A SYSTEM DYNAMICS APPROACH TO AIRCRAFT SURVIVABILITY-ATTRITION ANALYSIS

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(ABSTRACT)

Mathematical representation of military operations have long fascinated analysts and practitioners. In 1916 English mathematician Frederick W. Lanchester represented the attrition rates of two opposing forces in the form of two differential equations, functions of the size and combat effectiveness of each side. Lanchester's model was an intellectual breakthrough in the analysis of warfare insofar as it provided a deep insight into the possibilities inherent in simple models of combat. Interestingly enough, Lanchester's representation of the problem as a dynamic system is precisely the approach used in the system dynamics methodology employed here. In system dynamics, differential equations are converted to difference equations and there is virtually no limit to the number that can be employed to represent the known and complex details of a system. The attrition model developed here describes the interaction between twelve types of U.S. combat aircraft and twelve types of U.S.S.R. combat aircraft and indicates the winner or the loser at the end of an engagement or a battle during wartime. To guide the peacetime preparations, a generic baseline and modified aircraft are utilized and compared using an adaptation of the attrition model, so as to decide if the proposed modification of U.S. aircraft should be undertaken or not. Two measures of effectiveness are presented to evaluate the overall performance of the modified aircraft compared to the baseline aircraft -- decreased program life cycle cost and increased payload delivered to target per aircraft lost. Scenario analyses are performed to assess the combat aircraft effectiveness under changes to endogenous and exogenous parameters.

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INTRODUCTION

1.1 ENGINEERING -- MILITARY, CIVIL AND SOCIAL

Technology and public policy are closely related phenomena. Since the early civilizations, the nations have looked to technology to serve their needs, both social and military. The great pyramids were the result of governmental policy decisions to satisfy the pharaoh's desires. Classical civilizations emphasized public works, military technology, transportation and communication. The Chinese, Greeks and Romans built aqueducts to furnish good water for drinking and bathing. In Renaissance Italy, Leonardo de Vinci was one of many great men who worked as a military and civil engineer for the rulers of Milan and Romagna [1]

The many countries of the underdeveloped and developing world are in different stages of development. They include quite primitive, agricultural economies with no industrialization and with very little progress in the utilization of natural resources. The utilization of the two basic resources -- land and the men who work it -- has largely remained unchanged for centuries. Other countries have made significant progress towards developing some resources for export or to establishing fledging production capabilities in such basic industries as cement, fertilizers, chemical processing and fabrication; but have neglected agriculture to the point that they not only cannot feed their people, they cannot even see to it that their people are fed because of distribution problems. Engineers are desperately needed. Engineering can and must make contributions to the efficient use of existing resources and the development of new ones, as well as in the uplifting of developing countries through the elimination of starvation, deadly diseases, and natural disasters. These problems are so complex that it is impossible for one person to understand all the manifestations of any one of them. Besides, it apparent that the individual problems -- complex as they are -- are so interrelated that they cannot be attacked separately and independently. The solution of one problem is often the cause of another. A broader view, more imagination, a degree of social concern, and a higher sense of purpose than have prevailed are required.

The notion of doing social good, as expressed in the last sentence above, reflects the engineering profession's new quest for a social role. Many of the protestations that one hears regarding the increasing dedication of engineers to utilizing technology for social and individual benefit are unconvincing. The public image of the engineer as the man peering through a transit, slouched over a drawing board, or wiring resistors on an electronic breadboard, though technically wrong is intellectually correct. The engineering student being trained today probably cannot even live-up to this public image because he won't learn enough about surveying to find the North Star, enough about drafting to read a set of plans let alone produce them, or enough about electronics to detect a faulty television tube. Engineering education has conceded these problems, and perhaps rightly so, to technicians.

This would be regarded as logical if it freed engineers to do what has to be done in today's world and not merely to indulge himself by doing what he does best. Thus, it has freed structural engineers to devote whole courses to the detailed analysis of "plates and shells," but left them incapable of designing a complete structure -- which is left to the architect. It has freed the transportation engineer to learn more about coordinating traffic signals -- but the choice of new transportation routes are left to planners. An industrial engineer learns operations research but doesn't know how to go about measuring most of the parameters in the models. It has freed soils engineers to study the exponentially increasing number of empirical laboratory and field tests designed to solve problems of ever-decreasing priority. A typical engineering text is prefaced by the irreproachable sentiments that states the subject will perform a useful function for the benefit of mankind. While this is usually true, indirectly or obscurely, it is also true that engineering has abrogated its responsibility in responding to society's major problems to the economics, planning and management professions [2].

For years, decades -- perhaps centuries -- some engineers have interpreted their mandate as applying resources to the satisfaction of mankind's needs. This, of course, is what the development process is all about. We believe that engineering, in general and particularly in the developing countries, has not achieved what is implied in its definition -- because of overemphasis on specialization within sub-disciplines, overemphasis on components within systems, and overemphasis on principles rather than on application and implimentation. While there can be no doubt that the specialist, whose understanding of his own branch of engineering goes to the very limit of contemporary knowledge, has a place of the utmost importance in the design of engineering artifacts; the social need rarely expresses itself in a form to which specialists' knowledge is directly and simply applicable. This is particularly so when the artifact is a system -- a whole that is more than the sum of the parts, a synergistic entity that subsumes the contributions of all the specialists involved. This Dissertation endorses the position taken by such engineers as Goode [3], Gosling [4], Hall [5], Wilson [6], Whinnery [7], Dixon [8], Krick [9], Woodson [10], Beakley [11], Forrester [12], Wymore [13] and Drew [2] -- a plea for a new kind of engineer, a systems engineer.

1.2 TRANSPORTATION TECHNOLOGY AND WARFARE

Civil Engineering, once all of engineering except for Military Engineering, has been reduced to a coalition of left-overs from Mechanical, Electrical, Chemical, Mining, Petroleum, Aeronautical, Industrial, etc. This, its obvious weakness, may be its greatest strength as a discipline. Fragmented as it is, it still presents the greatest breadth of understanding in coping with modern day problems.

Civil Engineering is now conceived as consisting of the following subdisciplines: structures, soils, hydraulics, materials, water resources, geodetics, sanitary engineering, environmental science, construction, urban engineering, city management, and transportation. This Dissertation deals with transportation.

Efficient transportation has long been recognized as essential to the well-being of mankind. Early man found that by using sleds and primitive carts he could carry food and fuel with less effort. His children learned that when they hitched animals to the carts it was possible to ride on the load instead of having to pull it. Animal power made it possible to increase the size of carts and to carry still greater loads. These primitive inventions were perhaps the beginnings of the revolution in transportation -- a revolution which continues to this day and whose end is not in sight. Indeed the technological advances since World War II indicate that we are on the threshold of exciting innovations in transportation. By the end of the century we will see more changes which it will make it possible to travel farther, faster, and more efficiently [14].

The dynamic nature of the growth of science and technology in our century, and their impact on society and on the individual, are nowhere better evident than in the fulfillment of man's ancient dream to fly. Initiated in this century, aviation has grown, slowly at first and more rapidly later, until it has removed the barriers of space and time between the peoples of the earth. Air transportation was one of the earliest of the technologies of this century to require the intimate partnership of scientists, engineers, and industrialists of many skills to accomplish rapid progress at the frontiers of knowledge. No single human mind could comprehend all the knowledge embodied in the design, construction, and operation of a jet transport. Today we have many such difficult and complex technological developments, including nuclear energy, high-speed electronic computers and space vehicles. But aviation was one of the earliest to move from the individual creation of the pioneer inventor to the product of a new social invention, the design team of specialists working in harmony to produce a result far beyond the capability of any individual [15].

As man stands poised for the conquest of space, we are reminded of the role of water transportation in the conquest of our planet. First, the waters along the coasts became ancient man's highways. Horizons beckoned. Soon the seas were pathways to islands and hitherto unattainable shores. As man's use of the sea developed down through the ages, he learned more about ships. Three distinct phases of this development were defined by man's successive demands for transport for inland seas and coastal waters, transport plus distance-capability, and transport plus distance-capability plus speed. The fourth demand was for underwater transport.

Man's desire to explore the underwater world is probably as old as his wish to fly. To realize this ambition, early visionaries dived beneath the surfaces of rivers, lakes, and harbors in a wild variety of man-powered and often suicidal contraptions. Like the airplane, the submarines reached its present stage of development through the dreams and efforts of inspired, brave and, sometimes, even crackpot men [16].

It is no wonder that transportation has been referred to as "the arteries and veins" of the body of our civilization. Few if any elements of society match it in its pervasive influence on our existence. Our economic growth and well-being, our social structure, our pattern of living, our relations with the outside world, the variety, complexity, geographical spread, and specialization of production output -- all hinge on transportation.

Upon transportation also depends a nation's capability for defense and the ability to wage war, Churchill stated it as follows:

> "In a tale of war, the reader's mind is filled with the fighting. The battle -- with its vivid scenes, its moving incidents, its plain and tremendous results -- excites imagination and commands attention. The fierce glory that plays on red, triumphant bayonets dazzle the observer; nor does he care to look behind to where, along a thousand miles of rail, road, and river, the convoys are crawling to the front in uninterrupted succession, Victory is the beautiful, bright colored flower. Transport is the stem without which it could never have blossomed" [14].

To a great extent the history of technology is the history of transportation and the history of warfare. The role of the engineer in the development of military weapons and equipment has been extensive since the times of the Greeks and Romans. The first extensive military engineering developments date from the time of the ascendance of Alexandria around 300 BC. Alexander the Great encouraged the development of mechanized warfare. Modern warfare developed with the industrial revolution. Wide-ranging improvements in weapons, transport and communications, coincided with the development of mass-production techniques. Thus it has been transportation vehicles -- motor vehicles, tanks, aircraft, and submarines that have revolutionized the organization and methods of warfare.

1.3 ASPECTS OF AIR POWER

The history of military technology has been marked by new inventions hailed by prophets as the forerunner of a revolution in the military art. The cross-bow, the rifle, automatic weapons, the tank and the submarine -- all these and others in their day have forcibly imposed important modifications in technique, and have wrought great changes on the conduct of war. But all of them have had their counterpart in earlier ages and therefore, at least in this context, none can really be said to have changed the nature of war.

Slessor [17] identifies three factors which alone, perhaps, deserve the title of revolutionary: gunpowder, the machine gun, and the conquest of the air -- the third, the most revolutionary of all. For where other weapons have enhanced the capacity of men to kill each other in battle, and increased the depth of the battle-field, the "air" may stop men or their supplies arriving at the battle-field at all.

The basis for air power lies in the access to the sky just as the basis for sea power development was the historically demonstrated requirement of all great nations for access to the sea. It was seen that nations lose their chance for survival as great nations if they lose the power to use sea and air space and to prevent others from using this space against them.

