Assuming that both have the explicit responsibility of stopping an advancing T-72 tank, what then is the relative effectiveness of each soldier in stooping the tank? These assessments have been made by strategists and tacticians countless times in battle, yet a single reliable measure has yet to be formulated. (9:38)

Edward J. Laurence has identified several ways of measuring the characteristics of an arms transfer and of a national defense structure. These measurements are:

Variable	Values/Attributes
Type/number of equipment	5 T-62 tanks, 10 F-5 A/C
Military utility	Payload, speed, combat radius.
Logistics	Attributes depicting extent of logistic support accompanying transfer
Technical/training	Number of donor personnel to accompany equipment/ number of recipient personnel to be trained in

	donor nation.
Dollar Value	Static valuation formula incorporating production costs, inflation, depreciation
Production Arrangement	Package deal, assembly, license, co-production, co-development
Mode of payment	Cash, credit, gift, barter
Delivery stage	Rumor, agreement, delivery, ready for use in combat

(9:38)

Unfortunately, relatively reliable and comprehensive data is available only for the dollar value of transfers, and annual military expenditure. But even this data is fraught with error and inaccuracies in measurement.(14) Furthermore, this dollar-only data may not provide information to answer questions of military capability, technology transfer, or the economic burden of military transfers. Pierre indicates that the maintenance of balances within regions will depend upon the size of the transfer, quality of materials transferred, and rate of receipt of weapons from outside suppliers.

As supported by Rosen (31:126), this model assesses troop effective strength using both numbers of troops and literacy level. Fighting smart is generally more effective than throwing hordes of soldiers at the opposition assuming both are equal. Education never makes up for lack of training, or incompetency in leadership, however, increases in literacy generally portend a greater ability to handle sophisticated weapons, and formulate tactics that exploit advantages over the adversary. The trade-off of soldiers versus intelligence is depicted in Figure 3.24. This table has been arbitrarily constructed, and improvements could be gained through extensive use trade-off studies using marginal analysis and other decision maker utility assessment techniques.

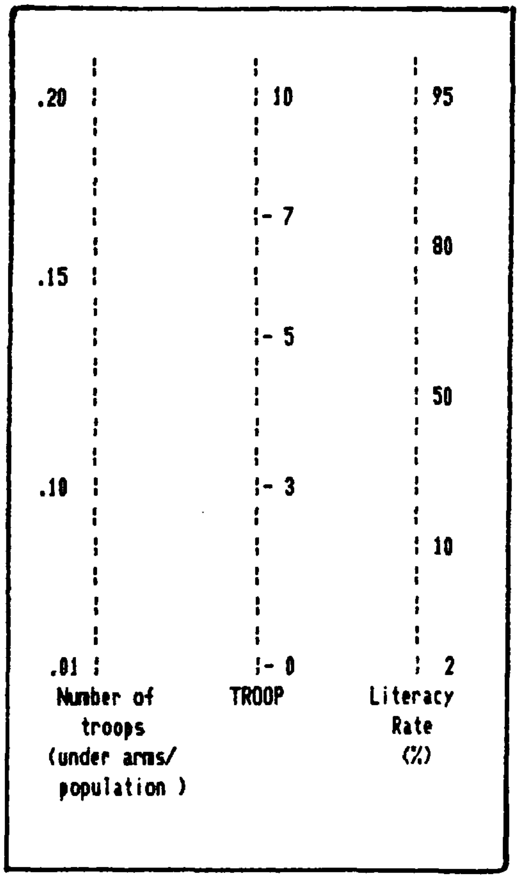

FIGURE 3.24 TROOP INITIALIZATION NOMOGRAM

Formulating a single measure assessment of arms, to encompass both quality and quantity, as well as suitability to the mission has vexed military experts for centuries. Traditional assessment of arms has been through the economic instrument, with comparisons of nations made on the basis of dollars spent to procure weapons. As previously noted,this generally provides little actual information about the type and nature of the arms, or their capability to provide defense. As an example, Libya's Colonel Quadafi has directed a vigorous buildup of arms during the late 1970's, procuring $2.1 billion worth of arms in the period 1977-1980. However, intelligence reports indicate that most of this equipment still lies in its packing crates, slowly deteriorating under the desert sun. To assess capability on the basis of expenditures in this case would provide an erroneous impression. However, a combination of factors including military expenditures could provide an insight into the actual arms capabilities.

In observing the world arms trade and the trends of warfare during the past century, it appears that the air instrument is a fairly good indicator of the sophistication of arms employed by a nation. Few nations possess significant naval weapons with the ability to display substantial force within a particular region. Although most nations have some form of ground based force, effective employment of this device requires extensive mobilization, and a commitment to occupy a particular place. Both naval and ground based force projection methods rely on traditional employment techniques, with few differences in actual tactics noted during the past 40 years. There has been some shift towards increased reliance on mechanized transport and use of standoff weapons, but the preponderance of innovation has been directed towards developing effective air arms.

The use of airpower has become an integral part of foreign policy, particularly in cases where a show of force is desired. The United States dispatches a single AWACS radar surveillance aircraft and a small contingent of air superiority F-15 fighters to troubled regions as a show of force. Israeli fighters perform retaliatory air strikes against its Arab neighbors for acts of terrorism taking place in Israel. Argentina attempted to defend its claim to the Malvinas islands using its Super Entendard fighters equipped with Exocet missiles. Foreign nations eagerly place orders with Northrop for its newest version F-5 fighter. If anything, these examples serve to illustrate the importance of a nation's air arm in assessing its arms posture. Both the possession of the weapons, as well as having them in a ready status determines much of the arms capability of the nation.

This model provides an initial assessment of arms capability through a combined measure containing both arms expenditures, and air arm capabilities. To assess air arm capabilities, one must observe the single instrument of latest year aircraft in active inventory. To qualify for latest year, the nation must have a minimum of 5 aircraft of the type in service, and under the pilotage of national pilots. Since the preponderance of aircraft in use have been developed by superpower or major power nations, latest year is derived from the date that the aircraft type entered inventory of a major power. For example, the Lockheed F-80 (T-33) entered the United States inventory in 1949. A nation possessing at least five F-80 fighters as the most modern aircraft in their inventory will hold a latest year rating of 1949 for use in the nomogram.* Although this model construct ignores the aspects of ground forces, and naval forces in assuring defense of the nation, the simplicity of the measure of arms using both national defense expenditures and latest aircraft year captures many of the salient characteristics of the arms posture. Embodied in these measures are indications of logistics struc-

-----

* A detailed appendix (Appendix C) of common fighter aircraft in use in the Third world provides information on the year of entry for use in the model, and this nomogram.

ture (newer aircraft need more varied parts), military utility (type of year group aircraft indicates capability), technical/training structures (newer equipment requires more sophisticated maintenace), quantity of equipment on hand (it costs more to maintain more), and national intent to employ armed forces as a policy means (one spends on what is important).

Figure 3.23 is used to determine the initial national arms posture.

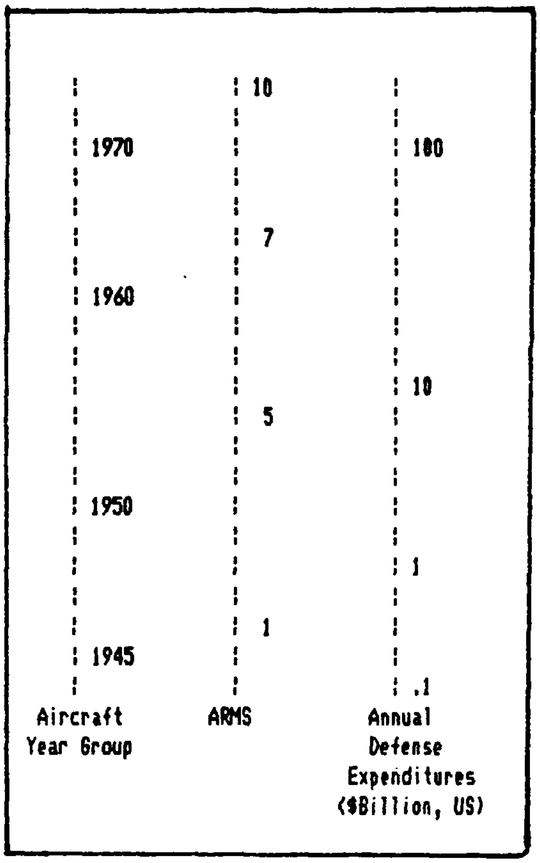

FIGURE 3.25 ARMS INDEX INITIALIZATION NOMOGRAM

The assessment of total defensive capability follows from the belief that people are as important to the total effort as the weapons they use. Accordingly, an initial value for defense (DEFENS) is the simple average of ARMS and TROOP.

Stability Assessment

In Chapter II, stability assessment was discussed at some length, and several observations were made. In review, regional stability assessment has been a largely subjective matter, depending on the particular decision maker's personal perceptions, and intelligence of nation situation. Most nations desire a relatively stable system in which change progresses smoothly along a predetermined path, with little or no variation or disturbance along the way to the "good life." However, the nature of advancement does not follow any perscribed path, nor does it necessarily make itself amenable to accurate prediction. Furthermore, individuals, acting in accordance to roles laid out in front of them by their respective society, will usually attempt to maintain a certain continuity with the past, and to regulate change in their lives to fit learned of behavior. However, a handful of innovators in a cultural system will attempt to find new, more appropriate, more efficient, and more effective ways in carrying out life's business, and on occasion, disrupt the orderly flow of change.

Instability of a social nature as envisioned by this model results when the rate of change in the social system (as embodied in technology) outstrips the cultural ability to absorb change, or when a significant gap in actual cultural sophistication and embodied technology exists. Additionally, instability of a geographic nature will be introduced into a regional system when one or more neighbors invade yet another neighboring nation. This model uses two separate measures of stability. STABL1 measures the difference of between cultural legacy and technology, STABL2 measures the rate of change in technology and cultural legacy, and incorporates instability due to war resulting from invasion or expansion. Figure 3.26 illustrates the flow diagram for both.

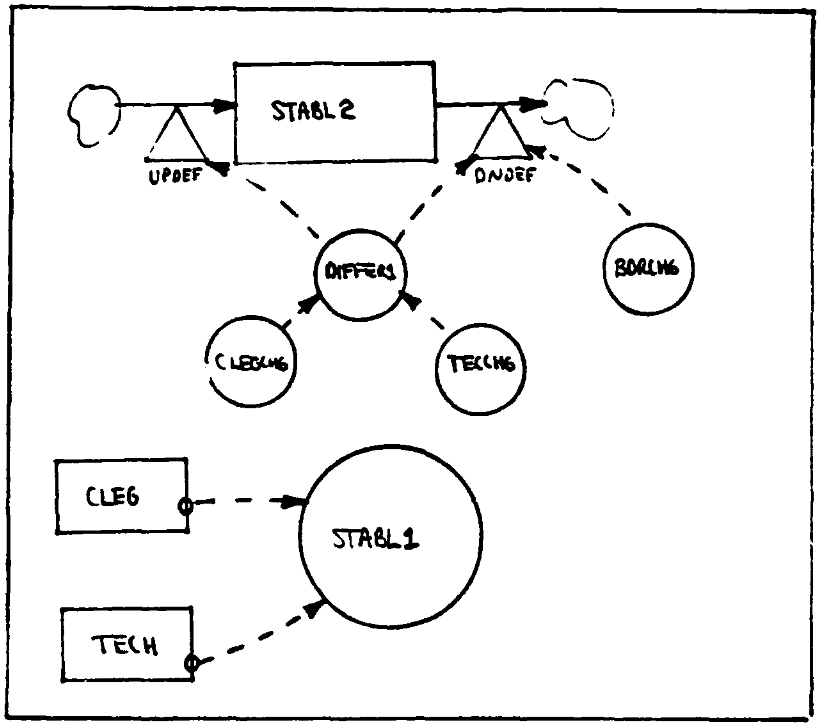

FIGURE 3.26 STABILITY INDEX FLOW DIAGRAM

The absolute difference measure of stability (STABL1) envisions stability increasing with a decreasing cultural legacy in a near exponential relationship. Cultural legacy is constructed such that a low value implies a positive orientation towards change, and a high value exemplifying change averse behavior. Technology, however, is indexed in an opposite manner, with a high value indicating technological sophistication, and a low value indicating primative technology.