Concepts of warfare expand, eventually, as human activity expands. Areas of warfare often expand ahead of concepts as new capabilities of navigation reach out, first across the seas, then into the air, and ultimately into space. The first great expansion left the narrow limits of traversable land to cross the global oceans. From there, curiously, progress extended up and down at the same time and established a peculiar commonality between aircraft and submarines. Each operates in only one medium, yet in its medium each is supreme. Roscoe [18] notes that in World War II Japan was drowned in its "third dimension," losing most of its vital shipping to aircraft and submarines. But while the third dimension is limited on the way down, it has no limit on the way up. This means that whether we like it or not, the zone of war above the surface can no longer be limited.

Major events in the eight decades since the Wright Brothers' first powered flight start with American involvement in World War I. The most significant legacies of this involvement include the following: (1) aviation caught the fancy of the American public; (2) the 200,000 pilots and technicians the U.S. trained for the conflict became the nucleus for postwar civil and military developments; (3) the evolution of the theories of air power, its organization, tactics, and strategy; and (4) the initiation of the first aviation research laboratories and airframe and engine industries. Between the World Wars, noteworthy developments include Lindbergh's non-stop flight from New York to Paris and General Billy Mitchell's court-martial for his overzealous promotion of aircraft carriers as the weapon system of the future [19].

On August, 1939, just four days before the outbreak of World War II, a slender, unconventional research airplane designated the Heinkel 178 took off from Marienhe Airfield in Germany to make the first successful flight of a turbojet aircraft. By 1944, the Germans, desparate for a means of halting the Allied bombing offensive, had developed a dazzling operational jet in the Messerschmitt 262. Before the war ended, Great Britain, the U.S., and Japan each had developed and flew jet fighters [20]. Although the first fighting jets had little effect on the outcome of that conflict, their appearance set the stage for future generations of jet warplanes -- aircraft that would play a vital role in determining the fate of contending nations.

In the U.S. police action in Korea, air power was employed very effectively in a tactical role in support of ground operations. In Vietnam, there was a gross failure by the U.S. to employ its available strategies air power properly. Failure to win these two wars decisively by unleashing air power was more a political decision than a military constraint.

A constructive look at U.S. air power in the future must be based on a sound analysis of the history of air power employment in past wars, plus an appreciation of the probable economic conditions and political leadership which will exist. Obviously, there must be an accurate and continuing study of what nuclear weapons and advancing technology will do to aerospace warfare. The radical change in the time factor, as a result of nuclear weapons, must be realized. Never again will the U.S. have years or months in which to build its army, navy, and airforce, or to convert its industrial capacity to its full weapons-making potential. The U.S. will win or lose with military power available when the war starts, and the kind of military power required to prevent war is exactly the kind required to win any war it enters.

1.4 THE AIRCRAFT SURVIVABILITY CONCEPT

One of the elements of design which significantly contribute to the effectiveness and availability of military aircraft weapons systems is the extent to which combat survivability are embodied in the earliest acquisition phases and subsequently regarded throughout the development and operational phases of their respective system life cycles. The steadily mounting costs of these systems and the essentially of realizing high force readiness and operational effectiveness require utmost attention to be given to combat survivability.

As the result of high damage and aircraft loss rates in Southeast Asia, the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) was established in the

1970's [21]. The JTCG/AS is chartered to coordinate the non-nuclear survivability Research and Development effort within the three Services of the Department of Defense.

"Survivability" -- the capability of a weapon system to continue to carry out its designated missions in a combat threat environment -- is a function of both "susceptibility" (the combination of factors that determine the probability of hit by a given threat) and "vulnerability" (the extent of degradation of the system after having been subjected to combat threat) [22]. From these definitions, the broad scope of the concept of survivability is evident leading the JTCG/AS to update its response to its charter requirements to include the promotion of survivability as a design discipline and the coordination of research and development results among the Services and industry, as well as within the Services.

The Joint Technical Coordinating Group on Aircraft Survivability was formed as a tri-service organization to bring together expertise in each of the Services to plan and execute a program to reduce the vulnerability of current fleet aircraft, and to develop design criteria and improved technology to increase the survivability of future aircraft. Specifically, the purpose of the JTCG/AS is to: (1) provide a mechanism to coordinate the individual Service programs to increase the combat survivability of aeronautical systems in a nonnuclear threat environment; (2) provide for the implementation of efforts to complement the Services' survivability and vulnerability programs; (3) assume a liaison on role with the Services to ensure that all survivability research and development data and systems criteria are made available to the developers of new aircraft.

The JTCG/AS must provide technical data and inputs for survivability improvements to cognizant aircraft program managers in the Navy and Army, as well as system program directors and system managers in the Air Force. Continuing JTCG/AS assistance to those offices is provided for both the design and production of new aircraft, or retrofitting of existing aircraft. Furthermore, to support the overall JTCG/AS objectives, the responsibilities of the JTCG/AS include the following: (1) coordinate research and advanced development efforts contributing to the reduction of vulnerability for aeronautical systems in a nonnuclear threat environment; (2) plan and propose joint critical technology programs contributing to the improvement of survivability in aeronautical systems; and (3) conduct studies to assess enhanced survivability design features in a combat environment.

1.5 THE COOPERATIVE RESEARCH EFFORT

The Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) has undertaken the development of a tool for efficiently allocating its resources among candidate research and development projects aimed at improving the combat survivability of aeronautical systems. The objective of the model is to aid the JTCG/AS Central Office staff in their interactions with the JTCG/AS Subgroups, Committees, and Principal Members, as well as with other DOD organizations and industry.

The survivability model is to detail the essential survivability management parameters and their causal relationships throughout the life cycles of the weapon systems which are within the charter of the JTCG/AS. Other aspects to be included in the model are: forecasting macro-behavior; predicting the consequences of proposed actions or inactions; conducting sensitivity analysis to establish research and data gathering priorities; and providing aids to communication among those concerned with survivability issues.

The approach to the model development is based on System Dynamics, a field of management science that was begun by Professor J.W. Forrester of the Massachusetts Institute of Technology's Sloan School of Management. Systems Dynamics is a methodology for analyzing complex, dynamic social, technological, economic, and political systems to show how the system components and policies affect the behavior of the overall system. Systems Dynamics modeling strives to express in the form of mathematical equations the structure of the system upon which the proposed policies act. The methodology is based upon the foundations of decision making, feedback systems analysis, and simulation. Generally, the model provides a way to analyze problems whose variables change over time, which permits analysts to determine the system response to factors within the decisionmakers' control, such as policy, and factors beyond the decisionmakers' control, such as threat responses.

There are three phases to the model development project: Phase I, the development of the pilot model; Phase II, the calibration of the model; and Phase III, the implementation of the model. Each phase of the program is to be one year in duration.

Phase I activity is to focus on the content and structure of the model. A pilot model was developed based on published survivability documents and on discussions with the survivability community. At the end of Phase I a pilot model and a plan for model validation are to be completed.

Phase II is to emphasize the calibration and detailed requirements of the model. Continuing refinements to the survivability parameter relationships will be made as necessary. During this phase, model validation is to be initiated.

Phase III will address the implementation of the model to the overall JTCG/AS planning activities. All users will be instructed as to the use, capabilities and limitations of the model. At the end of Phase III, the capabilities described above are to be fully operational.

In December 1982, contracts were awarded to a prime contractor and two subcontractors for the conduct of this research. The prime contractor is the Virginia Polytechnic Institute and State University with Dr. Donald R. Drew and Dr. Thanh K. Tran Principal and Co-Principal Investigators. The VPI & SU research team is responsible for total model development and integration of survivability related information into the model. The principal investigator ensures that the model is comprehensive such that it spans survivability considerations from weapon systems design to operations. The final package is to include variables and parameters that can describe: the inherent capability of enemy threats in various operational environments; aircraft susceptibilities; systems responses to the threats;

vulnerability reduction techniques; tactics considerations; and survivability enhancement tradeoffs associated with aircraft design alternatives. Additionally, a capability to optimize the allocation of resources to modernization, improvement, and retrofit programs for weapon systems will be developed. Technological obsolescense issues will be also incorporated into the model.

The task of providing technical support and liaison with the survivability community was assigned to Booz, Allen and Hamilton with support provided by the SURVICE Engineering Company under subcontract. This effort began in June 1983.

The Booz, Allen technical support provided included: an orientation to survivability information in general, and identification of survivability parameters and measures of effectiveness. In particular, sources of information such as the Combat Data Information Center, published reference handbooks and technical interchanges with recognized experts in the survivability community were used as inputs to the model development.

Overall monitoring of the model development and technical support activity is provided by a JTCG/AS Steering Committee chaired by the Executive Director of the JTCG/AS Central Office.

1.6 PURPOSE AND OBJECTIVES OF DISSERTATION

The purpose of the research described in this dissertation is to accomplish the attrition modeling associated with the development of the JTCG Aircraft Survivability Management Model. Since the JTCG Aircraft Survivability Management Model has been conceptualized as being comprised of five submodels -- Economy, Budget, Procurement, Attrition, and Survivability, this dissertation deals with the formulation of the Attrition Submodel and Survivability Submodel and with synthesis of these with the Economy, Budget and Procurement Submodels. Specifically, then, the objectives of the research described in this dissertation are:

1. To develop an Attrition Submodel which can represent U.S.S.R. and U.S. air combat force levels and will determine "winners and losers";
2. To develop a survivability tradeoff component for the Survivability Submodel which will evaluate competing U.S. aircraft systems; and
3. To combine the above submodels with the three peacetime submodels, Economy, Budget and Procurement -- so as to provide feedback from wartime scenarios analyses to peacetime national security planning.

In keeping with the purpose and objectives, steps in the plan of research include

1. To review aircraft combat survivability concepts, classical attrition models, game theory and other promising approaches (Chapter II);
2. To place the aircraft survivability-attrition problem in a systems context and to describe the system dynamics methodology as preludes to the application of the latter to the former (Chapter III);
3. To provide an overview of JTCG Aircraft Survivability Management Model and its submodels so as to help establish the detailed requirements of the submodels to be emphasized in this research (Chapter IV);
4. To place the aircraft combat survivability phenomenon in a unified mathematical form as a prelude to modeling it using system dynamics and to review and supplement existing Lanchester theory and to identify and solve analytically relevant special cases as a prerequisite to modeling them using system dynamics (Chapter V);
5. To describe in detail the Attrition Submodel and the survivability tradeoff component of the Survivability Submodel, expressed in system dynamics form (Chapter VI);

6. To show how the submodels are combined and used (Chapter VII) to
    - evaluate survivability enhancement techniques
    - determine U.S. air combat effectiveness against Soviet threats
    - close the loop for guiding national security planning

Chapter II

LITERATURE REVIEW

2.1 MILITARY PROBLEM SOLVING

The most realistic way to access the operation of military forces is to operate them and observe how they perform. It would also be necessary to obtain extensive enough data for useful analysis of the potential outcome, such as assessment of potential casualties, effectiveness of the various weapons, and so forth. This would be an undertaking of enormous magnitude and expense and doubtful feasibility. But smaller-scale exercises and tests do yield such data, which, however unrealistic they may be, provide useful inputs to more purely analytical approaches [23]

Gaming, simulations, models are widely used for training and educational purposes by the Department of Defense.

2.1.1 War Gaming

War gaming has a long history of military respectability as an educational and training device. The oldest applications of gaming have been to military problems. It is customary to attribute the first stress on military exercises and analysis to the Chinese general, Sun Tzu, who lived around the fifth century B.C. There is also a literature on Chess and Go (or Wei Chi) as war games. Nevertheless, the first clear formal play of a war game appears to have been in 1824 under the investigation of Lieutenant von Reisswitz of the Prussian guard [24].

Whether this technique of examining action and counteraction survived because the hypothetical general found that it contributed to his military success, or because it was a useful way of thinking through complex situations, or simply because it was an entertaining pastime is unimportant. The important thing is that it did survive and over the years has undergone many changes and developments [25].

War gaming -- in which military men representing both sides play their forces on a map, with a referee team to calculate the effects of weapons and maneuvers and to use those effects to assess the outcomes of engagements -- has been developed as a substitute for such field exercises. War games of this kind also use a great amount of time making it impossible to examine many alternate tactics and force structures to find their effects on the outcomes. Ultimately, too, they must rely on the underlying analytical representations of the weapon systems and of the operations of forces. Since the multiple interactions among the weapon systems are extraordinary complex, the usual simple analytical representation of the direct effects of single weapons against individual targets leads to fundamental oversimplifications in using manual war games to assess interactions among military forces. To overcome these disadvantages, the military and operations research communities through the years have attempted to simulate military combat by using computers [23].

Currently a war gaming may be accomplished manually, may be computer-assisted, or may be wholly computerized. A computer war game requires the use of a model, that is, computer program, that contains all the rules, procedure, and logic required to conduct the game.

2.1.2 Computer Simulation

Computer Simulation is an analytic technique using mathematical and logical models to represent and study the behavior of actual or hypothetical events, processes, or systems over extended periods of time. It provides a means of gaining experience and of making and correcting errors without incurring the costs or risks of actual application [26].

The computer simulation offers opportunities to test theories and proposed modifications in systems or processes; to study organizations and structures; to examine past, present and future events; and to use forces that are difficult or impractical to mobilize.

It is suggested [26] to use simulation when:

1. It is either impossible or extremely costly to observe certain processes in the real world.
2. The observed system is too complex to be described by a set of mathematical equations.
3. No straight forward analytic technique exists for solution of appropriate mathematical equations.
4. It is either impossible or very costly to obtain data for the more complicated mathematical models describing a system.

On the other hand, simulation should not be used according to this source when

1. Simpler techniques exist.
2. Data are inadequate.
3. Objectives are not clear.

2.1.3 Mathematical Models

Mathematical models such as Lanchester differential equations and game theory will be discussed in sections 2.4 and 2.5.

2.2 AIRCRAFT SURVIVABILITY ANALYSIS

2.2.1 Introduction

Aircraft combat survivability is defined by the U.S. Department of Defense as the capability of an aircraft to avoid and/or withstand a man-made hostile environment. The inability of an aircraft to avoid the hostile environment can be measured by P_H, the probability that the aircraft is hit by a damage-causing mechanism, and is referred to as the susceptibility of the aircraft [27].

Vulnerability can be measured by $P_{K/H}$, the conditional probability that the aircraft is killed, given a hit by a damage mechanism.

The probability of kill of the aircraft, P_K, is the product of the probability of hit (susceptibility) and the conditional probability of kill, given a hit (vulnerability). Thus,

Aircraft Kill = Susceptibility * Vulnerability

$$P_K = P_H * P_{K/H} \tag{2.1}$$

The capability of the aircraft to survive is measured by P_S, the probability of survival. Its relationship to P_K is given by

$$P_S = 1 - P_K \tag{2.2}$$

2.2.2 Survivability per Encounter [28]

A hostile weapon system's effectiveness is measured by its ability to defeat a target. First, a radar or visual line-of-sight to the target must exist before any engagement can take place. Next, the target aircraft must be detected, recognized, and identified as an enemy. Projectile or missile launch can then occur given that the target is within the (1) range, (2) angular-rate limitations, and the (3) maneuverability limits of the defense weapon. Successful guidance to the target is a function of the defense system (i.e., free flight projectile, radar or IR guided, etc), and kinetic aspects of the target. The degree of sophistication employed in an analysis of defense system effectiveness depends upon the intended use of the results and the confidence level placed upon the inputs.

The probability of survival per encounter ($P_{S/E}$) can be determined as follows:

$$P_{S/E} = (P_{LOS})(P_D)(P_L)(P_G)(P_{DET}) \overset{n}{\pi} (1-P_{SSK}) \qquad (2.3)$$

where:

P_{LOS} = probability of line-of-sight to the target

P_D = probability of detection, given line-of-sight

P_L = probability of launch or firing, given detection

P_G = probability to successful guidance, given launch or firing

P_{DET} = probability of warhead detonation (fuzed warheads), given successful guidance

n = number of shots fired during a pass

P_{SSK} = single-shot kill probability

2.2.3 Survivability per Sortie [28]

The probability of a single aircraft surviving multiple engagements with the various weapons of a zone defense is calculated by the expression:

$$P_{SM} = \underset{i}{\pi}\, P_{S_i} = \underset{i}{\pi}\, \exp - \frac{N_i\, D\, 2R_{eff_i}\, (1-P_{S/E_i})}{A_i} \qquad (2.4)$$

where:

P_{SM} = probability of mission survival over ith engagements with the zone defense weapons mixture.

A_i = the area in which the weapon systems or firing units are expected to be randomly distributed.

N_i = the number of ith type weapon systems in area A

R_{eff_i} = the effective range of the ith type weapon system

D = the distance the aircraft flies through area A without significantly changing altitude or airspeed.

P_{S/E_i} = the probability of the aircraft surviving a single encounter with the ith type weapon system at a given airspeed and altitude.

P_{S_i} = probability of surviving multiple engagements with the ith type weapon system.

2.3 SURVIVABILITY METHODOLOGIES

The survivability of an aircraft can be enhanced by a good design that does not cause weight, cost, or performance penalties, by the addition of extra elements to the design that do involve penalties, and by the optimum utilization of the aircraft.

The goal of the aircraft survivability discipline is the early identification and successful incorporation of those specific survivability enhancement features that increase the effectiveness of the aircraft as a weapon system. A reduction in vulnerability could lead to an increase in susceptibility (e.g., adding a lot of heavy armor could slow the aircraft down and make it easier to hit) and vice versa [27].

During the past two decades, many computer models were built to estimate aircraft survivability. Some of these models were widely used; others were used only by the developing organization. A selected number of survivability computer programs [29] are described in this section.

2.3.1 PACAM V Aircombat Model

PACAM V has been developed from a series of earlier versions in an evolutionary process.

The original version (PACAM I), prepared for the Aeronautical Systems Division commencing in 1968, was designed to simulate one-on-one aerial combat in three-dimensional space. Both sides used the same tactics, and both used the same policy, i.e., fully aggresive. A limited maneuver suite was available, and each aircraft fought unaware of weapon usage by his foe.

In developing PACAM II, the program was completely rewritten for efficient operation and ease of input. The major thrust of the development was in the area of tactics.

PACAM III efforts were aborted in favor of PACAM IV.

The principal thrust of the PACAM IV development was to permit dynamic reaction to weapons firing, with all the concomitants effects. The concepts of kill evaluation and action based upon missile detection led to requests for stochastic determination of these variables by an optional Monte-Carlo routine.

Finally, and most significantly, the model was designed to permit multiaircraft combat. The ability to handle fighter-fighter combat only is retained completely in the PACAM V program.

PACAM V is written in Fortran IV; it comprises some 72 subroutines.

2.3.2 SAMS (Surface-to-Air Missile Model)

SAMS model was developed to provide a standard surface-to-air missile engagement model to support survivability and vulnerability assessments of current and future Air Force weapon systems.

The SAMS is a generic computer program that can be used to model the characteristics and capabilities of ten Soviet SAM systems, designated by the U.S. DOD as SA-2, SA-3, SA-4, SA-5, SA-6, SA-7, SA-8, SA-9, SA-10, and SA-11. The characteristics and capabilities include sensor lock-on and tracking parameters , missile flight dynamics (including aerodynamics and propulsion), missile guidance and control, and offensive/defensive vulnerability and countermeasures. The model simulates the interaction between a single airborne target and a specified SAM missile fired from a designated location.

Since SAMS is basically a one-on-one engagement simulation, each engagement simulates a single mission, a single-site, and a single target. Multiple sites or multiple launches from the same site are multiple executions of the SAMS simulation.

SAMS models the subsequent motion of the warhead fragments and determines kill probability based on target attitute, presented areas, and vulnerability characteristics.

2.3.3 SCAN Target Vulnerability Model

SCAN is a digital computer program developed at the Pacific Missile Test Center to predict the probability that an aircraft will survive an attack by a missile armed with a fragmentation warhead. The program simulates the encounter between a missile and its airborne target and computes the expected target damage. The encounter conditions can be obtained from missile flight simulations, from missile performance data, or as user-supplied values. The program reports hit and survival probability computation results at specified component, subsystem, system, and total aircraft levels.

SCAN gives the analyst several options in defining individual aircraft components and in using vulnerability criteria to compute the expected damage level. These options allow the analyst to construct efficient models commensurate with time, effort, and cost constraints.

2.3.4 P001 AAA Gun Simulation

P001 is a digital computer program developed by the Air Force Armament Test Laboratory at Eglin AFB. The model simulates one-on-one engagements between a target aircraft and a ground-based gun system. Since its creation, P001 has been modified by many organizations. The basic version considers various error sources that arise in predicting an aircraft/projectile intercept point. Computations are performed over an entire flight path and probability-of-kill results are accumulated after calculation for each increment of the flight path.

Gun types are described in terms of the numbers of barrels, projectile characteristics, system reactions, and tracking capabilities. The user may simulate a single type of gun system on any model run. However, on any run, more than one weapon of that type may be simulated to gather data on different engagament geometries. Various types of guns may be simulated by rerunning the model using new data.

Target air vehicles are described in terms of their flight path, signature, and vulnerable area. The internal flight-path generator is capable of producing only straight and level flight paths. Other types of flight paths must be generated separately by a flight-path generator (such as BLUE MAX computer program) and read into the simulation as an input file.

2.4 ATTRITION MODELS

Mathematical representations of combat attrition have long fascinated analysts and practitioners. Among the most famous of the individual approaches and techniques that have been developed is the Lanchester Equations.

In 1916 an English mathematician, F.W. Lanchester, published "Aircraft in Warfare" in which he used differential equations to describe losses, or attrition rates on each side as functions of the magnitudes and the effectiveness of the forces involved [30]. The solution of the equations, under prescribed initial conditions, would provide a basis for prediction of the outcome of a battle. The basic equations are of the following form:

$$dx/dt = - by \qquad (2.5)$$

$$dy/dt = - cx \qquad (2.6)$$

where x and y represent the numbers of opposing aircraft and the parameters b and c are combat effectiveness coefficients for the two sides. The rates of change of x and y with respect to time are the respective attrition rates.