Instability in this context results when cultural legacy is greater than technology. However, with decreasing values of cultural legacy, the effect of high technology decreases. To exemplify such a relationship, an inverse relationship is used. The DYANMO code follows:

```
A STABL1.K(I)=TECH.K(I)-((1/CLEG.K)*10)
```

STABL1 - Stability index 1 (dimensionless)
TECH - Measure of embodied technology (dimensionless)
CLEG - Measure of cultural legacy (dimensionless)

The STABL1 measure resulted from experimentation with a response surface of possible outcomes, with a number of structures used until a logical structure was found. Recall that initial values of CLEG vary between 1 and 10, as do values of TECH. Assume that we have a static system with respect to technology (set at 5), and that due to cultural changes and the effects of education, cultural legacy (CLEG) is decreasing. The response surface would look like:

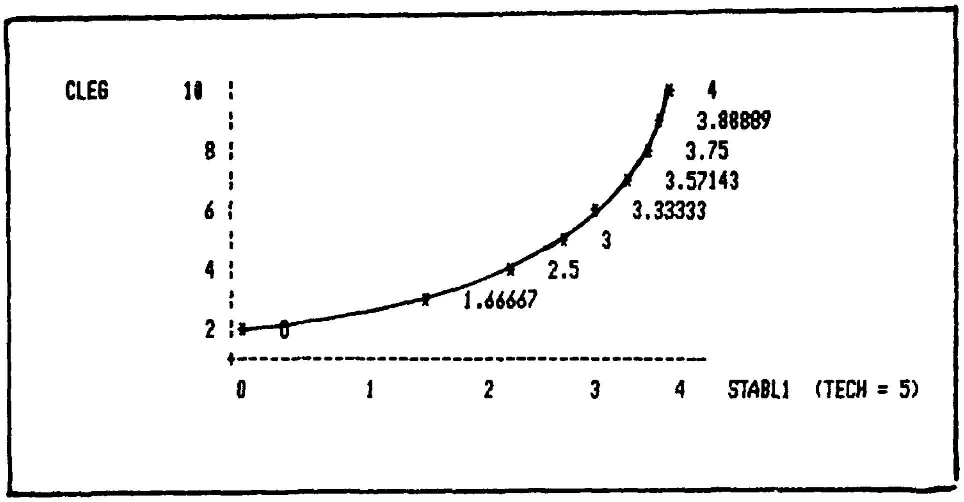

FIGURE 3.27 CLEG CHANGE RESPONSE CURVE

As one notices in the above response surface, in the region that cultural legacy is greater than technology, the trend towards instability, is nearly flat and nearly linear. As cultural legacy increases beyond the point of equivalence with technology, exponential growth of instability results (increasing values for STABL1 implies increasing instability). The intuitive appeal is immediate. One would logically expect social malaise when the absolute level of technology exceeds the cultural capability to absorb. Furthermore, one might reasonably expect that the instability to grow at increasing rates when the imbalance increased. In regions that social structures were capable of absorbing advanced technology, one would reasonably expect some instability as a result of small imbalances, but at a moderate level. This equation appears to model this effect quite adequately.

The development of the STABL2 measure of stability is concerned more with the dynamics of the system using measures of technology change, cultural legacy change, and boarder change as indices of increasing or decreasing stability. In this context, and derived from earlier causal and flow diagrams (Fig 3.24), stability is decreased by concurrent positive changes of technology and cultural legacy, and increased by concurrent negative changes in technology and cultural legacy. Increases in boarder change decrease stability. As the response surface is a four dimensional hyperboloid sheet, it will not be graphed here. The DYNAMO code is as follows:

```
L LSTAB2.K(I)=STABL2.J(I)
N LSTAB2(I)=LSTA2I(I)
T LSTA2I(*)=5/5/5
L STABL2.K(I)=STABL2.J(I)+DT*(UPSTAB.JK(I)-DNSTAB(I))
N STABL2(I)=ISTAB2(I)
T ISTAB2(*)=5/5/5
```

```
A DIFFER1.K(I)=TECCHG.K(I)-CLEGCH.K(I)
R UPSTAB.KL(I)=STABL2.K(I)*CLIP(0,DIFFER1.K(I),DIFFER1.K(I),0)
R DNSTAB.KL(I)=STABL2.K(I)*(CLIP(DIFFER1.K(I),0,TECCHG.K(I),0)
X +BDRCHG.K(I))
```

LSTAB2 - Last period dynamic stability measure (dimensionless)
STAB2 - Current dynamic stability index (dimensionless)
UPSTAB - Increase in stability (dimensionless)
DNSTAB - Decrease in stability (dimensionless)
BDRCHG - Period change in boarders (%)
DIFFER1 - Difference in rate of change of technology and cultural legacy

Increases in STAB2 indicate increasing instability in the national system. To prevent absurdities in stability assessment, the CLIP function is used to prevent increases in stability due to the DNSTAB mechanism, or decreases in stability through the UPSTAB mechanism. Initialization of the STAB2 is flexible with no set values perscribed, however, use of a number close o zero in a very dynamic system might lead to negative values of STAB2 indicating increases in stability, when in fact the system is very unstable. Choosing an initial value close to 10 appears to be a good alternative for all situations.

Summary

In this chapter the causal diagrams of Chapter II were used as a basis for the development of a specific system dynamics model to assess regional stability in light of arms transfers. Flow diagrams leading to explicit computer code, in addition to further discussion of the nation system have aided in the completion of a tentative model of the national system of many, if not all, developing nations. Furthermore, explicit measures of such dynamic entities as national embodied technology, cultural legacy, interconnection, trade intensity, government intensity, and defense structure capability have been developed. The construction of numerous nomograms are a tentative approach for use in initialization and quantification of these often hard to quantify variables, and provide a basis for examination of otherwise unexaminable system behavior. By using various modifications of inputs through experimental structure, this model could possibly be used to assess the regional stability impact of transferring arms into any given nation.

The next chapter deals with the various tests undertaken to ascertain the validity of the model and verify its operation under various operating conditions. Specific tests are examined and system behavior explored.

Chapter V explains the use of the model for experimentation. Specifically, this chapter explores the effects of a specific arms transfer action as a policy option in an otherwise stable three nation region. Responses in national and regional stability are explained, and implications of these findings discussed.

CHAPTER V

Model Validation and Verification

Introduction

In the first three chapters, a tentative model was developed to assess the effects of arms transfers on regional stability. Theory was developed and illustrated in causal diagrams, explicit relationships were defined and conceptualized in flow diagrams, and a complex set of computerized variable relationships were implemented in DYNAMO computer code. The completion of the modeling process using a system dynamics methodology calls for validation of the constructed model, and verification of correctness of the computer model in operation.

This chapter will initially discuss the verification process used in assuring proper system operation. Included in the discussion will be the use of microcomputer spreadsheet techniques and sector development methodology. The latter portion of the chapter deals with specific techniques used to validate the completed model, and assure that the model can be of use to the interested decision maker. Additional discussion will focus on the philosophical nature of validity the problems traditionally encountered in attempting to validate any computerized simulation model.

Verification

The process of verification is concerned with confirming that the

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UNCLASSIFIED J K MCFETRIDGE DEC 83 AFIT/GOR/OS/83D-8 F/G 5/4 NL

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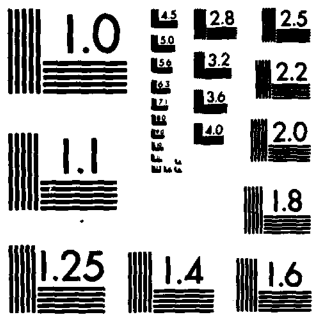
1.0
4.5
2.8
2.5
5.0
5.6
3.2
2.2
6.3
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

output of a model is that which is specified. In computerized models this takes many forms. Simple models and equations are often checked by hand calculation to assure that the computer output is correct. Error traps are often built into the logic of a program to prevent numerical absurditiy and meaningless output. Sophisticated correction schemes have been built into computer operating systems to deal with the inherent inaccuracies of digital machines modeling continuous systems. However, rather than dealing with the intricacies of digital computing equipment or the hand checking of computer calculations specifically, let us turn instead to the processes used in development of the model.

In using the system dynamics approach, the modeler is directed to initially use explicit graphs of known system behavior and to determine specific causal structures representing feedback structures that might lead to this specific performance. When possible, further information of believed critical variables in the operating should be gathered and used to refine initial hypothesis of system behavior. From these initial observations and hypothesis, an analytical computer model should be developed in a sector-wise manner. The sector model should reflect known system relationships, as well as hypothesized relationships. Operation of this sector model should produce response variables that are both plausible and within the reasonable realm of system performance. (30:46)

Accomplishment of this initial phase of verification took place using a microcomputer and the CP/M based spreadsheet software package, SUPERCALC, developed by Sorcim, Inc. Specifically, this spreadsheet allows a modeler to represent specific DYANMO levels and variable structures in the 128 row by 56 column structure of discrete blocks of the spreadsheet. The modeler is allowed to place algebraic equations that depend explicitly on the assigned value of another discrete block, and perform operations on rows and columns of the spredsheet. Modification of any variable or value held by any block results in instantaneous recalcualation of the entire spreadsheet. This modeler specifically established DYNAMO like equations using columns of the spreadsheet as time periods, and rows as specific variables. SUPERCALC facilitates the use of this structure in that the user can readily copy the structural relationships of any one column to any other column in the spreadsheet, while establishing new relationships. As an example, if block B2 (column B,row 2) held the equation

(2*A3) - (5/B1) + EXP(A1)

then a copy of column B to column C would leave block C2 with the equation

(2*B3) - (5/C1) + EXP(B1).

Modification of any block can be accomplished through the use of the EDIT command, and specific exploration of a response surface can be generated by outputting any stream of information to an external plot routine. Time lagged information or material flow can be accomplished using averaging techniques across rows, or through use of random exponential generation techniques. Specific decision structures are as a rule difficult to modify, however, ease of experimentation on a readily available microcomputer system offset difficulties in use.

Specific sector analysis used such devices as the extreme value test, and response plots to assure verification of operation. After inital workup on SUPERCALC, explicit relationships were translated into DYANAMO code, run on a larger CDC 7500 using specific DYNAMO software, and checked against results from the SUPERCALC model. On several occasions, this methodology helped to identify DYANAMO logic errors and was particularly effective in helping to determine order of equation calculation within the DYANMO language. Specifically, SUPERCALC calculates equation values from top to bottom of a column, sequentially across all rows.

DYNAMO, however, uses a different method of calculation, partially enforced by its internal time keeping mechanisms. DYANMO starts by solving for all independent variables, then addresses each level from beginning to end as coded, evaluating contributing levels as they are called from the level under primary consideration. This can cause a level further down the line to be evaluated prior to the expected sequential approach, and caused quite a lot of difficulty in establishing a mechanism to assess percent change in specific variables. This particular phase of verification proved to be the most arduous and frustrating aspect of use of the DYNAMO code.

Some small differences were noted in several response variables, however, investigation of the differences indicated that the discrepancy was due to the precision of data handling between the larger 64-bit word of the CDC system and the 8-bit word size of the Osborne 1. This difference became quite apparent in use of the exponetial function to approximate a third order information delay using the Osborne, and in random deviate generation for use in simulating weather effects in the primary production sector of capital production. However, the use of a microcomputer spreadsheet program was quite valuable in developing any complex system model in a component-wise manner.

Further verification of model operation took place through the use of a contrived static system simulating a region in near perfect equilibrium. The result was decreasing instability, and fully predictable growth and decay patterns in every major sector. Figure 4.1 illustrates the response of STAB2 in this system.

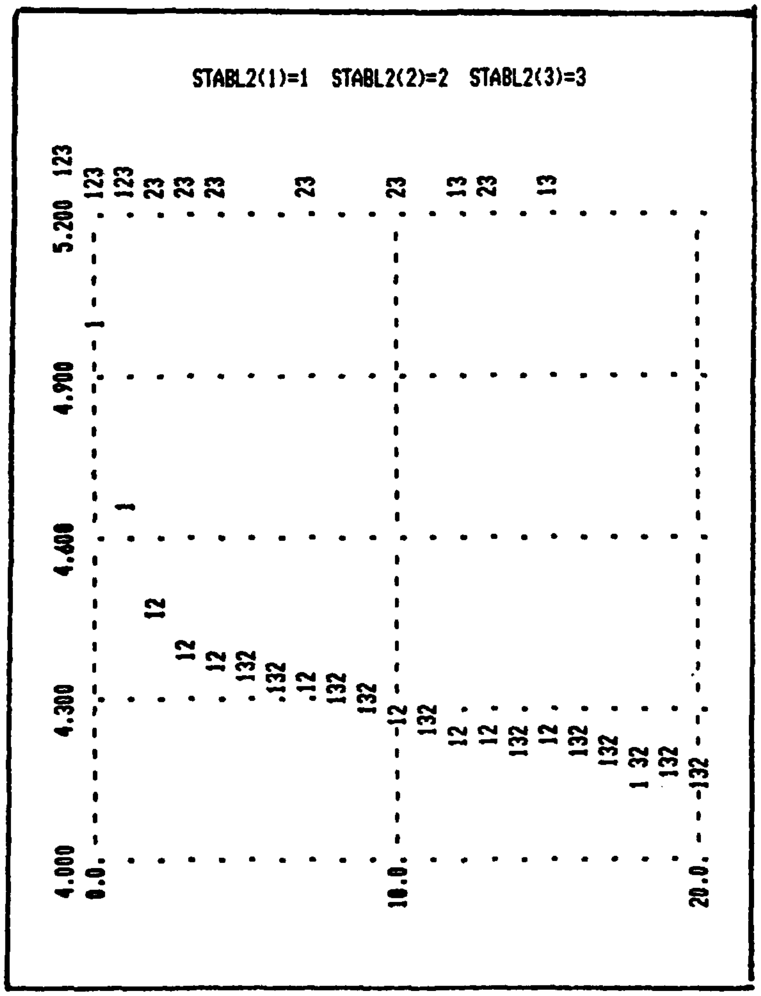

FIGURE 4.1 STATIC SYSTEM STABILITY INDEX

In summary, it appears that the model runs with no major logic error in its formulation. Each of the sectors, through development in

SUPERCALC models and upscaling to DYNAMO coded models, behave as designed, with no extreme anomalies found through extreme condition testing. For all extensive purposes it appears that the model is fully verified. From this point, the next step is to establish the validity of the model.