Lanchester also developed another equation, called the linear law. The simultaneous differential equations are:

$$dx/dt = -bxy \qquad (2.7)$$

$$dy/dt = -cxy \qquad (2.8)$$

This equation never leads to annihiliation of either side.

Variation of the basic equations have been used to analyze the outcomes of specific battles. In 1954, J.H. Engle [31] published a well known study which attempted to verify the application of Lanchester's basic equation to the casualty data of the Japanese and American sides during the battle of Iwo Jima. The model he considered was

$$dx/dt = P(t) - by \qquad (2.9)$$

$$dy/dt = -cx \qquad (2.10)$$

where $P(t)$ denotes resupply to the American side. The Japanese began with a fixed force and did not introduce extra forces as the combat continued. On the other hand, American forces landed 54,000 troops on the first day; none on the second; 6,000 on the third; none on the fourth and fifth; 13,000 on the sixth; and none thereafter. The initial number of Japanese troops was determined by a body count at battle completion, which occurred 36 days after its commencement. It was found to be 21,500. Engle was able to show that, given the values of $b=.0544$ and $c=.0106$, the Lanchester equation produced results that fit the data extremely closely.

Springall [32] considered the following model:

$$dx/dt = - bxy - my \tag{2.11}$$

$$dy/dt = - cxy - ny \tag{2.12}$$

where b,c m and n are the attrition coefficients. This model has the unusual feature of replacement of forces in the field from reserves, which at least for some conflict applications, adds one further dimension of realism. Both sides deploy only a constant fraction of their initial strengths actually in the field, the remainder being held in reserve and used to replace casualties. This phase continues until only one side can replace and finally there may follow a phase which is in classical Lanchester equation with no replacement possible.

The emphasis on the deterministic approach has persisted to the present day. The explanation seems to reside in the difficulty involved in solving the equations associated with a stochastic formulation, and the complexity of the solutions in the rare cases where the equations have been solved. Because of the fact that force sizes are often very large and it was believed that a deterministic approach provides an adequate approximation to the stochastic results. In the light of recent work, this has been found to be substantially correct, at least for non-time dependent results. A stochastic analysis nevertheless has to be carried out in order to permit this conclusion [32].

Isbell and Marlow [33] have formulated the stochastic equivalent of the following deterministic model:

$$dx/dt = -by - mx$$

$$dy/dt = -cx - ny$$

but were unable to solve it except for the case where $b + n = m + c$

Helmer [34], Snow [35] and Weiss [36] have considered various cases involving heterogeneous forces, that is to say, each side is composed of different types of unit. The results are so complicated that there seems little hope that the stochastic equivalent of their work will be developed in the immediate future.

If we wish to consider a lengthy set of engagements including operational losses inflicted by surface threats, we may extend the basic model to the more complex one [26]:

$$dx/dt = a - by - mx \tag{2.15}$$

$$dy/dt = p - cx - ny \tag{2.16}$$

in which m and n are the operational air-ground attrition coefficients and a and p are combat aircraft production rate.

2.5 GAME THEORY

2.5.1 Introduction

Game theory is a mathematical theory that deals with the general features of competitive situations [37] such as political campaigns, military battles, advertising and marketing campaigns by competing business firms, and so forth.

Game theory provides a framework for analyzing competitive situations in which the competitors (players) make use of logical thought processes and mathematical techniques to determine optimal strategies for winning. If one player wins what another player ~~player~~ loses, the game is called a zero-sum games. A two-person game is a game having only two players. Two person, zero-sum games, are also called matrix games. If one player always chooses the same strategy (pure strategy) or chooses pure strategies in a fixed order, his opponent will in time recognize the pattern and will move to defeat it, if possible. Generally, therefore, the most effective strategy is a mixed strategy, defined by a probability distribution over the set of pure strategies [39].

Unlike the models based on the Lanchester equations, in which the players are modeled as mechanisms, the game theory model treats human players as efficient, rational actors lacking personal and social qualities beyond their ability to compute advantages, choose strategy, and aim at maximal gains [26].

2.5.2 Solution by Linear Programming

Any game with mixed strategies can be solved rather easily by transforming the problem into a linear programming problem.

Supposing that

x_i=probability that player I will use strategy i(i=1,2,..m)

and

y_j=probability that player II will use strategy j(j=1,2,..n)

where m and n are the respective numbers of available strategies. Thus player I would specify his plan for playing the game by assigning values to $x_1, x_2, \ldots x_m$. Since these values are probabilities, they would need to be nonnegative and add up to one.

Each player is going to randomize his choice of strategies. Consider the player I; the expected payoff from him if player II happens to have picked strategy 1 is

$$p_{11}x_1 + p_{21}x_2 + \ldots\ldots\ldots\ldots + p_{m1}x_m \qquad (2.17)$$

where p_{11} is the payoff if player I uses strategy I and player II uses strategy i.

If the player I wishes to minimize the payoff, he has to minimize the maximum of expected payoff for each strategy that his opponent choses.

$$V_I = \text{minimize } [\text{max of } (p_{i1}xi, p_{i2}x_i, \ldots\ldots p_{in}x_i)] \quad (2.18)$$

where

$$p_{i1}x_i = p_{11}x_1 + p_{21}x_2 + \ldots\ldots\ldots\ldots + p_{m1}x_m$$
$$p_{i2}x_i = p_{12}x_1 + p_{22}x_2 + \ldots\ldots\ldots\ldots + p_{m2}x_m$$
$$\cdot$$
$$\cdot$$
$$p_{in}x_i = p_{1n}x_1 + p_{2n}x_2 + \ldots\ldots\ldots\ldots + p_{mn}x_m$$

and if max of $(p_{i1}x_i, p_{i2}x_i, \ldots\ldots, p_{in}x_i)$ is equal to V_I, this problem can be formulated as:

Minimize: V_I

Subject to: $p_{i1}x_1 \leqslant V_I$

$p_{i2}x_i \leqslant V_I$

$\cdot$

$\cdot$

$p_{in}x_i \leqslant V_I$

$x_1 + x_2 + \ldots\ldots\ldots + x_m = 1$

$x_1, x_2, \ldots\ldots\ldots\ldots x_m \geqslant 0$

V_I is unrestricted

2.5.3 Application of Game Theory to Military Battles

An important problem in tactical air war is concerned with the allocation at each strike of the tactical forces among such competing air tasks as counter-air, air-defense, and ground support operations. Berkovitz and Dresher [39] formulated a two-person multimove game in which the allocation decisions of the combatants represent the moves of the game. In this game model they assumed that counter-air missions destroy enemy forces, air-defense missions reduce the enemy's counter-air operations, and ground-support operations contribute to the payoff. Assuming that at the start of the air operations the BLUE side has p planes and the opposing side, RED, has q planes. Suppose that on the first strike BLUE dispatches x planes on counter-air operations and u planes on air-defense operations, and the remaining amount, m=p-x-u planes, on ground-support operations. Similarly, suppose that for his first strike RED allocates y planes to counter-air, w planes to air-defense, and the remaining number, n=q-y-w planes, to support his ground forces. Assuming that each of BLUE's penetrating planes can destroy b planes of the enemy, then BLUE's initial counter-air strike can destroy at most b max(0,x-cw) RED planes; where cw is the number of interceptions by RED which is proportional to w. If the replacement of RED is s planes, BLUE's initial counter-air strike will destroy

$$\min [q-aq+s,\ b \max(0,x-cw)] \text{ RED planes}$$

The planes used in air-defense are assumed to survive, and the aircraft that fail to penetrate the opposing air-defense are assumed to return to base. After the initial strike, RED's forces is reduced to

$$q_1 = \max [0,q+s-aq - b \max (0,x-cw)]$$

In exactly the same manner, at the end of the initial strike, BLUE's inventory of planes is

$$p_1 = \max [0,p+r-dp - e \max (0,y-ku)],$$

where the coefficients d,e, and k have the same interpretation as a,b, and c respectively, and r is the number of BLUE replacements.

Berkovitz and Dresher's illustrative work is notable for its high analytic quality and for its judicious emphasis on qualitative rather than quantitative results. There is some danger, however, that the quantitative aspect of the result may be only an artifact of the model and the precise quantitative results would be impossible without a much more complicated and detailed model which required an extremely difficult mathematical task. Even though a game theory model may be elegant, the game description may not be sufficiently robust or sensitive to important contextual subtleties and changes [26].

2.6 SOVIET MILITARY POWER

2.6.1 Introduction

Aviation and its auxiliaries have developed spectacularly in the twentieth century, creating an industry with great potential for peace and war. Aircraft, particularly since World War II, have been the key to the rapid increases in overall combat effectiveness and firepower on the modern battlefield.

Since each type of aircraft produced is a manifestation of defense requirements formulated some five to ten years before the new model is first flown, combat aircraft are a fairly good indicator of defense thinking. During the last decade, a significant broadening of the Soviet Union's concept of air power became apparent [40].

The appearance of new military hardware -- such as the MIG-23 Flogger B, MIG-27 Flogger D, SU-17 Fitter C and SU-19 Fencer ground-attack planes, the MI-24 Hind attack helicopter, the helicopter cruiser Moskva used for antisubmarine warfare, the aircraft carrier KIEV with YAK-36

Forger vertical takeoff and landing aircraft -- marked the transition of the air forces to a balanced force capable of performing a variety of basic military tasks [40].

2.6.2 Structure of the Soviet Armed Forces [40]

The Soviet armed forces are divided into five services: strategic missile forces, ground forces, national air defense forces, air forces, and the navy. Both the national air defense forces and the navy have their own airforces. Interceptors are found in PVO Strany, the air arm of the national air defense forces, and maritime strike, reconnaissance, and anti-submarine warfare aircraft are found in the Naval Air Force. The Soviet air force itself is divided into three components: Frontal Aviation, concerned with theater warfare, especially in Europe; Long Range Aviation, the USSR's strategic-bomber force; and Military Transport Aviation, its airlift group.

The Soviet air forces are planned and organized according to unique Soviet perceptions of military needs, based on strict operational or functional requirements. The PVO strany, along with Warsaw Pact air-defense forces, protects the Soviet Union. Frontal Aviation provides support for the ground forces. Long Range Aviation, Military Transport Aviation, and the Naval Air Force have both supporting roles and independent tactical and intercontinental missions.

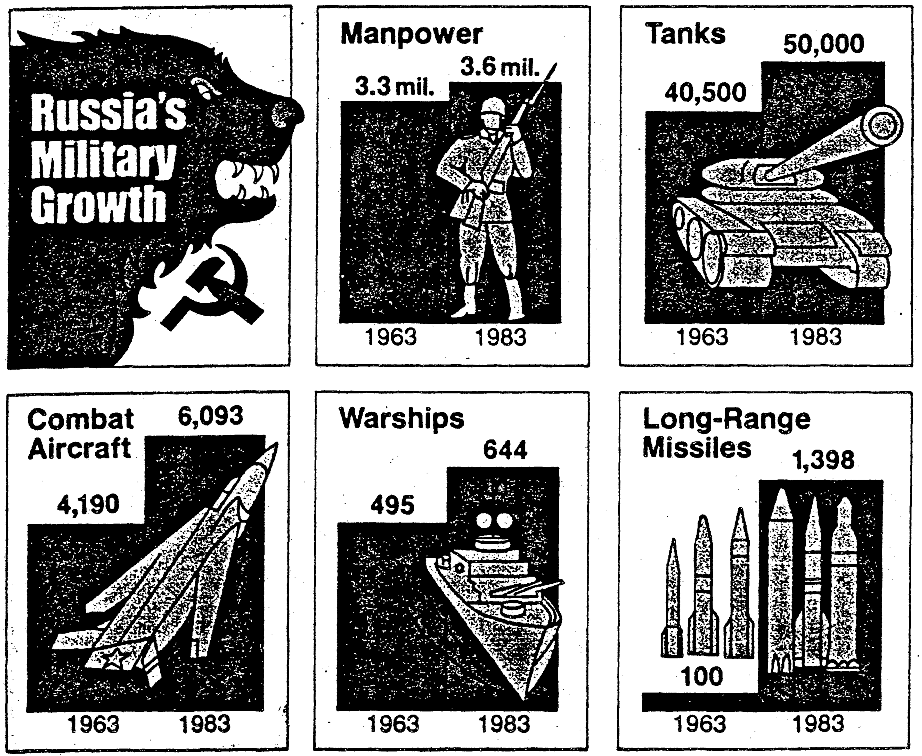
2.6.3 The Growth of Soviet Military Power

The growth of Soviet military power is real, particularly in the area of nuclear missiles capable of striking the United States with great accuracy. And the quantity of Soviet conventional weapons -- fighters, tanks, infantry carriers -- is impressive as shown in Fig. 2.1.

Some Western experts believe that the rise of the Soviet military has had less to do with current trends, than with the basic nature of Communism. According to Paul Craig Roberts of Georgetown University's Center for Strategic and International Studies:

> "No one should be surprised at the military's prominence. It is the bodyguard of the communist system and its road to ultimate triumph. It is also the only succesful institution in the system at a time when the pressure of economic failure is intensifying" [41].

In the contrary to the rapidly growth, the Soviet Union seems short on research and development, perhaps on inventiveness as well. Its weapons are, largely, copies or adaptations of the United States's. Even the Soviets admit sometimes that they are not innovators. In 1982 the Soviet chief of staff, Marshall Nikolai V. Ogarkov, published a pamphlet noting that the United States has been the first one to produce new generations of weapons, such as atomic bombs, multiple-warhead missiles and nuclear-powered submarines.



USN&WR—Basic data: International Institute for Strategic Studies

U.S.NEWS & WORLD REPORT, Jan. 23, 1984

Fig. 2.1 Russia's Military Growth

American weapons in Israeli hands already have bested Soviet weapons in the Middle East. That comparison could mislead; Arab nations aren't given the best Russian equipment, and their combat training lags. But some of the latest Soviet military gear is being used in Afghanistan, and that war shows no signs of ending. These facts indicate that the Soviet weapons maybe deficient in quality compared with the American weapons.

2.6.4 New Aircraft Development

While continuing to produce 30 Backfire bombers a year, which if equipped with in-flight refueling could be used in a nuclear strike against the U.S., the Soviet has begun to develop a new strategic jet dubbed the Blackjack to complement its older TU-95 bear long-range bombers [42].

Two new fighter jets being developed by the Soviets, the MIG-29 Fulcrum and SU-27 Flanker, are to contain high-tech radar and weapons-guidance avionics. MIG-29 is a single-seat air superiority fighter in the class of the F/A-18 Hornet, armament is said to include a 30 mm gun and up to eight air-to-air missiles with lookdown/shootdown radar capability. SU-27 is believed to be in the same category as the F-15 with a maximum speed of Mach 2.3 [43].

A mystery Soviet jet known as Aircraft 101 is believed to be a new supersonic fighter designed to intercept and shootdown the U.S. made cruise missiles. This four-engine aircraft, apparently developed from the TU-128 Fiddler, may be able to carry as many as 30 air-to-air missiles and radar that sees "beyond visual range."

Chapter III

SYSTEM DYNAMICS -- SYSTEMS ENGINEERING METHODOLOGY

3.1 INTRODUCTION

The last four decades have seen the emergence of what has come to be known as the "systems approach." In the decade of the 1940s the most striking examples of the systems approach are the Manhattan Project, in which the U.S. produced the first Atomic Bomb, and "Blackett's Circus," the multidisciplinary group of operations analysts that brainstormed many military problems during the Battle of Britian. In the 1950s the systems approach manifest itself in the form of national security planning by the two superpowers. In the decade of the sixties the systems approach meant space exploration to many -- particularly the Apollo Program to those in the U.S. In the 1970s the systems approach became pervasive throughout industry and government -- applied, more and more to "Metaproblems" -- problems involving many disciplines.

The systems approach is a method -- much like the scientific method -- for conceptualizing problems. This approach, demonstrably succesful in military, industrial, and managerial contexts over the years, has now become firmly embedded in practically every discipline. An important step in the execution of the systems approach is the development of models -- abstractions of the systems or the phenomena being studied. The application of the systems approach, in general, and the development of models, in particular, are sophisticated combinations of art and science. The purpose of this chapter is to provide a general background about systems and models.

3.2 THE NOTION OF A SYSTEM

To understand the systems approach, we must first understand the word system, man has always been conscious of system -- the antonym of chaos. Ancient societies devised such systems as: (1) the calender so he would know when to plant and when to harvest; (2) writing as an improved means of communication and record-keeping; and (3) measurements making it possible to build and to standardize. These developments are significant as ways of structuring knowledge for learning [44,45].

The notion of a system has been assigned a variety of meanings. One common definition is: "A system means a grouping of parts that operate together for a common purpose" [12]. An example of a complex system is a national economy in which the parts work together to produce, distribute, and consume goods and services. Horton [46] interprets system's meaning as being similar to the meaning of the word organization. Organization means the definable relation of parts to each other and to the whole.

While its roots are as old as science, the systems approach is still in its embryonic stage leading to an honest lack of agreement in the interpretation of terms, as well as what Hoos [47] refers to as a "lexical laxity" in their usage. This is particularly true of the word system. Indeed, because system is used by so many people with diverse backgrounds, it is perhaps more realistic to merely communicate the notion of a system to the extent that its practical application is clear, rather than to strive for a formal definition.

A system possesses several important characteristics: structure, wholeness, openness, function and purpose. Considering each: a system is a set of interrelated elements; its structure is often, but not necessarily, hierarchical. Second, a system possesses wholeness; it is more than the sum of its parts. For example, an all-star team is seldom as good as the best team in the set from which the players are selected. Third, a system is open; it interacts with its environment -- influences it and is constrained by it. Functionally, a system may be viewed as a process converting inputs to outputs according to certain established rules of transformation. This fourth characteristic of a system provides the basis for the "black box" concept in which the grouping of the details of the input-output transformation in a transformer or "box" as if the system were devoid of structure, becomes a matter of convenience either because a knowledge of the structure isn't necessary or because it is too difficult to deal with. Purpose, the fifth characteristic of a system, is perhaps the most significant. Systems are self-organizing and self-renewing. They are self-renewing in the sense that an element may be replaced over the lifetime of the system without the system losing its identity. Self-organization permits a system to select goals and objectives and the means of achieving them [4,5,48,49].

3.3 SYSTEMS THEORY

There are many who believes that systems concepts require mathematical rigor if they are to be dealt with effectively. Systems theory refers to the mathematical approach to defining, describing, and classifying systems according to their characteristics, behavior, content, and structure. Wymore [13] distinguishes it from the "nature of systems" or what we referred to in the previous section as "systems concepts" -- terms that have been used extensively where the appeal was to intuition rather than to mathematical elegance.

In its development, systems theory depends on such abstracts branches of mathematics as symbolic logic and set theory as well as the classical mathematics of calculus. Its aim is to state principles which apply to systems in general to provide techniques for their investigation, hopefully, or at least for their description. Three aspects of this development are the linguistic, the logical, and the set-theoretic methods of systems descriptions. The idea in the linguistic method is to describe the domain of objects of the system by "statements" ascribing certain properties of, and relations between, the entities in question. Drawing conclusions from these inputs, also in the form of statements, is a form of system analysis [50].

The logical method is based on symbolic logic, an attempt to reduce all human reasoning to a mathematical notation. Basically it builds on the linguistic approach in that by representing simple "statements" by precise symbols, the relations between many statements describing some phenomena can theoretically be read and interpreted as precisely as an algebraic equation. The obvious advantages are exactness, clarity, and brevity [51].

The third approach to the description and study of systems is based on set theoretic conditions. In fact, the precise definition of a system, if one exists, lies in set theory [10]. Set theory can be used to give one a clearer look at the internal logic of a system, a means of understanding the different ways the component elements may be joined to perform the various system functions. By gaining an appreciation of the way sets operate, one can learn something of the structure, state, decomposition, attributes, behaviour, reproducibility, and controllability of systems.

Mathematical equations are not the only means of abstraction for describing systems. Man has found many ways to characterize the systems he detected about him -- often in terms of the dominant technology of the era: (1) the static presentations of the Egyptians that persists in the pyramids of power of contemporary organizations; (2) the mechanical order that marked the advent of the industrial revolution, still seen in the characterization of the "big wheel" as the key element in a benign group of gears and pinions meshed together; and (3) the description of hydraulic and later energy and information systems in terms of continuous process flow diagrams [52].

Obviously these representations which were essentially pictorial served only to identify the elements of the system and to give some interactions. They did not permit manipulation. With the advent of graph theory this shortcoming was overcome. Not only do graphs, as functional representations of systems, permit manipulation in much the same manner as analytical representations of systems, they do more. First, they convey the topological aspects of the system as a whole whereas in most analytical representations the structure of each component is described by a separate equation. Secondly, graphs permit one to perceive more clearly the roles of such elements of mathematical equations as variables, parameters, and operators.

Theoretically, any system which may be considered abstractly as a set of elements with relationships between the elements may be represented as a graph. There are an abundance of examples throughout the physical, social, and biological sciences [53,37].

Whereas systems theory deals with the relationships between system elements, general systems theory deals with the relationships between scientific disciplines. This is important to systems engineers because of their interdisciplinary responsibilities. The quest of general systems theory is to provide a framework for unifying disciplines in an orderly and integrated body of knowledge, through the formulation and derivation of those principles which are valid for systems in general [54].

Some of the basic requirements that a general theory should satisfy are: (1) it should be precise; (2) it should be applicable to the arts and humanities as well as to science and engineering; (3) it should not be restrictive as to type of system (open or closed) or to type of input (deterministic or stochastic); and (4) it should permit the formulation of all the fundamental problems dealing with systems [55].