Validation

This model has been created for a specific purpose: assessment of the specific effects of arms transfer on regional stability. Its adequacy or validity can be evaluated only in terms of that purpose. The goal of this and all system dynamics model is to address a problem, not a system, and is designed to answer a reasonably well-defined st of questions. (30:310) The concept of validation is not a binary decision model variable where the model is valid or invalid. Rather it is a matter of degree, in which one could assign a value between one and one hundred to express the degree in which the model creates the same problems and behavior characteristics as the system being modeled. (34:208) In the system dynamics approach, validation is an on-going mix of activities embedded throughout the iterative model-building process. No single test suffices to validate a system dynamics model or measure its degree of validity. An observer wishing to make a judgement about the validity of systems dynamics study must follow much the same path as the modeler. (30:311)

Although there is no one test of validity of the model, the intent of this section is to demonstrate tests of agreement between the behavior of the model and that of the real system. As such, realize that simulation modeling, and in particular system dynamics models such as this, is not an expression of absolute truth or correctness, but rather exemplifies a succession of theories that hopefully progressively approaches the truth.

Forrester and Senge, recognizing the many inherent difficulties in establishing the validity of a system dynamics model, have developed a battery of tests to assist in building confidence, and establishing validity of the modeling technique. These test are listed in Table 4.1 below.

Tests of Model Structure

1. Structure Verification
2. Parameter Verification
3. Extreme Conditions
4. Boundary Adequacy
5. Dimensional Consistency

Tests of Model Behavior

1. Behavior Reproduction (symptom generation, frequency generation relative phasing, multiple mode, behavior charcteristics)
2. Behavior Prediction (pattern prediction, event prediction, shifting mode prediction)
3. Behavior anomaly
4. Family Member
5. Surprise Behavior
6. Extreme Policy
7. Boundary Adequacy
8. Behavior Sensitivity

Test of Policy Implications

1. System Improvement
2. Changed Behavior Prediction
3. Boundary Adequacy
4. Policy Sensitivity

(10:227)

TABLE 4.1 CONFIDENCE BUILDING TESTS

One will notice the absense of the general class of statistical tests from this list. The nature of system dynamics models permits many tests of of model structure and behavior not available with other types of models. Forrester and Senge assert that this class of tests "are either inappropriate or, at best, supplementary for system dynamics models." (10:209) This is in part due to the nature of the output of a system dynamics model using DYNAMO, and its time series nature. The output is designed to identify trends of behavior rather than discrete point response, and as such an lend itself to spectral analysis, tests of multicollinearity, and tests of variability, however, tests of this nature provide little additional confidence in the model, nor do they help the modeler establish the model's validity.

Richardson and Pugh make reference to many of the above tests, distilling the validation process into two questions:

> 1. Is the model suitable for its purpose and the problem it addresses?
>
> 2. Is the model consistent with the slice of reality it tries to capture? (30:312)

They recognize that a perfect match between model and reality can never be achieved, and that any assessment of validity is at best subjective, and relies on a shared consensus of policy maker and modeler. The question now is, is this model valid, and if so to what degree? To accomplish this task, the model will be subjected to two structural suitability tests, a parameter insensitivity test, and two tests of consistency of the model structure with the real system.

Suitability of Structure.

A system dynamics model containing equations that mix dimensions and generally do not match left-hand side with right serves no purpose other than exemplify poor modeling techniques. The test of dimensional consistency assure that all dimensions of equations agree with on another.

This model avoids many of this type of problem due to the use of dimensionless measures of value. The notion of percent change is used to modify flows and levels. When dimensions are used they are explicitly stated, such as percent of population, average age of the population, number of miles of railroads and roads, square miles of territory, and so on. The use of nomograms in particular avoids the need to massage data within equations, and allows more attention to actual system behavior than to the mechanics of the system. When dimensional units were used, experimentation using SUPERCALC methods identified needs for data manipulation, and led to iterative improvements. The model as it now stands is dimensionally neutral, with the key response variable being totally without recognizable dimensions.

"The modeler should mentally test each equation ... to be sure it remains meaningful under extreme conditions, even if unlikely."(30:315) This extreme condition test assures the modeler of the robustness of equations, implying robustness of the model, when the possibility of operating in extreme conditions where one or more equations may behave unreasonably.

During development of the model SUPERCALC models of the equations were hand massaged, explicitly checking for anomalies in behavior. One formulation (MACRO PCTCHG) has been found to be suspect at extreme conditions. The formulation of this MACRO takes the difference between a level variable during the last period and subtracts it from the current period value, and divides this difference by the absolute value of the last period. Problems of sensitivity of response are particularly acute in the region close to zero when a pronounced period change is noted. In this region, changes of 1000% are not uncommon, and in the unlikely case that the last period value for the variable is equal to zero, a calculation mode error (division by zero) would be encountered. To avoid a mode error, an artificial lower bound of .0001 is included in the formulation. Additionally, to prevent operation in this region, no system variable would be initially set to zero if using the provided nomograms. In operational tests of the completed model, an output of the period values of all variables was examined, with no intuitively nonsensical patterns or values seen.

Parameter Insensitivity Test

Although it it possible to build confidence in a model by proving the accuracy of the values of all parameters beyond reasonable doubt, the cost in doing so may be prohibitively high, and in the case of social models, inherently futile. It is much easier to build confidence in the model if it displays relative insensitivity to changes in parameter values.(30:411) More importantly, do policy conclusions stemming from model output analysis change with reasonable changes in parameter values? Careful analysis of these points prior to decision time could forestall serious policy errors.

To accomplish this test, a series of five simulations were run and the following assumed critical structures modified one at a time to observe stability output. The structure and the observed response indicated sensitivity in certain regions however, the model operation was surprisingly robust. The variable modification and its response are noted below.

Variable Action	Response
1. Modify DCONT (Democratic Control Table) to display less control in later years	No perceivable response.
2. Modify MINF (Media Influence) in CLEG sector to display less sensitivity to media in the young	Slight increase in instability across the board.
3. Modify RAWPART to show shifts of internal usage and effect exports.	No perceived change.
4. Increase weighting of defense change to 2 in formulation of GI	Earlier signs of Instability with increases of arms.
5. Eliminate Immigrant structure from formulation of CLEG.	Increased instabilty in all regions.

The use of these five tests built increased confidence in the robustness of the model. Changes in assumed tabular values did not skew the model excessively enough to make the responses untenable. Other changes provided a better feel for the operation of the system, however, the modification of structural values did not generally affect the output of indicated stability.

Consistency Tests

The acid test of any model in the eyes of the policy maker is essentially, how consistent is the model itself with reality? If the modeler has devised a means of predicting the crop harvest in southern Illinois, without including such variables as weather, acres sown, fertilization schedules, but instead uses variables such as fish per square mile in the Great Lakes, or Eskimo's emmigrating from Alaska, the decision maker would tend to be leary of the results, even if the alternative structure provided an accurate estimate over time. Modelers and decision makers must be able to observe some connections through causal structures to the system being modeled, and generally both are considerably more receptive to models having components, decision structures, and sectors similar in nature to the real world system. Richardson and Pugh note two tests to check consistency of the model structure with the real system.

The test of face validity asks if the model's structure look like the real system. "Are those who know the system most closely convinced that a reasonable fit exists between structure of the model and the essential nature of the system?" (30:316)

Test for Face Validity.

In establishing face validity of the model, this modeler used expert opinion from varied sources, using a multidisciplinary, eclectic approach to assure that assumed structures and relationships existed. Particular attention was given any quantitative relationships that had been discovered in expert research, and these relationships were included as expert opinion. In areas that quantitative relationships were not available, the modeler relied on social scientist expert observations of critical social relationships and included many of the intricacies of social interaction and the human element into the model of the system. An attempt was made to include the combined capabilities of people in a nation in maintaining a cultural identity and providing for a livelihood. Aggregate measures depicting such values as religious structures and social mores were included to add the usually ignored aspects of human sensitivities when dealing with arms transfers into a region. Elements of inter-nation strife and perceptions of threat provide a juncture for analysis and exploring hypothetical causal relationships. In its complexities, this model appears to provide a reasonable framework for analysis of regional stability with respect to arms transfers.

Test for Parameter Value Consistency.

In establishing parameter value consistency one must assure that the parameters are recognizable in terms of the system, and when chosen that these parameters are consistent with the best information available about the system. This model holds strong link to actual real world parameters, requiring in excess of 50 points of contact with the real world system. Observable phenomena such as birth and death rate, industrial output, agricultural output, miles of roads, numbers of ports, number of troops, type of arms, literacy rates, number of radios, and so on provide a high level of surface content of the essential characteristics making up the nature of the systems being simulated. Additional attention to inclusion of dynamic rates already observed, such as change in literacy, change in manufacturing production, change in imports and exports, number of airports under construction, and so on provide initial performance levels, eliminating many of the traditional simulation problems of start up transients.

The model does depart from observable system phenomena through the use of nomogram derived surrogate variables, such as interconnection, embodied technology, and human capital, but with good reason. These variables have been identified by sociologists, political scientists, and cultural geographers as being important to the operation of a national system. Their exclusion due to lack of precise measurements would be the same as saying its not important to the system, and would be similar to saying that wind did not exist for cavemen simply because they lacked accurate tools to measure it. It is better to include believed critical variables and accept error in measurement than to discard them as having no importance at all.(34:213)

Behavior Consistency Tests

The final tests of establishing a sense of validity to a model lie in the observations of whether the model behaves as designed when tested against a reference behavior. The system dynamics model that cannot reproduce its reference behavior is for all intent, invalid. However, the validation of this particular model has no one specific reference behavior to draw from. The model from its inception has been designed as a generic model, drawing from common national and regional structures. In arriving at a single, all-purpose model for assessing regional stability with respect to arms transfers, no one particular nation or region represents the actual world system, but rather any group of nations not sharing in the status of major power, or superpower can be represented. As an alternative, a single relatively well behaved region is chosen and examined in light of model behavior.

To determine if the assessment of stability functioned as designed, the apparently stable region of Bolivia, Peru, and Chile, located in west-central South America was chosen for assessment. In comparison to other regions, there has been no major war along any axis in the past 90 years; no major upheavals in territorial location,or human dislocation have occurred in 50 years; all have been freed from colonial status for over 100 years; and production of goods and services has remained relatively constant over the past 30 years. As a region containing three less than major power status states, this region has been quite stable from a geographical and social point of view. The model should represent the same to be a useful tool in assessing stability. Data was gathered from open literature sources for three nations to provide a distinct regional and national flavor to all fields of the model.

Running the model for a 20 year period using this data provided the stability index output for STABL1 and STABL2 as shown in figures 4.2 and 4.2.

The continuing downward slope of the three nation axis indicates that stability is increasing (instability decreasing) in the region over the simuation period. The initial sharp drop in instability over the first three years of simulation appears to be the result of start up transients in the modeled system.

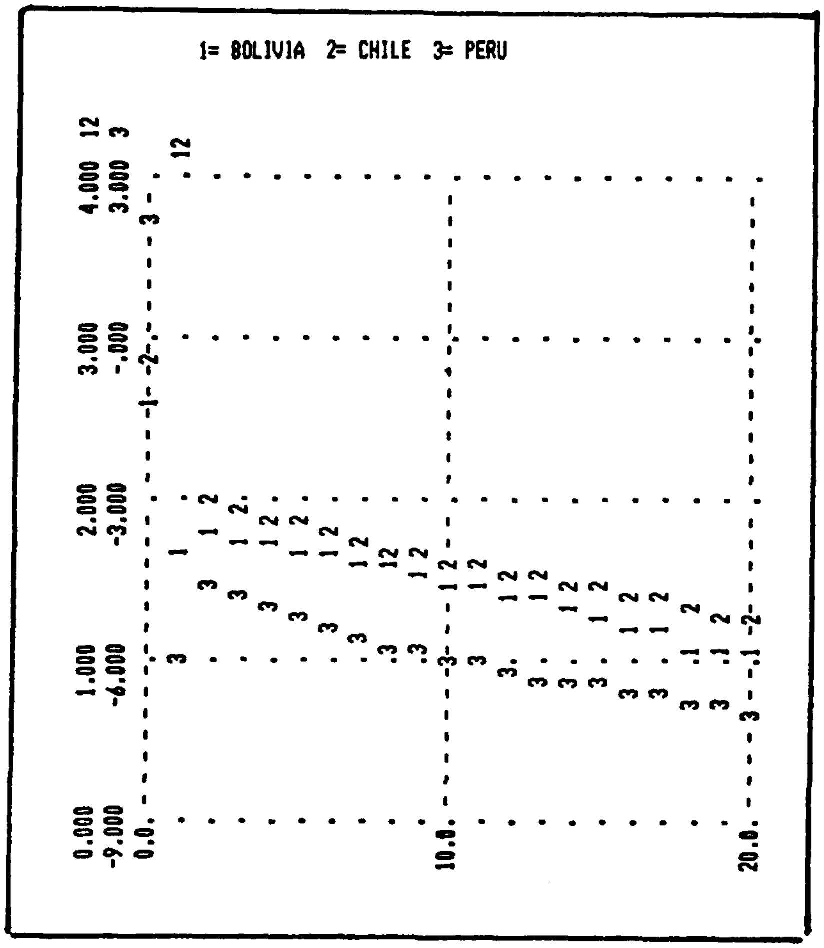

FIGURE 4.2 STABLE SYSTEM STABILTY ASSESSMENT 1

In a similar manner, the declining slope of STABL2 indicates a stable system, continuing on to a more stable relationship. This similarity of response and of roughly the same magnitude confirmed the selection of the two stabilty assessment techniques as being sound, and quite valid. However, as a caution recall that this model represents only the situation as currently existing. No new arms are placed into service, nor are existing arms replaced as they wear out. Training and troop levels are set to remain the same over the period of the simula-

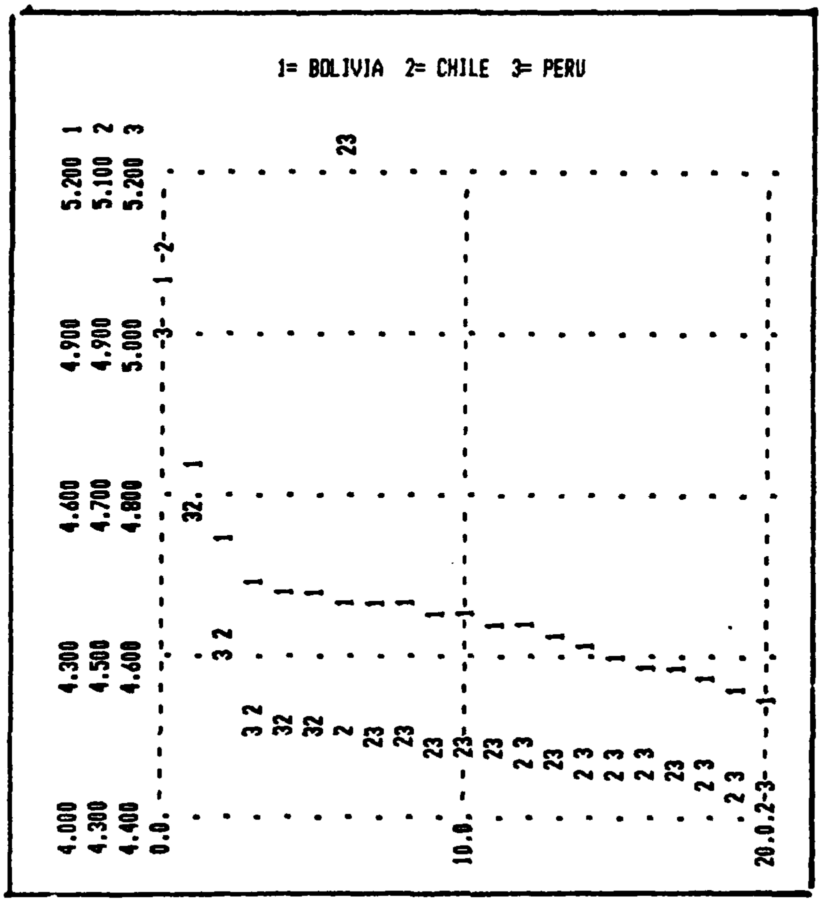

FIGURE 4.3 STABLE REGION STABILITY ASSESSMENT 2

tion, yet population, trade, production, and media are allowed to progress as they will over the period.

Additionally, model outputs of production rates exhibit some small decline, population age increases on the average 1.5 years over the span of time, Bolivia continues to decline in exports, and all continue to see population growth, however at an abated rate. All these behaviors are apparently consistent with available information and official forecasts for this region.

Summary

As a result of testing in development, detailed examination of the model structure, and testing against a reference mode, the model tentatively appears to be both valid and ready for experimentation as a policy tool. Operation of the model was verified in developmental stages and validated against a reference system. Expert opinion served to tentatively validate structures and the real world provides statistical data to lend a national flavor to each nation simualted in the model. It would appear safe to say at this point that this model might have the potential for use as a policy tool to assist decisionmakers in the assessment of arms transfer on regional stability.

Chapter V will use the constructed model to explore the impact of a specific arms transfer into the stable region of Peru, Chile, and Bolivia on regional stability, and explore specific nation response in light of this transfer.

CHAPTER V

EXPERIMENTATION

Overview

Over the past four chapters, a detailed, yet still tentative, model has been developed to assess the regional impact of specific arms transfers. Theory concerning the nature of the system that this phenomena takes place has been integrated and investigated. Tests have been run on the completed model to assure that a relatively valid model of the system exists, and it tentatively appears that the model is valid. Verification of operation was performed throughout the model development, and its internal consistency confirmed by similar findings of the two distinct stability assessment measures. The hypothesized stable region of Chile, Peru, and Bolivia provided a reference mode for model operation, and the region appears to be stable in both rates of change of key variables and in absolute terms with respect to levels held internal to each nation. From this juncture, experimentation will be conducted with respect to stability when additional arms and requisite training are introduced into the region.

Situation Assessment and Background

The nations of Peru, Chile, and Bolivia have existed in relative peace since the 1879 War of the Pacific in which Bolivia lost its direct access to the sea. On occasion, Peru and Chile have made veiled threats towards each other, yet no altercation or open conflict has been noted. Political parties in power seem to change nearly with the seasons, with the current allignment of Peru and Chile towards dictatorial, repressive regimes, and Bolivia enjoying relative freedom under a representative form of government. Chile is the most advanced in terms its people of the three nations enjoying a greater literacy rate, and higher per capita income, yet it suffers from having several large population centers with little peripheral development. Its economy rests largely on the fate of its copper deposits and world demand for this product, however it has begun to develop additional light industry to supplant this dependency. Peru is the richest in terms of annual production of the three nations, and has seen regular growth in both consumer goods and industrial production. However, Peru has been saddled with a public policy of continuously increasing its birth rates, which has resulted in a large bulge of young people still dependent on a smaller, working population. Literacy development is still pitifully low with less than 45% of the population able to read or write.

Bolivia is the far poorer sister of the three. It is a landlocked nation, isolated from its western neighbors by the vast Andes mountain chain, and dependent on the good graces of Uraguay and Argentina for access to the Atlantic Ocean. This nation is heavily dependent on subsistence farming for survival with roughly 50% of its labor force involved in agriculture. However, national leaders recognize the importance of education and have been increasing expenditures roughly 6% per year, and has increased its literacy rate from the low teens in the 1960's to its current 67%. Unfortunately, there has been little trickle-down effect to industry with a net decline in production of 2% per year over the past five years.

In the past five years both Peru and Chile have attempted to procure updated arms from various sources, with largely mixed success. Peru, with distinct Marxist leanings, has been provided with Soviet SU-22 fighters after being denied weapons by the Carter administration for human rights violations. Chile has also sought out arms from the United States and other Western sources, yet has had limited success, due in part to the excesses in repression of the Pinochet regime. Chile has procured a limited amount of arms from Israel and Brazil, yet has been generally denied access to truly advanced technology items. Regional analysts point to the building arsenals of both Peru and Chile and claim that there is a potential arms war brewing. Neither Chile nor Peru have been of great strategic importance to either superpower, and with increasing limits on resourcess and increased domestic demands, neither has been particularly willing to supply arms without some measure of increased internal control.(26:96) Bolivia, being protected by mountains to the west, and having few resources to defend against its eastern neighbors, has been a steady recipient of United States cast-off Korean War and WWII surplus. Starting with the current situation, a scenario can be cast to explore the implications major arms transfers into the region.

Scenario Construction

Chile with the aid of the Israeli government has managed to gain concessions from the new American administration in 1986 concerning the use of General Electric jet engines in export versions of the improved KFIR fighter. Chile has been saving its money for the occasion of being able to purchase new fighters as its older F-5A models are beginning to show serious wear, and have a limited ability to conduct an air defense role. Rather than go through the complications of obtaining loans, Chile decides to pay cash and receive 35 new aircraft, which has been conservatively estimated to increase their defense capability by 20% in terms of quality, and 16% in terms of quantity. Additional training will be given by Israeli pilots in Israel to 50 Chilean pilots, which defense analysts believe will increase the quality of defense forces some 20%.

Bolivia at the same time offers the United States a deal to purchase all its old T-33 aircraft for cash and concurrently grants the exploration rights to United States corporations searching for new deposits of titanium. These T-33 aircraft will be refitted by a private firm to increase its capability as an air defense and medium range interdiction fighter. Training for pilots will be undertaken in the United States with an expected increase in defense capability of 18% in troops, 25% in arms quality, and 17% in arms quantity. However, there is a two year time lag in this process due to human rights investigations and time required to decommission the old aircraft, and refit them for export.

Peru, although already holding a respectable fleet of aircraft, perceives a threat from all this development and decides it is time to visit the Soviet ambassador requesting more arms in return for limited "development assistance". The Soviets, after balking, transfer 30 of the crated MiG-23 aircraft that have been stored in Libya since 1978 and guarantee continued support for the local "People's Revolutionary Movement" in the form of additional advisors and technical experts. Defense estimates expect a 15% increase in quality and quantity (old airplanes, and lack of logistics support), and only a 8% increase in training as new pilots get checked out in older versions of the already held MiG-21 in anticipation of the new aircraft.

Given this information, what is the expected outcome on the regional stability of Peru, Chile, and Bolivia? Is rough equivalence maintained throughout the six year phase-in of the new aircraft? Are there domestic trends that indicate increasing instability? Will the likelihood of war increase, or will there maintain a status quo for the period?

Experimental Results

Using the simulation model RSAM I, information of the buildups in armaments and increases in troop strength was factored in. Specifically, a pulse function timed for a single release of additional change into the rate control mechanisms of armaments and troop effective strength simulated the specific increases in arms. The following stability assessment graphs (STABL1 and STABL2), and the defense capability graphs show the specific results of these actions.