Boulding [56] suggests two complementary approaches to the organization of general systems theory. The first approach is to build up general theoretical models relevant to phenomena which are found in various disciplines. Such phenomena include population change (births, aging, deaths), growth (as for bacteria, cells, societies, capital, knowledge, etc.), the interrelationships among individual units in a system (as described in the theory of information and communication, for example), and the relationship of an individual unit to its environment. To these may be added competition (as between parts of the system) and arrangement [57] (the way the parts are put together such as random, classified, coordinated, or in patterns). Bertalanffy [54] has coined the words wholeness, sum, mechanization and centralization to explain some general ways in which individual elements of the system relate to each other and to the system.

It is difficult not to be apprehensive about certain implications of systems theory and general systems theory. Regarding the former, there are fundamental problems for which no mathematical techniques are available. Regarding the latter, real world problems cannot wait for a theory to evolve that really will relate the empirical findings in all the disciplines. In the meantime, two non-quantifiable characteristics can and must be developed: (1) intuition based on original thought and experience and (2) a highly developed problemsolving ability.

3.4 CREATIVE PROBLEM SOLVING

The modus operandi for dealing with complex problems is referred to as the systems approach. There are as many different interpretations of this procedure as there are definitions of the word system. The intent, of course, is to provide a convenient framework for performing analysis and/or design. Basically, the system approach is a creative problem-solving process consisting of a logic and an order of action [8].

The traditional method of studying systems -- while usually analytical -- was piecemeal. A system was divided into discrete and unique pieces and then each piece was examined in isolation from the others. Design of improved systems and policies for systems was frequently inadequate because it failed to consider objectives for the total system and the interrelationships of the parts and their effects.

The system approach incorporates an orderly sequence of reasoning -- both deductive and inductive. Just as in the application of the "scientific method," one usually alternates between these two forms of logic, using deductive reasoning to draw conclusions (an output) by applying a major premise (law) to a minor premise (the input) and using inductive reasoning to develop new major premises (laws) by studying appropriate input-output patterns. In this context the systems approach is, itself, a system -- one transforming an operational need into a description of system performance parameters and a preferred system configuration that have been optimized from a life cycle viewpoint [58]. The systems approach is a process with a certain order of action in problem definition and solution.

First, there is the recognition of a need, determining if it is a high priority need, and assessing just what is the chance of success. Second is the collection of information which, at the least, should spare one the embarrassment of "re-inventing the wheel." The next step is to identify the problem as specifically as possible. Buhl [59] illustrates this nicely using the situation that confronted Tom Sawyer -- that is, "thirty yards of unpainted board fence nine feet high." Tom, as everyone who has read Mark Twain's classic knows, conned every kid in town into white-washing the fence by making use of proper problem definition. He identified the problem, not as "how can I paint the fence," but as "how can I get the fence painted."

The needs of mankind haven't changed; they are still food, shelter, clean air and water, good health, etc. What is changing is the broader manner in which we interpret these needs. For example, when we address ourselves to the problem of health, which of the following do we mean?

1. Is it Webster's health which is "the conquest of disease and pain"?
2. Is it WHO's health which is "the state of complete physical and mental well-being"?
3. Is it, broader still, the ability of a purposeful system to fill its needs and pursue its objectives with a level of efficiency displayed by other systems of the same type in a similar environment, with the

> absence of desire to decrease its own or another's ability to be healthy? [60]

If we accept the first definition of the problem, our approach to the solution is the conventional one - corrective medicine. If we start with the second, we broaden our attack to include preventive, as well as corrective, medicine. If we interpret the problem according to the third, we have a definition that applies equally well to organizations as well as organisms, and it permits us to make ethical comparisons between smokers, terrorists, drug addicts, vigilantes, etc. Now if we recall the third characteristic of a system, the environmental context, we can even put limits on the health problem. Thus, the bottom line is this: an individual from any species can be no healthier, ultimately, than its environment. This sort of steady state analysis is a very important part of systems methodology.

"Creative problem solving," as opposed to "problem solving," is solution through innovation rather than through evolution. In the past technological systems changed gradually with little risk of erring. Solutions were generally only modifications of older solutions to older problems using current technologies. Today, there are a new set of problems for which, in many cases, there are no historical precedents. In order to be a creative problem solver a systems analyst must be able to generate new and useful ideas. Therefore, the fourth step in the systems approach is the search for ideas using such techniques as the following: (1) brainstorming -- an organized group effort aimed at generating ideas by releasing the imagination of the participants from built-in constraints; (2) inversion -- the conscious breaking of conventional ways of looking at the problem; (3) analogy -- projecting from one discipline to another; and (4) empathy -- personal identification with the problem [46].

After the generation of alternatives, the next step is their evaluation and comparison. What this really means is the evaluation of system outputs for each alternative in terms of the goals of the system according to certain criteria. Evaluation is facilitated if the objectives of the system have been properly specified in the problem definition phase. Objectives are operational statements of goals; they are measurable as opposed to goals which are idealized. Evaluation is followed by selection and implementation of the preferred solution.

Implicit in the systems approach is the assumption that the system can be modeled. The model is an idealized representation of the problem, the system. Hopefully the model is a good representation so that the solution to the model is a good approximation of the optimal solution to the problem. The model permits one to manipulate many alternates without expensive experimentation on the real-world system.

In conclusion it should be kept in mind that the creative problem solving process is iterative as well as sequential. It never ends. As one goes through the process his awareness of the objectives are sharpened. Future demands on the system present themselves and must be considered. New alternatives are generated, and improved models are assembled for their evaluation.

3.5 APPLICATION OF THE SYSTEMS APPROACH -- SYSTEMS ENGINEERING

Because contemporary problems cross many disciplines, the systems approach must be multidisciplinary, interdisciplinary and transdisciplinary. Regarding the former, sometimes a multidisciplinary team of specialists can be assembled to work on separate functions or parts of the whole problem under the direction of supervisors who may not know the details of each specialist's work but who know enough about the overall objective to guide and coordinate the completion of the task.

The synergistic appeal of the systems approach lies in the "transdisciplinary" team capability. In other words, bring together an engineer, a sociologists, an economist, and a chemist, for example, and let them attack a problem using the systems approach and the result will be different from and more than the sum of the individual contributions. However, if the full potential of the team is to be achieved, at least some members of the team must possess an interdisciplinary perspective in order to see relationships between realms of knowledge and to organize the contributions of specialists so that overlaps are controlled and voids are prevented.

Thus, the systems approach must be more than just a way of defining problems; it must be a point of view for conditioning generalists. One strategy for increasing the number of well-trained generalists is to convert specialists to "T-men." These professionals, while preserving a depth in their original area (the vertical stem of the T), would strive to obtain the necessary breadth (the horizontal cap of the T) by using their own disciplines as points of departure by relating the behavior of different systems to systems in their own fields.

Operations analysis, the Manhattan Project and Cybernatics provided the immediate antecedents for systems engineering. Systems engineering proceeded to evolve during the early post World War II period in the U.S. in response to the complexity of national security planning. In this period it was not so much an intellectual discipline as a style for dealing with complex problems. Throughout the 1950's it was thought that systems engineering was only appropriate for programs that were essentially concerned with things like aircraft and missiles, but inapppropriate for programs which dealt with people. This myth was put to rest in the 1960's when it was realized that systems engineering could be of great use in planning and designing dams, airports and freeways and other engineered systems. In the 1970's there has been increasing application of systems engineering to social systems.

The ascription of universal transferability and applicability of the systems approach by many of its proponents is cited as evidence of methodological arrogance by its detractors. Hoos [47] claims these same exaggerations are characteristic of many serious works -- technical proposals, final reports, books, and theses, especially when the prize is a contract, a royalty, or a degree. While it is important that systems engineers be able to articulate, when required to, what they are, how they do and what they do, they should also strive to maintain a strong and relevant problem-orientation so that we will be known for what they accomplish. In other words, the objective of systems engineering is not to sell, but to solve.

3.6 SIMULATION MODELS

An important aspect of the systems approach is model-building. A model is an abstraction of reality that captures the functional essence of the system with sufficient detail. To be used instead of the system for investigation and experimentation -- with less risk, less time, and less money. As a surrogate for a system, it comes as no surprise that definitions and interpretations of "model" are as varied as for "system." To Henize [61], models are intellectual tools that helps us distinguish what is possible from what is impossible and then, from the realm of the possible, to distinguish the better from the worse. To Horton [46], a model is anything that illuminates and clarifies the interrelations of subsystems and components, of actions and reactions, and causes and effects.

To the extent that a particular model is an appropriate representation of the system, it can be a valuable aid to policy analysis and policy making. Indeed, most policies are probably formulated by the interpretation, and application of mental models -- whatever their limitations. Mental modeling is a natural capability that can be a powerful tool when employed by skilled practitioners. However, there are other types of models that can make significant contributions to the study of complex systems and the formulation of policy stemming from such analysis. These include physical models including scale models and analog models and symbolic models including verbal models, graphical models, and mathematical models. The symbolic class of models has far broader application. Verbal models tend to be written narratives or oral expressions relating to a system. They explicitly reflect the implicit ideas of a mental model and are probably the primary means of influencing an individual's mental model. Thus they are important, and perhaps even indespensible, to the policymaking process.

Mathematical models are "symbolic" in that they use mathematical notation usually expressed in equation form to describe a system. Often these mathematical equations have graphical analogs -- one type of graphical model. (However, some graphical models such as a pie chart or bar chart do not have mathematical counterparts). Three characteristics of mathematical models that render them especially useful are: they are precise, they are concise, and they are manipulatable. On the other hand, unfortunately, these highly desirable qualities are not generally appreciated by policymakers who do not understand the symbology or rules of manipulation. Ideally, this communication gap between model builders and model user is bridged using verbal and graphical models.

Simulation models are a special class of mathematical models. Except in rare instances, simulation models are dynamics -- they involve changes in the state of the system through time. A simulation model expresses the dynamic relationships among system parameters -- variables and constants -- which may be linear or non-linear. Simulation models may be classified as deterministic or stochastic. In deterministic models it is assumed that the exact values of all variables can be computed and the values of all parameters are known. In stochastic models, input parameter values are represented by random variables corresponding to appropriate probability distributions.

Simulation models can be classified as micro or macro depending on the level of aggregation of the variables. Typical examples of ways of disaggregating simulation models are by age groupings, geographic areas, income levels, professions, religious affiliation, political groups, etc. The obvious tradeoff is determining the proper level of aggregations is cost versus realism [62].

When a simulation model is executed on and solved by a computer, it is called a computer simulation model, or sometimes simply a computer model. Because computers, being logic machines, are general symbol manipulators, a human problem solver using a computer only need think through his problem once. He can use the computer program he developed repeatedly to analyze and experiment with his problem under many different conditions. In effect, in computer simulation the computer program represents the system [63].

3.7 SYSTEM DYNAMICS

An important concept in the systems approach is that of systems state. The state of a system refers to the value or the nature of system attributes at a particular moment in time. Most commonly, states of a system are studied for a chronological succession of instances (which may be seconds, minutes, hours, days, weeks, months or years) throughout some desired period of time. This leads to the construction of a history of some state variable of the system.