Specifically, figures 5.1 and 5.2 show no difference at all from the reference modes of stability found in chapter 4. Initially, this finding seemed somewhat surprising, as one might suspect that arms transfers of this sort would have a greater impact on the domestic scene and the overall region stability. Suspecting a possible operational failure of the model, an additional output of the relative defense structures was requested (figure 5.4), showing an incremental increase in actual defense capability over the reference mode (figure 5.3). This output confirmed proper operation of the model, however the behavior is

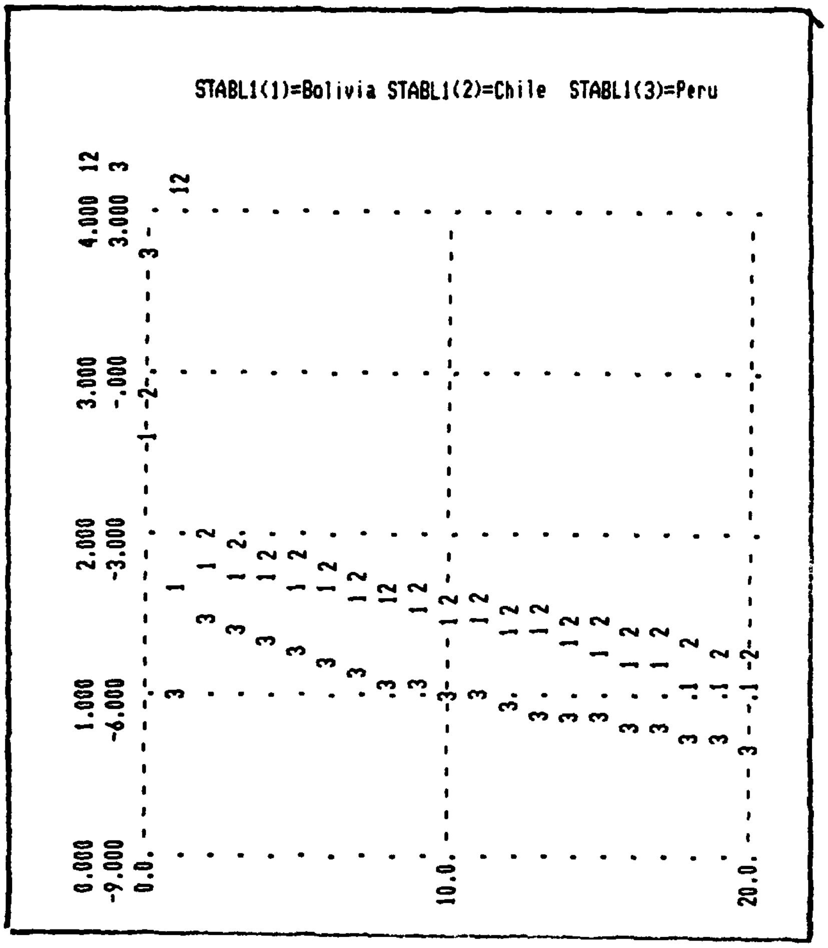

FIGURE 5.1 EXPERIMENTAL STABILITY ASSESSMENT 1

counterintuitive. Perhaps the best speculation for the results of an unchanged trend towards greater stability lies in the model construction. The model specifically does not allow for the volatile nature of human emotions, or the saber rattling that often accompanies arms build-ups. These factors tend to build regional tension, and often are a precursor for actual conflict. However, in light of the extremely depressed condition of these three nations, the results begin to make intuitive sense.

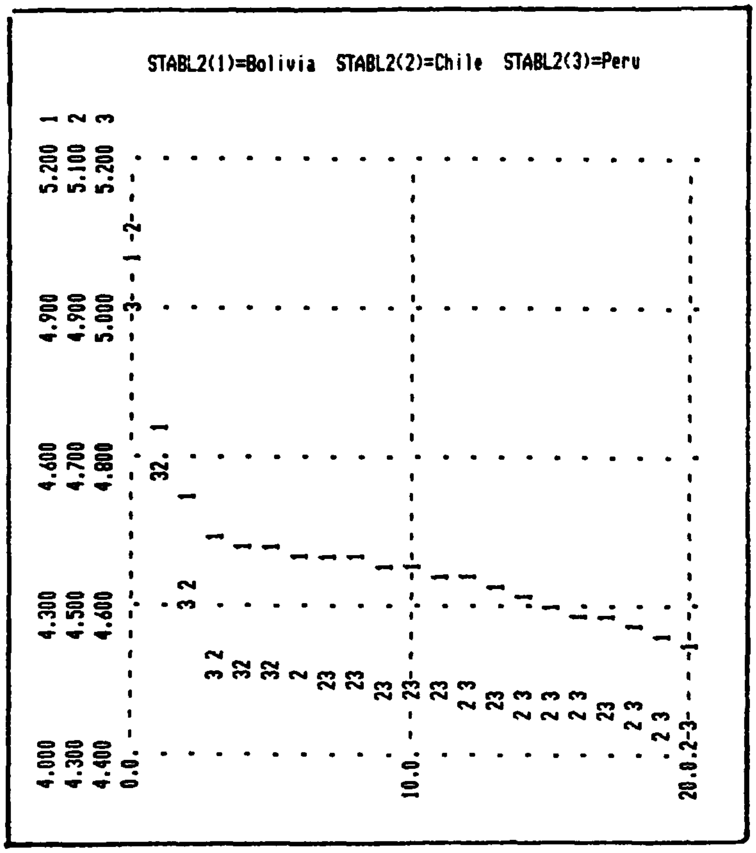

FIGURE 5.2 EXPERIMENTAL STABILITY ASSESSMENT

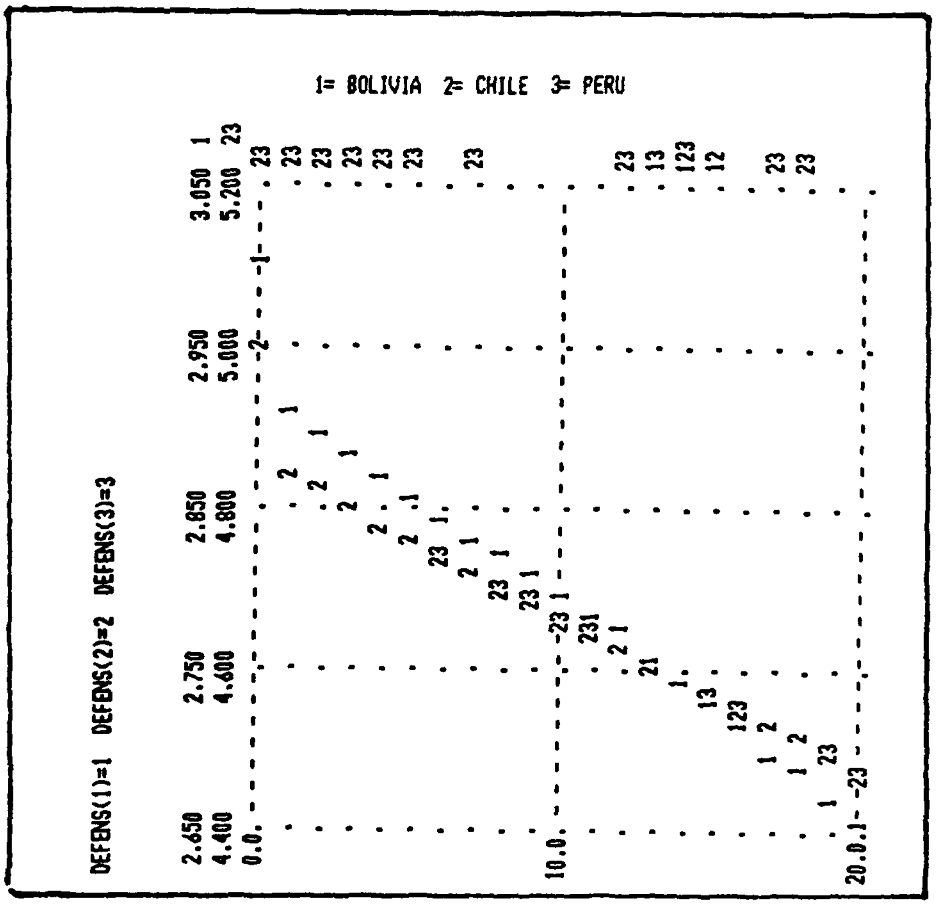

FIGURE 5.3 REFERENCE MODE DEFENSE CAPABILTY

It appears that none of the nations has the necessary infrastructure to support these increases in arms, and these increases in arms will have little immediate impact on the development of the nations or the region. Not one of the nations has a well developed industrial sector, nor do they enjoy a high rate of literacy. Outside of a small handful of military personnel, the increase in weapons should do little to reverse or modify the continuing trend to increasing poverty in the Third World.

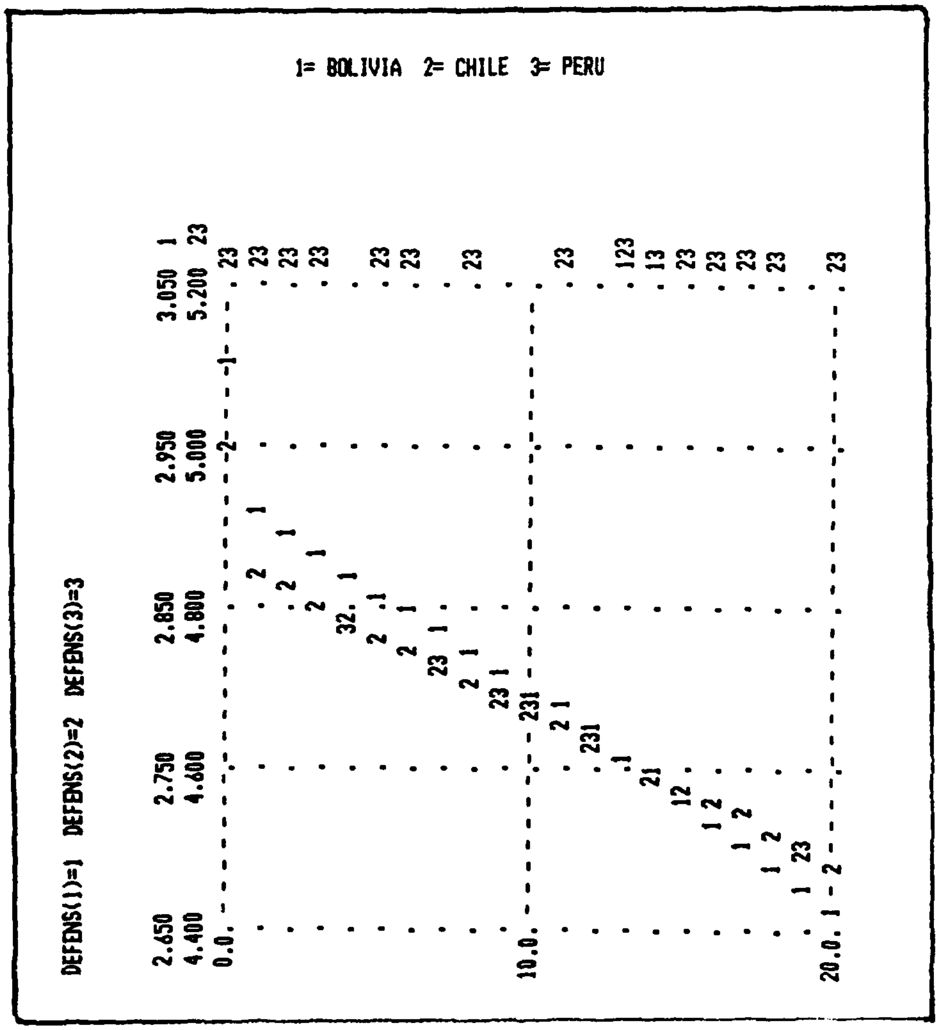

FIGURE 5.4 DEFENSE CAPABILITY WITH TRANSFERS

Further experimentation on other regional systems would be instructive, however, it will not be pursued in this research.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In Chapter I, the problem of a lack of substantive, dynamic policy model for use in assessment of the effects of arms transfers on regional stability. Specific research questions and objectives for the research were identified as a guide for the course of research. Now at the end of the research effort, these initial questions need be addressed and the research effort evaluated in terms of the objectives.

This research has developed a potentially powerful model for research into the effects of arms transfers by decision makers, and tentatively provides a vehicle for investigation of the effects of specific policies on both regional and national stability. In identifying elements of the world structure leading to and facilitating arms transfers, specific theory was integrated into an overall generic model of a national system. This structure was captured in a dynamic computerized model that has been demonstrated, yet not conclusively, in assessing regional stability under specific arms transfer actions.

In this process, critical variables were synthesized using multiple measures of the believed crucial variable, and the dynamic nature of interaction simulated in a sophisticated computer model. A unique criteria of assessing regional stability using internal and external conflict measures of technological change versus cultural change was formulated, validated against a reference mode, and experimented with, resulting in increased confidence in this measure. Guidance and instruction on the specific use of the model has been sprinkled throughout the text, and specific examples of variables included in appendices. Specific alteration of inputs to explore policy implications remains open to the interested user.

In summary, we have a model that given its purpose, works, at least in the specific situations identified in chapters four and five. Its usefulness can now only be assigned by the potential users, that is by policy makers providing direct support to the arms transfer process ance and making decisions concerning specific transfers. The ultimate test of this research's usefulness and its validity lies in its use.

Recommendations

In recognizing that there lies room for further research and improvement of this model, the following specific recommendations are made.

1. The structure and interrelationships of control in the government sector need further research. The current table function contains too many assumptions and may not be valid for a highly socialistic or mixed form of government.

2. The inclusion of a service sector in the capital production sector may be useful. Many Third World nations are becoming increasingly service oriented and the exclusion of this sector could lose some of the technical growth encountered.

3. Further definition and refinement concerning the effects of media on a nations cultural legacy,and in particular its religious structures and social mores could provide additional insight into the change mechanisms at work in this sector.

4. Further experimentation on a broad range of developing nations and regions would be useful to determine the actual effectiveness of the model in assessing the specific impact of arms transfers on a nation and region system.

5. Econometric evaluation and further research is necessary to determine the actual percentages that innovation transfer and innovation/invention contribute towards technical growth. The fixed percentages identified by Dennison's work are a begining, and identify a specific situation for a set time, however, are a static assessment and do not necessarily reflect the dynamics of national technological growth. A more appealing scheme would be to have a variable scale based on level of technology already in place, and reflecting a decreasing dependence on innovation transfer in advanced nation systems.