A system is said to be stable when its measured performance varies within an acceptable range despite changes to its components and associated attributes. A system may also display erratic or unsatisfactory behavior when its performance falls outside the range of acceptance. This instability may often be anticipated and corrected by "feedback." Feedback may occur on two levels: (1) through automatic adjustments to a system, and (2) through feedback of data to a human monitor who interprets these data and makes the necessary adjustments. When the feedback provides information for and causes changes in the direction of system stability, it is called negative feedback. Negative feedback helps a system adopt to the unexpected and undesirable changes in system components, their attributes, and their relationships. Another type of system feedback is positive; it tends to be maladaptive because it tends to contribute to greater system instability. These concepts of feedback theory and simulation modeling provide the foundations of a systems methodology, called system dynamics.

System dynamics modeling, developed by Professor Forrester of M.I.T. is a methodology that deals with deterministic, dynamic, non-linear, closed boundary systems. Its initial application in 1961 was to the study of the behavior of industrial systems where the short-term dynamics of production rates and inventory levels were analyzed [64]. Forrester expanded his system dynamics techniques in Principles of Systems in 1968 [12]. More recently he has applied his modeling methods to longer term problems of the city [65] and to the problems of world growth [66]. Currently, Forrester is developing a dynamic model of the United States economy. Dennis Meadows, an ex-student of Forrester has developed a similar world model in his Limits to Growth (popular summary) [67] and Dynamics of Growth in a Finite World (technical version) [68].

System dynamics is based on principles borrowed from engineering -- especially feedback concepts. It makes possible a representation of decision policies and information flow. The major concepts of this methodology can be organized and sequenced as follows: All systems that change through time can be represented by varying levels and rates. A level represents an accumulation within a system. This could be people, dollars, pollution, natural resources and almost anything tangible or intangible. It is analogous to a storage device or facility. It also provides an indicator of the condition or state of a system. A rate is a flow from one area to another of what has been accumulated. Rates of flow cause, and control changes to levels. A rate of flow need not be constant -- it can vary. These flows symbolize activities within the systems. Decision rules control system activities -- that is rates of flow. Decision rules are called policies by Forrester. A policy describes how available information is used to generate decision. It defines what a decision maker does (or should do) when he receives specific kinds of information.

A policy determine how goals are set, what information sources are used for making decisions, and the nature of the respons to available information about present and past conditions of the system and to various personal and political pressures. The environment, once determined, is considered constant during a particular set of time periods being simulated. According to Forrester, feedback loops are the basic building blocks of a system. A simple feedback loop is a closed path connecting a decision point (decision rules which control rate of flow), a system level and the environment. Available information is the basis for a current decision that causes action to be taken. The action in twin; alters the level of some system variables. it should be kept in mind that there are often delays or distortions (noise) appearing around a feedback loop.

There are two types of feedback. The "goal seeking" or negative feedback has a goal or desired value for a level. If the level departs from this value to the rate of flow is modified to bring the level back to its desired value much like a thermostat. Conversely, positive feedback loops contribute to either persistent growth or continuous decline of levels -- frequently past what is desired. A system dynamics model consists of multiple positive and negative feedback loops linked together -- frequently in a complicated manner. Sometimes the different types of feedback loops dampen extreme fluctuations of system variables. Sometimes, feedback loops exhibit "exponential growth" where there is, in each succeeding time interval, greater and greater increases in a level. Examples of this type of growth are seen in cell devision, the chain reaction of an atomic explosion, and in the multiplication of rabbits.

Level equations and rate equations are developed to quantify the system activities, interrelationships, and flows. Data for the equations are obtained by some combination of available data and educated guesses. The system is simulated under alternative policies (decision rules), levels, and environments, and resulting system behavior described.

The Future Group, a private organization in Glastonbury, Connecticut has recently devised a new technique which tries to capitalize on the strengths of system dynamics and another technique entitled cross-impact analysis. Cross impact analysis attempts to capture the interrelationships among events. This technique, when performed on a computer, allows the consideration of a large number of events and the determination of sequential and indirect (second and third order) effects that are not usually apparent in a purely intuitive analysis. Probabilistic system dynamics adds to the two aforementioned techniques "a consideration of the interactions between the events and the model. These new interactions are of two types: (1) the impacts of the events on the model (model structure, parameter values, etc.) and (2) the impacts of model variables on event probabilities. This new technique has been applied to the study of Japanese national development policies" [69].

Forrester's technique has been applied to such disparate areas as solid waste generation, narcotic addiction, commodity production, research and development, merchant shipbuilding, and sports and recreation. The greatest asset of the method is that it forces comprehensive consideration of the system rather than singling out a particular facet and trying to understand it alone. Forrester has made us aware that interrelations in complex systems often tend to hide ultimate causes far from the point where results are seen and has shown that simulation technique gives us a feasible approach to understanding such systems.

3.8 CAUSAL DIAGRAMMING

System dynamics has been interpreted as everything from a mere book-keeping scheme in the performance of computer simulation to a proformed group of ideas that explain phenomena -- a paradigm [70]. Within these extremes, most would classify it as a methodology -- a system of rules which guide scientific inquiry. Three components of a methodology for computer simulation models are the following: (1) a substance component which specifies how the model's variables and relations are selected; (2) a set of criteria that can be used to determine whether the results generated by the model are acceptable; and (3) a technique used to structure and run the model. If a shared value component is added about what problems are important -- a component composed of criteria which are used to evaluate whether a model is suitable for some purpose, he we have a modeling paradigm.

In its execution a methodology is comprised of procedures, tools, and techniques. Procedures are orders of action for defining a problem in terms of variables, determining relationships between the system parameters, generating solutions, and evaluating alternatives. Tools are graphical constructs that aid in the execution of the steps in a procedure. Techniques are formal methods for solving a mathematical model representing a system. In system dynamics, the procedure consists of the development of three alternative and complementary forms of model -- verbal, graphical and mathematical. The "tool" and "technique" associated with this procedure are causal diagramming and dynamic simulation.

"Gestalt" is a German world meaning the way a physical entity, experience, or phenomenon is put together or has been made, referring to the pattern or shape of it. Through graphics it is possible to portray a gestalt-like statement about a complex problem identifying its structure, elements, and interactions. The many figures of variables and their interactions depicted throughout this dissertation are examples of a graphic gestalt called a causal diagram.

The significance of the causal diagramming tool in the system dynamics methodology is that it takes us out of a communication cul-de-sac, providing a common vocabulary, specialists, administrators, and cultures. Because of the sense of fragmentation and isolation that can be conveyed by hundreds of pages of verbal description concerning the workings of a system, causal diagrams can be as useful for their communicative ability as for their scientific rigor. To extent an analogy: the narrative of verbal models function like the readings of a long, detailed Victorian novel, whereas the causal diagrams function like a film based on the novel. Certainly much detail is left out, but the "movie" communicates a whole or gestalt perspective that is hopelessly lost in the details of the "novel." A picture is worth a thousand words.

During most of the present century, social scientists and economists have devoted their energies to the establishment of basic propositions showing that one aspect of society is related to class, unemployment is related to inflation, urbanization is related to industrialization, etc. The basic approach has been a "casual" one based on some simple statistical measure of association showing the relation between variables which usually only represent attributes of elements of the system. As a result, the traditional approach does not adapt to the full dynamics of the system process, expecially when feedback loops are present. And such feedback loops are to be found everywhere: in engineering, physics, chemistry, and biology -- and in socio-techno-eco-political systems, in general [71].

Feedback loops are the end result of causal processes and they cannot be analyzed using casual methods such as regression and econometric. First of all the assumption of independence of variables is violated. Secondly, although the coefficients of the variables in the equations of both may be estimated from data in the same way, there is the advantage of the explicit assumptions made regarding the casual structure of the system, making it possible to ascertain through analysis the effects of structural or policy changes. Basically these changes may be made in the social, technological, economic, or political elements of the national development system.

Some of the other problems that complicate performing system analysis using models in addition to feedback -- problems easily handled by system dynamics are: the nonlinearities in which an output is seldom a linear combination of inputs, noise in the feedback mechanism such that information on the state of the system is never perfect, and the presence of time-lags and delays preventing corrective action from being taken instantaneously. These will be treated in subsequent sections after treating the problem of causality and the communicating technique -- causal diagramming.

Thus, an important tool for developing the model of a dynamic system is the causal diagram. The key variables which record the way the system works are identified from the verbal description and these are connected by arrows. The direction of the arrow shows the direction of causation for a pair of variables. The variable at the head of the arrow is the dependent variable; the variable at the tail of the arrow is the independent variable for the paired relationship defined by an arrow. The sign on the arrow identifies the polarity of the relationship between the two variables, plus or minus. A plus relationship means that the dependent variable changes in the same direction as the independent variable; a minus sign means that it changes in the opposite direction. An example of the development of a causal diagram from a verbal description, and the use of qualitative analysis, appears below.

3.8.1 Urban Transportation Model

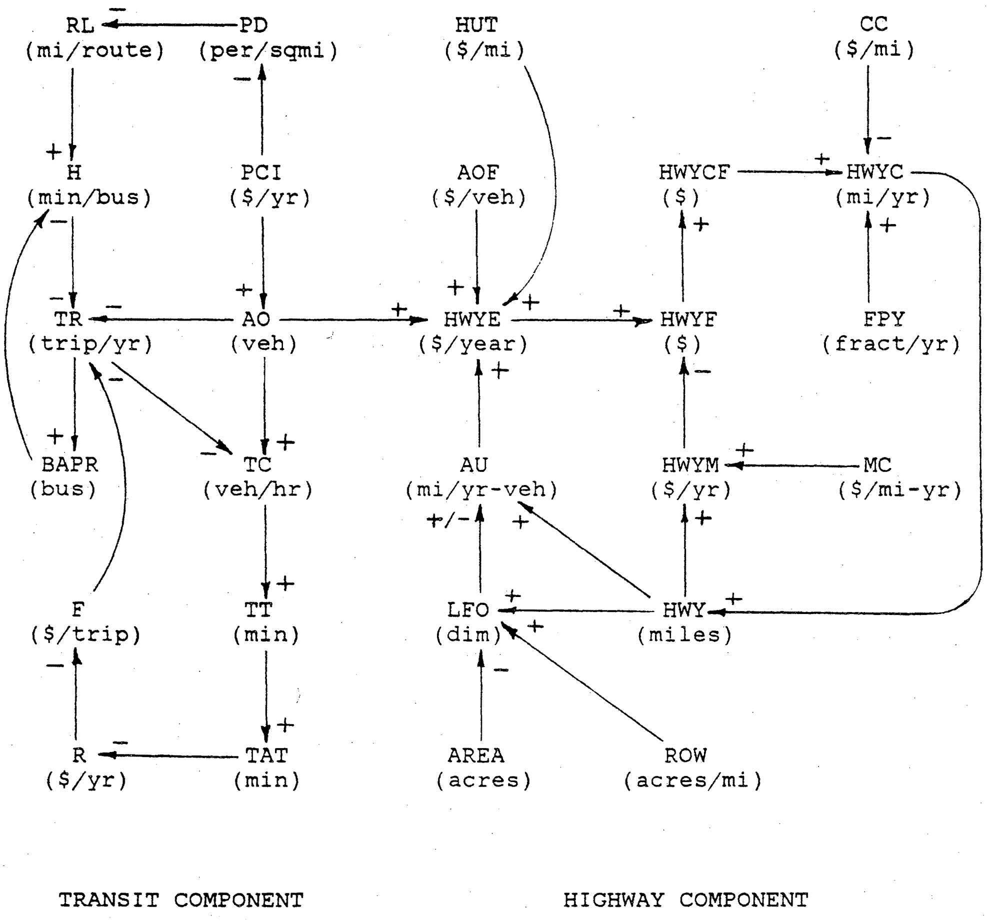
The dynamics of a system as a whole raise a wide range of problem, for its parts may operate in conflict making it difficult to solve the individual problems separately. The urban transportation phenomenon affords as excellent example. The "parts" are highway transportation described in the first paragraph, and public transit, which is described in the second paragraph below.