6. Although this work has tentatively identified the intricate workings of a national and regional system, additional insight into critical variables and their interactions would serve to improve its capacity as a policy model. In particular, further observation of the interactions aside from the military aspect would assist in defining more of the structure in the regional system that define regional stability.

As with all work, there must be an end. Hopefully this will not be the end of research and investigation into the structure and dynamics of arms transfers in the regional system, but rather that this work cn be used as a stepping stone to further understanding.

APPENDIX A

DYNAMO CODE OF MODEL

RSAM I

```
*  **************************************
   *                                    *
   *         REGIONAL STABILITY         *
   *               MODEL                *
   *                                    *
   *     VERSION 3.0  REGIONAL LEVEL    *
   *                                    *
   *        CAPT KEN MCFETRIDGE         *
   *                                    *
   **************************************


FOR I=1,3
   1 = NATION 1
   2 = NATION 2
   3 = NATION 3


  **************  MACROS ESTABLISHED  ************
MACRO PCTCHG(LEV.K,LLEV.K)
A PCTCHG.K=(LEV.K-LLEV.K)/SWITCH(.0000001,
X MAX(-LLEV.K,LLEV.K),LLEV.K)
MEND

  ***************  CAPABILITIES/THREAT MATRIX *********
A DEFEN1.K(I)=(SUM(DEFENS.K))-DEFENS.K(I)
A THRIND.K(I)=DEFEN1.K/DEFENS.K(I)


  **************** INTERCONNECTION INDEX ***************
L LICC.K(I)=ICC.J(I)
N LICC(I)=LICCI(I)
T LICCI(*)=4.45/4.45/4.45
L ICC.K(I)=ICC.J(I)+DT*ICCMOD.JK(I)
N ICC(I)=ICCI(I)
T ICCI(*)=4.5/4.5/4.5
R ICCMOD.KL(I)=ICC.K*(TXCHG.K(I)+TINTCH.K(I)+
X MEDCHG.K(I)+GICHG.K(I))/4
```

```
    **************** TECHNOLOGY INDEX ****************
L LTECH.K(I)=TECH.J(I)
N LTECH(I)=LTECHI(I)
T LTECHI(*)=4.94/4.94/4.94
L TECH.K(I)=TECH.J(I)+DT*TMOD.JK(I)
N TECH(I)=TECHI(I)
T TECHI(*)=5/5/5
R TMOD.KL(I)=TECH.K(I)*(MIN(ICCCHG.K(I),.6*CAPCHG.K(I))+
X MIN(HCPCH3.K(I),.4*CAPCHG.K(I)))


    *************  BOARDER CHANGE **************
A BDRCHG.K(I)=PULSE(.33,WARTIM.K(I),999)+
X PULSE(-.33,INVADT.K(I),999)
A WARTIM.K(I)=CLIP(TIME.K+DT,999,THRIND.K(I),5)
A INVADT.K(I)=CLIP(TIME.K+DT,999,.333,THRIND.K(I))


    *************  LANDMASS  ***************
L LLAND.K(I)=LAND.J(I)
N LLAND(I)=LLANDI(I)
T LLANDI(*)=25.0/25.0/25.0    THOUSAND SQ MILES
L LAND.K(I)=LAND.J(I)+(DT*BDRCHG.J(I)*LAND.J(I))
N LAND(I)=LANDI(I)
T LANDI(*)=25.0/25.0/25.0     THOUSAND SQ MILES


     *************  MEDIA SECTOR  ***************
L LMEDIA.K(I)=MEDIA.J(I)
N LMEDIA(I)=IMEDIA(I)
T IMEDIA(*)=4.45/4.45/4.45
L MEDIA.K(I)=MEDIA.J(I)+(DT*TECCHG.J(I)*MEDIA.J(I))
N MEDIA(I)=MEDIAI(I)
T MEDIAI(*)=4.5/4.5/4.5


        ************* CULTURAL SECTOR ***************
L LCLEG.K(I)=CLEG.J(I)
N LCLEG(I)=LCLEGI(I)
T LCLEGI(*)=8.001/8.001/8.001
L CLEG.K(I)=MAX(.00001,(CLEG.J(I)+DT*(CLEGR.JK(I))))
N CLEG(I)=CLEGI(I)
T CLEGI(*)=8/8/8
R CLEGR.KL(I)=CLEG.K(I)*(REMORS.K(I)-MINF.K(I)-IMMCHG.K(I))/3
A MINF.K(I)=TABLE(MEDT,POPAGE.K(I),0,1,.1)
T MEDT=.05/.04/.03/.025/.02/.015/.01/.005/0/0/0
L LIMM.K(I)=IMM.J(I)
N LIMM(I)=LIMMI(I)
T LIMMI(*)=.049/.049/.049
L IMM.K(I)=MAX(.0001,(IMM.J(I)+DT*(IMMR.JK(I)-NSTR.JK(I))))
N IMM(I)=IMMI(I)
```

```
T IMMI(*)=.05/.05/.05
R IMMR.KL(I)=IMM.K(I)*DIMM.K(I)


A DIMM.K(I)=TABLE(DIMMT,ICC.K(I),0,10,1)
T DIMMT=0/.015/.02/.03/.04/.05/.065/.08/.097/.09/.082
R NSTR.KL(I)=DELAY3(IMM.K(I),10)
L LPOP.K(I)=POP.J(I)
N LPOP(I)=LPOPI(I)
T LPOPI(*)=19.8/19.8/19.8
L POP.K(I)=POP.J(I)+(DT*(BRA.JK(I)-DRA.JK(I))*POP.J(I))
N POP(I)=POPI(I)
T POPI(*)=20/20/20
R BRA.KL(I)=(BRF.K(I)*BR(I))-(TABLE(AGF,POPAV.K(I),10,25,5)*BR)
T BR(*)=.06/.06/.06
T AGF=.94/.65/.30/0
A BRF.K(I)=TABLE(BRAF,TECH.K(I),0,10,1)
T BRAF=1.1/1.07/1.055/1.04/1.03/1.01/1.0/.98/.96/.95/.925
R DRA.KL(I)=DRF.K(I)*DR(I)
T DR(*)=.03/.03/.03
A DRF.K(I)=TABLE(DADJF,TECH.K(I),0,10,1)
T DADJF=1.2/1.18/1.16/1.13/1.1/1.05/1.0/.95/.90/.85/.8
A POPAGE.K(I)=POPAV.K(I)/(MAGE(I)*MAGEF.K(I))
L POPAV.K(I)=(((POPAV.J(I)*POP.J(I))-(DRA.JK(I)*DT*POP.J(I)
X *DA.J(I))+(BRA.JK(I)*DT*POP.J(I)))/POP.J(I))+DT
N POPAV(I)=POPAVI(I)
T POPAVI(*)=26.5/26.5/26.5
A DA.K(I)=.8*(LOGN(RAND.K(I)))/((-1)/(MAGE(I)*MAGEF.K(I)))
A RAND.K(I)=MAX(RND.K(I),(-RND.K(I)))
A RND.K(I)=NOISE()*2
A MAGEF.K(I)=TABLE(MAGFT,TECH.K(I),0,10,1)
T MAGFT=.70/.74/.80/.90/1.0/1.15/1.25/1.28/1.29/1.3/1.34
T MAGE(*)=50/50/50
L LREMOR.K(I)=REMOR.J(I)
N LREMOR(I)=IREMOR(I)
T IREMOR(*)=8.01/8.01/8.01
L REMOR.K(I)=REMOR.J(I)+DT*REMCHG.JK(I)
N REMOR(I)=REMORI(I)
T REMORI(*)=8/8/8
R REMCHG.KL(I)=REMOR.K(I)*((IMMCHG.K(I)+LITCHGS.K(I))/(-2))


  ****************** CAPITAL PRODUCTION SECTOR *************
L ARLAND.K(I)=ARLAND.J(I)+DT*(UPFRM.JK(I)-DNFRM.JK(I))
N ARLAND(I)=ARLANI(I)
T ARLANI(*)=.12/.12/.12
R UPFRM.KL(I)=(TABLE(PFRM,POPCHG.K(I),-1,1,.2)+
X TABLE(DFRM,PRI1.K(I),0,10,1))/2
T PFRM=-.008/-.0075/-.006/-.005/-.002/0/.002/.005/.007/.009/.01
T DFRM=0/.01/.015/.02/.025/.032/.040/.052/.067/.08/.1
R DNFRM.KL(I)=TABLE(NFRM,PRI1.K(I),0,10,1)
T NFRM=.01/.009/.008/.007/.006/.005/.004/.003/.002/.001/0
L PRI1.K(I)=PRI1.J(I)+(DT*(.02+(NOISE()/5)))
```

```
N PRI1(I)=IPRI1(I)
T IPRI1(*)=5.0/5/5
L LHMCAP.K(I)=HUMCAP.J(I)
N LHMCAP(I)=(IHMCAP(I)/LPOP(I))*LITER(I)
T IHMCAP(*)=4.82/4.82/4.82
L HUMCAP.K(I)=HUMCAP.J(I)+DT*(UPHC.JK(I)-DNHC.JK(I))
N HUMCAP(I)=(HUMCAI(I)/POP(I))*LITER(I)
R UPHC.KL(I)=(LITCHG.K(I)*HUMCAP.K(I))
L LLITER.K(I)=LITER.J(I)
N LLITER(I)=ILLITER(I)
T ILLITER(*)=.85/.85/.85
L LITER.K(I)=LITER.J(I)+DT*(LITMOD.JK(I))
N LITER(I)=ILITER(I)
T ILITER(*)=.84/.84/.84
R LITMOD.KL(I)=MAX(0,CAPCHG.K(I)-POPCHG.K(I))
R DNHC.KL(I)=((WAR.K(I)+DEPF.K(I)+MAX(0,POPCHG.K(I)))/3)*HUMCAP.K(I)
A WAR.K(I)=TABLE(WART,BDRCHG.K(I),0,1,.1)
T WART=0/.08/.15/.17/.20/.25/.30/.36/.42/.46/.5
A DEPF.K(I)=TABLE(DPT,POPAGE.K(I),0,1,.1)
T DPT=0/.002/.004/.006/.008/.01/.015/.025/.033/.040/.05
L LPROD2.K(I)=PROD2.J(I)
N LPROD2(I)=LPRO2I(I)
T LPRO2I(*)=74.8/74.8/74.8
L PROD2.K(I)=PROD2.J(I)+DT*(PRODR.JK(I))
N PROD2(I)=PROD2I(I)
T PROD2I(*)=75.0/75/75
R PRODR.KL(I)=((RPRCHG.K(I)*GOVTYP(I))+MIN(((PR2CHG.K(I)+FFCHG.K(I)+
X HCPCHG.K(I))),RAWCHG.K(I)))*PROD2.K(I)
T GOVTYP(*)=1/1/1             --- IF = 0 IMPLIES NON - CAPITALIST ---
L LRAW.K(I)=RAW.J(I)
N LRAW(I)=LRAWI(I)
T LRAWI(*)=49.8/49.8/49.8
L RAW.K(I)=RAW.J(I)+(DT*CHRAW.JK(I))
N RAW(I)=RAWI(I)
T RAWI(*)=50.0/50/50
R CHRAW.KL(I)=(TECCHG.K(I)+DRAWF.K(I))*RAW.K(I)
A DRAWF.K(I)=TABLE(DRAW,RPRCHG.K(I),-.1,.1,.02)
T DRAW=-.1/-.08/-.06/-.04/-.02/0/.04/.06/.1/.12/.24
A RPRCHG.K(I)=NOISE()/10
A RAWUSE.K(I)=PROD2.K(I)*RAWPART(I)
T RAWPART(*)=.4/.4/.4
L LFFPRO.K(I)=FFPROD.J(I)
N LFFPRO(I)=IFFPRO(I)
T IFFPRO(*)=75.0/75/75
L FFPROD.K(I)=FFPROD.J(I)+DT*(UPFF.JK(I)-DNFF.JK(I))
N FFPROD(I)=FFPROI(I)
T FFPROI(*)=75.1/75.1/75.1
R UPFF.KL(I)=MIN((TXCHG.K(I)+(2*PR2CHG.K(I))/3),
X PFFCHG.K(I))*FFPROD.K(I)
A PFFCHG.K(I)=MAX(-(NOISE()/10),(NOISE()/10))
R DNFF.KL(I)=TABLE(ALSRC,TECH.K(I),0,10,1)*FFPROD.K(I)
T ALSRC=.02/.017/.01/.006/.0057/.0055/.0057/.0065/.0075/.009/.01
A FFUSE.K(I)=(PROD2.K(I)*INDFF(I))+(PROD1.K(I)*AGFF(I))
T INDFF(*)=.2/.2/.2
```

```
T AGFF(*)=.1/.1/.1
L LPROD1.K(I)=PROD1.J(I)
N LPROD1(I)=IPROD1(I)
T IPROD1(*)=13.0/13/13
A PROD1.K(I)=CROPV.K(I)*(ARLAND.K(I)*LAND.K(I))*PEFF.K(I)*WX.K(I)
A PEFF.K(I)=TABLE(PEFT,TECH.K(I),0,10,1)
T PEFT=.2/.3/.35/.40/.42/.46/.55/.62/.70/.73/.76
A WX.K(I)=NORMRN(1.0,.15)
A CROPV.K(I)=TABLE(CVALT,TECH.K(I),0,10,1)
T CVALT=1/2/3/4/5/6/7/8/9/10/11
A RAWEXP.K(I)=RAW.K(I)-RAWUSE.K(I)
A FFEXP.K(I)=FFPROD.K(I)-FFUSE.K(I)
L LCAPRO.K(I)=CAPPRO.J(I)
N LCAPRO(I)=ICAPRO(I)
T ICAPRO(*)=400.0/400/400
A CAPPRO.K(I)=(PROD1.K(I)+PROD2.K(I)+RAWEXP.K(I)+FFEXP.K(I))
X /POP.K(I)


  ******************  TRADE SECTOR  *********************
L LIMP.K(I)=IMP.J(I)
N LIMP(I)=LIMPI(I)
T LIMPI(*)=39.9/39.9/39.9      MILLION DOLLARS
L IMP.K(I)=IMP.J(I)+DT*(UPIMP.JK(I)-DNIMP.JK(I))
N IMP(I)=IMPI(I)
T IMPI(*)=40.0/40/40           MILLION DOLLARS
R UPIMP.KL(I)=(ICCCHG.K(I)+DIMP.K(I))*IMP.K(I)
A DIMP.K(I)=(MEDCHG.K(I)+TECCHG.K(I))/2
R DNIMP.KL(I)=IMP.K(I)*MAX(GIF.K(I),BALF.K(I))
A IMPF.K(I)=IMP.K(I)/INTCON.K(I)
A GIF.K(I)=TABLE(GIFT,IMPF.K(I),0,1,.1)
T GIFT=0/.05/.08/.2/.5/.65/.75/.80/.82/.90/1.0
A BAL.K(I)=(EXPO.K(I)-IMP.K(I))/INTCON.K(I)
A BALF.K(I)=TABLE(BALT,BAL.K(I),-.4,1,.2)
T BALT=0/0/.05/.18/.35/.70/.92/1.0
L LEXP.K(I)=EXPO.J(I)
N LEXP(I)=LEXPI(I)
T LEXPI(*)=15.0/15/15
L EXPO.K(I)=EXPO.J(I)+DT*(EXPR.JK(I))
N EXPO(I)=EXPOI(I)
T EXPOI(*)=15.05/15.05/15.05
R EXPR.KL(I)=ICCF.K(I)*((TECCHG.K(I)+EXPF.K(I))/2)
A EXPF.K(I)=(MAX(-RAWCHG.K(I),RAWCHG.K(I))+MAX(-FFCHG.K(I),
X FFCHG.K(I)))/2
A ICCF.K(I)=TABLE(ICCT,ICC.K(I),0,10,1)
T ICCT=0/.25/.45/.625/.75/.80/.85/.90/.95/1.0/1.0
A INTCON.K(I)=(PROD1.K(I)+PROD2.K(I))+(IMP.K(I)-EXPO.K(I))
L LTINT.K(I)=TINT.J(I)
N LTINT(I)=LTINTI(I)
T LTINTI(*)=4/4/4
A TINT.K(I)=(INTCON.K(I)+EXPO.K(I)+IMP.K(I))/POP.K(I)


  ******************* TRANSPORTATION SECTOR  ******************
```

```
L LDOMTX.K(I)=DOMTX.J(I)
N LDOMTX(I)=IDOMTX(I)
T IDOMTX(*)=5/5/5
L DOMTX.K(I)=DOMTX.J(I)+DT*(UPDTX.JK(I)-DNDTX.JK(I))
N DOMTX(I)=DOMTXI(I)
T DOMTXI(*)=6/6/6
R UPDTX.KL(I)=DOMTX.K(I)*INCOCH.K(I)
R DNDTX.KL(I)=(DEP.K(I))*DOMTX.K(I)
A DEP.K(I)=TABLE(DEPT,LDOMTX.K(I),0,10,1)/100
T DEPT=5/6/3/2.5/2.4/2.5/2.6/2.7/2.8/2.9/3.0
L LINTX.K(I)=INTLTX.J(I)
N LINTX(I)=LINTXI(I)
T LINTXI(*)=4.5/4.5/4.5
L INTLTX.K(I)=INTLTX.J(I)+DT*(UPITX.JK(I)-DNITX.JK(I))
N INTLTX(I)=INLTXI(I)
T INLTXI(*)=4.6/4.6/4.6
R UPITX.KL(I)=(IMPCHG.K(I)+EXPCHG.K(I))/2*INTLTX.K(I)
R DNITX.KL(I)=(TABLE(DEPT,INTLTX.K(I),0,10,1)/100)*INTLTX.K(I)
L LTX.K(I)=TX.J(I)
N LTX(I)=LTXI(I)
T LTXI(*)=4.5/4.5/4.5
A TX.K(I)=(DOMTX.K(I)+INTLTX.K(I))/2


   ********************** GOVERNMENT SECTOR **************************
L LDEFEN.K(I)=DEFENS.J(I)
N LDEFEN(I)=IDEFEN(I)
T IDEFEN(*)=5/5/5
L LCONT.K(I)=CONTRO.J(I)
N LCONT(I)=LCONTI(I)
T LCONTI(*)=7.0/7/7
A CONTRO.K(I)=(GOVTYP*TCONT.K(I))+((1-GOVTYP)*DCONT.K(I))
A TCONT.K(I)=TABLE(TCT,TIME.K+NATTIM(I),0,200,20)
T TCT=4.5/6.5/7.5/8.4/9.2/9.6/9.65/9.6/9.4/9.3/9.25
A DCONT.K(I)=TABLE(DCT,TIME.K+NATTIM(I),0,300,30)
T DCT=0/.5/1.0/1.5/2.0/2.8/3.4/4.6/6.0/7.0/10
T NATTIM(*)=45/45/45
L LGI.K(I)=GI.J(I)
N LGI(I)=LGII(I)
T LGII(*)=5/5/5
L GI.K(I)=GI.J(I)+DT*(AVGGI.JK(I))
N GI(I)=GII(I)
T GII(*)=5.01/5.01/5.01
R AVGGI.KL(I)=((CONTCH.K(I)+DEFCHG.K(I))/2)*GI.K(I)


  **************** DEFENSE SECTOR  *****************
L LTHR.K(I)=THREAT.J(I)
N LTHR(I)=LTHRI(I)
T LTHRI(*)=5/5/5
A THREAT.K(I)=DEFEN1.K(I)+(BDRCHG.K(I)*LAND)
L LARMS.K(I)=ARMS.J(I)
N LARMS(I)=LARMSI(I)
T LARMSI(*)=40/40/40
```

```
L ARMS.K(I)=ARMS.J(I)+DT*(UPARMS.JK(I)-DNARMS.JK(I))*ARMS.J(I)
N ARMS(I)=ARMSI(I)
T ARMSI(*)=40.1/40.1/40.1
R UPARMS.KL(I)=MIN(THCHGS.K(I),CAPCHG.K(I))
X +UPQUAL.K(I)+UPQUAN.K(I)          EXPERIMENTAL FACTORS
A UPQUAL.K(I)=PULSE(QUALINC(I),TIMEUP(I),999)
T QUALINC(*)=0/0/0


T TIMEUP(*)=999/999/999
A UPQUAN.K(I)=PULSE(QUANINC(I),TINCR(I),999)
T QUANINC(*)=0/0/0
T TINCR(*)=999/999/999
R DNARMS.KL(I)=(DEPR+WAR.K(I))
C DEPR=.02
L LTROOP.K(I)=TROOP.J(I)
N LTROOP(I)=ILTRP(I)
T ILTRP(*)=6/7/8
L TROOP.K(I)=TROOP.J(I)+DT*(TRPMOD.JK(I))
N TROOP(I)=ITRP(I)
T ITRP(*)=6/7/8
R TRPMOD.KL(I)=INCNUM.K(I)+UPTNG.K(I)     EXPERIMENTAL FACTOR
A INCNUM.K(I)=PULSE(DRAFT(I),DTIME(I),999)
T DRAFT(*)=0/0/0
T DTIME(*)=999/999/999
A UPTNG.K(I)=PULSE(TRNG(I),TRTIM(I),999)
T TRNG(*)=0/0/0
T TRTIM(*)=999/999/999
L DEFENS.K(I)=DEFENS.J(I)+DT*(UPDEF.JK(I)-DNDEF.JK(I))
N DEFENS(I)=DEFENI(I)
T DEFENI(*)=5.2/5.2/5.2
R UPDEF.KL(I)=((THCHGS.K(I)+MIN(TRPCHG.K(I),ARMCHG.K(I))
X )/2)*DEFENS.K(I)
R DNDEF.KL(I)=DEFENS.K(I)*WR.K(I)
A WR.K(I)=TABLE(WRT,BDRCHG.K(I),0,1,.1)
T WRT=0/.2/.4/.6/.7/.75/.8/.83/.85/.87/.92


  **************** STABILITY INDEX  ****************

A STABL1.K(I)=TECH.K(I)-((1/CLEG.K)*10)
L LSTAB2.K(I)=STABL2.J(I)
N LSTAB2(I)=LSTA2I(I)
T LSTA2I(*)=5/5/5
L STABL2.K(I)=STABL2.J(I)+DT*(UPSTAB.JK(I)-DNSTAB(I))
N STABL2(I)=ISTAB2(I)
T ISTAB2(*)=5/5/5
A DIFFER1.K(I)=TECCHG.K(I)-CLEGCH.K(I)
R UPSTAB.KL(I)=STABL2.K(I)*CLIP(0,DIFFER1.K(I),DIFFER1.K(I),0)
R DNSTAB.KL(I)=STABL2.K(I)*CLIP(DIFFER1.K(I),0,TECCHG.K(I),0)
```

```
              *************** CHANGE VARIABLES SET ****************
L   STABCH.K(I)=PCTCHG(STABL2.J(I),LSTAB2.J(I))
N   STABCH(I)=STABCI(I)
T   STABCI(*)=.001/.001/.001
L   ICCCHG.K(I)=PCTCHG(ICC.J(I),LICC.J(I))
N   ICCCHG(I)=ICCCHI(I)
T   ICCCHI(*)=.001/.001/.001
L   TECCHG.K(I)=PCTCHG(TECH.J(I),LTECH.J(I))
N   TECCHG(I)=TECCHI(I)
T   TECCHI(*)=.001/.001/.001
A   TECHS.K(I)=SMOOTH(TECH.K(I),3)
L   CLEGCH.K(I)=PCTCHG(CLEG.J(I),LCLEG.J(I))
N   CLEGCH(I)=CLEGCI(I)
T   CLEGCI(*)=.001/.001/.001
L   POPCHG.K(I)=PCTCHG(POP.J(I),LPOP.J(I))
N   POPCHG(I)=POPCHI(I)
T   POPCHI(*)=.001/.001/.001
L   IMMCHG.K(I)=PCTCHG(IMM.J(I),LIMM.J(I))
N   IMMCHG(I)=IMMCHI(I)
T   IMMCHI(*)=.001/.001/.001
A   IMMS.K(I)=SMOOTH(IMM.K(I),3)
L   REMOCH.K(I)=PCTCHG(REMOR.J(I),LREMOR.J(I))
N   REMOCH(I)=REMOCI(I)
T   REMOCI(*)=.0001/.0001/.0001
A   REMORS.K(I)=SMOOTH(REMOCH.K(I),5)
L   MEDCHG.K(I)=PCTCHG(MEDIA.J(I),LMEDIA.J(I))
N   MEDCHG(I)=MEDCHI(I)
T   MEDCHI(*)=.001/.001/.001
L   HCPCHG.K(I)=PCTCHG(HUMCAP.J(I),LHMCAP.J(I))
N   HCPCHG(I)=HCPCHI(I)
T   HCPCHI(*)=.001/.001/.001
A   HCPCH3.K(I)=DLINF3(HCPCHG.K(I),2)
L   LITCHG.K(I)=PCTCHG(LITER.J(I),LLITER.J(I))
N   LITCHG(I)=LITCHI(I)
T   LITCHI(*)=.001/.001/.001
A   LITCHS.K(I)=SMOOTH(LITCHG.K(I),5)
L   CAPCHG.K(I)=PCTCHG(CAPPRO.J(I),LCAPRO.J(I))
N   CAPCHG(I)=CAPCHI(I)
T   CAPCHI(*)=.001/.001/.001
L   RAWCHG.K(I)=PCTCHG(RAW.J(I),LRAW.J(I))
N   RAWCHG(I)=RAWCHI(I)
T   RAWCHI(*)=.001/.001/.001
L   FFCHG.K(I)=PCTCHG(FFPROD.J(I),LFFPRO.J(I))
N   FFCHG(I)=FFCHI(I)
T   FFCHI(*)=.001/.001/.001
L   PR2CHG.K(I)=PCTCHG(PROD2.J(I),LPROD2.J(I))
N   PR2CHG(I)=PR2CHI(I)
T   PR2CHI(*)=.001/.001/.001
L   TINTCH.K(I)=PCTCHG(TINT.J(I),LTINT.J(I))
N   TINTCH(I)=TINTCI(I)
T   TINTCI(*)=.001/.001/.001
L   IMPCHG.K(I)=PCTCHG(IMP.J(I),IMPS.J(I))
N   IMPCHG(I)=IMPCHI(I)
T   IMPCHI(*)=.001/.001/.001
```

```
L  INCOCH.K(I)=PCTCHG(INTCON.J(I),INCONS.J(I))
A  INCONS.K(I)=SMOOTH(INTCON.K(I),3)
N  INCOCH(I)=INCOCI(I)
T  INCOCI(*)=.001/.001/.001
L  EXPCHG.K(I)=PCTCHG(EXPO.J(I),EXPS.J(I))
N  EXPCHG(I)=EXPCHI(I)
T  EXPCHI(*)=.001/.001/.001
A  IMPS.K(I)=SMOOTH(IMP.K(I),3)
A  EXPS.K(I)=SMOOTH(EXPO.K(I),3)
L  TXCHG.K(I)=PCTCHG(TX.J(I),LTX.J(I))
N  TXCHG(I)=TXCHI(I)
T  TXCHI(*)=.001/.001/.001
L  GICHG.K(I)=PCTCHG(GI.J(I),LGI.J(I))
N  GICHG(I)=GICHI(I)
T  GICHI(*)=.001/.001/.001
A  GICHGS.K(I)=SMOOTH(GICHG.K(I),3)
L  CONTCH.K(I)=PCTCHG(CONTRO.J(I),LCONT.J(I))
N  CONTCH(I)=CONTCI(I)
T  CONTCI(*)=.00001/.00001/.00001
L  DEFCHG.K(I)=PCTCHG(DEFENS.J(I),LDEFEN.J(I))
N  DEFCHG(I)=DEFCHI(I)
T  DEFCHI(*)=.001/.001/.001
L  ARMCHG.K(I)=PCTCHG(ARMS.J(I),LARMS.J(I))
N  ARMCHG(I)=ARMCHI(I)
T  ARMCHI(*)=.001/.001/.001
L  TRPCHG.K(I)=PCTCHG(TROOP.J(I),LTROOP.J(I))
N  TRPCHG(I)=TRPCHI(I)
T  TRPCHI(*)=0/0/0
L  THRCHG.K(I)=PCTCHG(THREAT.J(I),LTHR.J(I))
N  THRCHG(I)=THRCHI(I)
T  THRCHI(*)=.001/.001/.001
A  THCHGS.K(I)=SMOOTH(THRCHG.K(I),3)


  ************ OUTPUT CONTROLS ***********************
SPEC  DT=.25,LENGTH=20,PLTPER=1,PRTPER=1
PLOT STABL2
PLOT STABL1
PLOT POPAV
PLOT CLEG
PLOT TECH
PLOT ICC
PLOT DEFENS
RUN
```

APPENDIX B

Variable Initial Values

Bolivia, Chile, Peru

Variable	Bolivia	Chile	Peru
LICCI	3.800	4.900	4.500
ICCI	3.900	5.000	4.550
LTECHI	3.900	5.200	4.500
TECHI	4.000	5.210	4.500
LLANDI	424.160	292.260	496.220
LANDI	424.160	292.260	496.220
IMEDIA	4.000	5.600	5.000
MEDIAI	4.100	5.650	5.100
LCLEGI	7.100	4.300	5.500
CLEGI	7.000	4.300	4.500
LIMMI	10.000A	20.000A	4.900A
IMMI	11.000A	21.000A	50.000A
LPOPI	5.141	10.746	16.918
POPI	5.286	10.932	17.388
BR	43.500A	25.400A	39.000A
DR	16.000A	8.000A	12.000A
MAGE	50.720	65.650	56.530
POPAVI	17.940	23.250	18.460
IREMOR	9.200	6.500	7.800
REMORI	9.100	6.400	7.700
ARLANI	10.000A	20.000A	20.000A
IPRI1	5.000	5.000	5.000
IHMCAP	102.100	322.970	445.320
HUMCAI	102.200	323.000	445.400
ILLITE	.630	.890	.450
ILITER	.840	.840	.840
LPRO2I	282.490	1.816T	2.449T
PROD2I	300.280	1.750T	2.584T
GOVTYP	0.000	1.000	1.000
LRAWI	260.760	549.930	742.200
RAWI	264.970	573.020	754.070
RAWPAR	.150	.400	.400
IFFPRO	75.000	148.400	692.720
FFPROI	75.100	158.800	697.560
INDFF	.200	.200	.200

Variable	Bolivia	Chile	Peru
AGFF	100.000A	100.000A	100.000A
IPRODI	391.200	803.060	2.190T
ICAPRO	2.173T	8.729T	12.370T
LIMPI	670.800	3.542T	2.120
IMPI	764.000	3.574T	2.185
LEXPI	681.400	3.513T	3.724T
EXPOI	670.000	3.763T	3.588T
LTINTI	4.900	6.500	6.500
IDOMTX	5.000	7.000	5.000
DOMTXI	5.000	7.000	5.000
LINTXI	4.800	4.000	6.000
INLTXI	4.800	4.000	6.000
LTXI	4.900	5.500	5.500
IDEFEN	3.000	5.000	5.000
LCONTI	9.000	6.000	6.000
NATTIM	20.000	18.000	10.000
LGII	9.000	8.000	8.000
GII	9.000	8.000	8.000
LTHRI	10.000	8.000	8.000
LARMSI	4.000	6.000	4.800
ARMSI	4.000	6.000	4.800
QUALIN	.250	.170	.200
TIMEUP	5.000	3.000	7.000
QUANIN	.300	.200	.180
TINCR	5.000	3.000	7.000
ILTRP	22.400	84.900	94.900
ITRP	22.500	84.900	94.900
DRAFT	0.000	0.000	0.000
DTIME	999.000	999.000	999.000
TRNG	100.000A	.200	.240
TRTIM	5.000	3.000	7.000
DEFENI	3.000	5.000	5.000
LSTA2I	0.000	0.000	0.000
ISTAB2	5.000	5.000	5.000
STABCI	1.000A	1.000A	1.000A
ICCCHI	1.000A	1.000A	1.000A
TECCHI	1.000A	5.000A	1.000A
CLEGCI	1.000A	1.000A	1.000A
POPCHI	27.500A	17.000A	27.000A
IMMCHI	1.000A	1.000A	1.000A
REMOCI	100.000E	100.000E	100.000E
MEDCHI	1.000A	1.000A	1.000A
HCPCHI	1.000A	1.000A	1.000A
LITCHI	10.000A	20.000A	20.000A
CAPCHI	10.000A	40.000A	40.000A
RAWCHI	20.000A	70.000A	16.000A
FFCHI	-20.000A	70.000A	56.000A
PR2CHI	63.000A	36.000A	43.000A
TINTCI	1.000A	9.000A	1.000A
IMPCHI	.122	-9.000A	31.000A
INCOCI	1.000A	1.000A	1.000A
EXPCHI	-17.000A	65.000A	-38.000A

Variable	Bolivia	Chile	Peru
TXCHI	1.000A	1.000A	1.000A
GICHI	1.000A	1.000A	1.000A
CONTCI	10.000E	10.000E	10.000E
DEFCHI	1.000A	1.000A	1.000A
ARMCHI	1.000A	32.000A	37.000A
TRPCHI	0.000	0.000	0.000

APPENDIX C

INITIAL YEAR IN INVENTORY

Selected Fighters

Aircraft Designation	Manufacturer/Country	Year in Inventory
Meteor	Armsrong A/C LTD/UK	1947
CF-105	AVRO A/C LTD/Canada	1958
CF-100		1950
Hawk	BAC(Hawker-Siddley)/UK	1979
A-37 Dragonfly	Cessna/USA	1968
T-37		1955
OE-1 Bird dog		1944
F7U Cutlass	Chance Vought/USA	1952
F-8 Crusader		1957
F-102 Delta Dagger	Convair (General Dyanamics)/USA	1954
F-106 Delta Dart		1957
F-111		1968
F-16		1978
P-40 Warhawk series	Curtis/USA	1939
SB2C Helldiver		1941
Alpha Jet	Dassault-Brueget/France	1979
Ouragan	Dassault-Murael/France	1949
Mystere		1952
Super Mystere		1959
Etendard		1958
Super Etendard		1974
Mirage I		1955
Mirage III		1960
Mirage V		1978
F-2		1979
G-8		1980
Mosquito	DeHavilland/UK	1940
Vampire		1947
Venom		1947
Sea Venom		1948

Aircraft Designation	Manufacturer/Country	Year in Inventory
Sea Vixen	DeHavilland/UK	1949
A-26/B-26 Invader	Douglass Aircraft/USA	1945
Skyraider		1946
A4D Skyray		1947
Xavante	Embraer/Brazil	1975
Lightning	English Electric/UK	1959
Canberra		1953
A-10 Thunderbolt II	Fairchild/USA	1975
IA.58 Pucara	FMA/Argentina	1968
CM.170 Magister	FOUGA/France	1953
Meteor	Gloster/UK	1946
Javelin		1951
Wildcat/Bearcat	Grumman/USA	1941
A-6 Intruder		1964
F-14 Tomcat		1974
E-2 Hawkeye		1973
Victor	Hadley Page/UK	1953
Harrier	Hawker/UK	1968
Hunter		1954
Tempest		1947
Fury		1948
HAL HTT-16	Hindustan Aero/India	1966
HF-24		1978
KFIR	Israeli Aircraft/Israel	1972
A-7E Corsair II	LTV/USA	1967
C-130	Lockheed/USA	1960
P-38 Lightning		1939
P-80/T-33		1947
F-104		1954
FH-1 Phantom I	McDonnell/McDonnell Douglass/USA	1947
F2H Banshee		1948
F3H Demon		1952
F-101 Voodoo		1956
F-4 Phantom II		1959

F-15 Eagle		1973

Aircraft Designation	Manufacturer/Country	Year in Inventory
F-18 Hornet	McDonnell Douglass	1980
A-4 Skyhawk		1966
MiG 9	Mikoyan Gurevich/USSR	1946
MiG 15		1947
MiG 17		1950
MiG 19		1953
MiG 21		1959
MiG 23		1967
MiG 25		1968
MiG 27		1972
P-51 Mustang	North American/US	1941
F-5A Freedom Fighter	Northrup/USA	1959
T-38		1959
F-5E Tiger II		1972
F-20		1983
Tornado	Panavia/Inernational	1978
F-105	Republic/USA	1955
P-47 Thunderbolt		1941
F-84		1950
F-86		1951
F-87		1952
Vulcan	AVRO/UK	1956
SAAB 35 Draaken	SAAB/Sweden	1955
SAAB 37 Viggen		1967
SU-7	Sukhoi/USSR	1947
SU-9		1951
SU-11		1965
SU-15		1967
SU-20		1975

Source: ---, The Complete Illustrated Encyclopedia of the World's Aircraft, edited by David Mondey. New York: A&W Publishers, 1978.

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VITA

Captain James K. McFetridge was born on 6 April 1955 in Framingham, Massachusetts. He graduated from high school in Mendon, Masachusetts in 1973, and attended the United States Air Force Academy from which he received the degree of Bachelor of Science in June 1977. Upon graduation he attended basic Weapons Controller (17XX) School at Tyndall AFB, Florida, and was subsequently assigned to the 615 ACWS, Neubrucke AI, West Germany. While stationed in Germany he served as a Fourth Alllied Tactical Air Force Master Identification Officer and Chief Intercept Controller. In June 1980, he was assigned to the 848 ACWS, Wallace AS, Phillipines where he served a remote tour as Combat Crew Senior Director, Instructor Controller, Standards and Evaluation Controller. Upon returning stateside in July 1981, he was stationed with 21st Air Defense Squadron, Syracuse, New York as a Weapons Allocator until entering the School of Engineering , Air Force Institute of Technology, in June 1982.

Permanent Address: 202 Widefield Blvd.
Colorado Springs,
Colorado 80811

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