It is not difficult to show, as the opponents of highway transportation have, that highway construction is an explosive phenomenon. The argument goes something like this: the more highways HWY (mile), the more travel, the more highway earnings HWYE (dollars per year). The Highway Trust Fund HWYF (dollars) which is increased by highway earnings is used to maintain existing highways and build new ones. The amount of money spent on highway maintenance costs HWYM (dollars per year) depends on the miles of highways and the unit maintenance cost MC (dollars per mile per year). The number of miles of new highway construction HWYC (miles per year) depends on the balance in the Fund that is left after maintenance HWYCF, the unit construction cost CC (dollars per mile) and the portion of the balance programmed for construction each year FPY (fraction per year). The land fraction occupied by highways LFO (dimensionless) depends on the average highway right of way ROW (acres/miles), the total area AREA (acres) served by the highways, and the miles of highways. As more and more land is consumed by highways, there is less land for other uses and therefore less trips generated leading to less automobile usage AU (miles/year per vehicle). Automobile usage, highway user taxes HUT (dollars per mile), automobile ownership AO (vehicles), and auto ownership fees AOF (dollars per year per vehicle) determine highway earnings per year.

Throughout the period of explosive growth of highway transportation, there was a steady decline in urban transit operations in many places in the world. Many aspects of urbanization combined to form vicious circles which serve to suppress the variables of interest. Increases in per capita income PCI (dollars/year) lead to decreases in population density PD (person/sq.mi.) and to increased automobile ownership AO (vehicles). Increased auto ownership means less transit riderships TR (trips/year). Traffic congestion TC (vehicle/hour) increases as auto ownership increases and transit ridership decreases. The more traffic congestion, the greater the travel time TT (minutes) for all traffic including buses. Higher travel times mean higher turn-around-times for buses TAT (minutes) which reduce the revenues R (dollars/year) leading to increased fares F (dollars/trip). Increased fares reduce transit ridership. A decrease in ridership leads to less buses assigned per route BAPR causing larger headways H (minute/bus). Reduced population densities lead to increased route lengths RL (mi/route) and longer route lengths cause increased headways.

Decision variables do not have to be affected by massive outlays of capital for new technologies as is often prescribed. Sometimes system structural changes or policy initiatives can do the job. Causal diagrams for the two component models are shown in Fig. 3.1. Three "cheap" strategies for alleviating the exponential growth of private highway transportation and the exponential decline of public transportation, which the interested reader should incorporate into the model by extending the causal diagrams are:

1. A land zoning policy which would reduce the land area in the highway component and increase the population density in the public transit component.



URBAN TRANSPORTATION MODEL

Fig. 3.1 URBAN TRANSPORTATION MODEL

2. A financial allocation policy which would make budget transfers from the Highway Fund to a Transit Fund.
3. A capacity allocation policy which would convert existing freeway lanes to exclusive bus transit use.

3.8.2 Classification of System Variables

There are two basic components of the structure of a system from the system dynamics perspective -- flows and levels. Levels are state variables that represent the accumulations of resources in the system such as inventories of goods, persons, workers, jobs, housing and capita. Rates of flow represent the activities and decision functions in the system such as the movement of goods, births and deaths of persons, hiring and firing of workers, changes in employment opportunities, construction and demolition of housing, generation and use of capital, etc. In the context of causal diagramming the causal relationship between a rate variable such as production rate (stoves/week) and a level variables such as inventory (stoves) is a "physical flow" which will be represented by a solid line. However, the relationship between the level variable (inventory) and the rate variable (production rate) is an "information flow." It is the information regarding the state of the inventory that influences the production rate. Inventory is not physically transferred to the site of production-the factory. But factory output measured in stoves per week does accumulate as physical entities in inventory.

Our causal diagramming technique is now ready to be refined so as to easily identify these two special types of variables -- levels and rates -- simply by noting that levels appear at the heads of solid arrows (physical flows) and rates at the tails of solid arrows. Similarly, information on the state of the system to be used as a basis for decision making must emanate from level variables and will be represented by dotted lines. A few verbal models will be converted to causal diagrams using this notation to illustrate this concept, which becomes important when it comes time to translate the causal diagram into the mathematical model -- the system equations.

3.8.3 Aircraft Carrier Defense Model

The number of TF (Tomcat F-14 Fighter), a carrier-based aircraft, is increased by the production rate (PRTF) and decreased by the attrition rate of F-14 (ARTF). The attrition rate of F-14 depends on the hit rate on aircraft carrier (FRAC) and the indirect (ILPH) and direct loss per hit (DLPH). The hit rate on aircraft carrier by the attack bomber (AB) depends on the launch rate cruise missile

(LRCM), the probability of cruise missile surviving (PCMS) and the probability of cruise missile hitting carrier (PCMH).

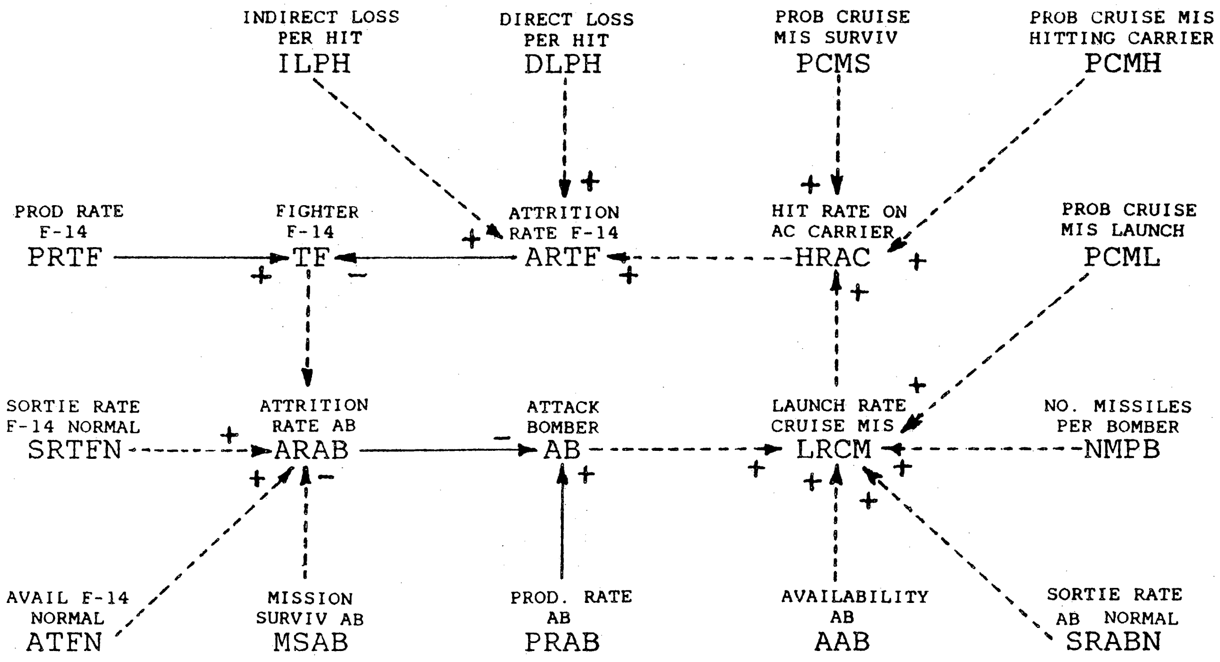
The sortie rate (SRABN), the availability (AAB) and the number of attack bomber (AB); the number of missiles per bomber (NMPB) and the probability of cruise missile launched (PCML) determine the launch rate cruise missile (LRCM).

The number of U.S.S.R. Attack Bomber (AB) is increased by the production rate (PRAB) and decreased by the attrition rate (ARAB). The attrition rate of attack bomber depends on the sortie rate F-14 normal (SRTFN), the availability of F-14 normal (ATFN), the mission survivability of Attack Bomber versus F-14 (MSAB) and the number of F-14. Increases in mission survivability MSAB, will decrease the attrition rate of Attack Bomber (AB). The causal diagram of this model is shown in Fig. 3.2.

3.9 DYNAMO EQUATIONS [72]

> The DYNAMO (DYNAmic MOdels) compiler-simulator language used in system dynamics models such as NRDM-2 is maintained by Pugh-Roberts Associates in Cambridge, Mass. It is now in use on a world-wide basis in many different configurations -- for batch processing and time-sharing -- for mini-computers and large "maxi-computers."

DYNAMO uses first-order difference equations to approximate the continuous process because they are more



AIRCRAFT CARRIER DEFENSE MODEL

Fig. 3.2

practical then differential equations in representing time sequences of system input and output. The essential variables of a dynamic systems study, (state variables and decision variables), are described in DYNAMO by level equations and rate equations, respectively. As discussed previously, the state variables (levels) describe the state or condition of the system at a given time; the rate variables describe how the states change with the passage of time. Because of the approximation involved in the translation of dynamic mathematical relationships (differential equations) into DYNAMO equations writing (difference equations), a clear set of conventions had to be established concerning the handling of the time dimension in system dynamics models.

If t represents the present, then (t-1) is the immediate past, and (t+1) is the immediate future. In terms of DYNAMO postscript convention, the following letter are used:

1. K to designate the present time, t.
2. J to designate the immediate past time, t-1, and
3. L to designate the immediate future time, t+1.

Not all of these postscripts are, however, applied to all types of variables. The level variable takes the postscripts K and J for the present and immediate past time, respectively. The rate takes the double postscript JK when it is an independent variable (on the righthand side of the equal sign) and KL when it is a dependent variable (on the lefthand side of the equal sign). A constant carriers no postscript. When a postscript is used with a variable name, it is separated from the variable name by a dot. The postscript convention for the types of variables commonly encountered is summarized in Table 3.1 [73].

The righthand side of the level equation is restricted to a fixed format that must contain: (1) the previous value of the level being computed -- when the simulation starts, this previous value is the specified initial value of the level, equation type N; (2) the solution interval DT as a multiplier of the flow rates; and (3) the rate(s) of flow -- any number of rates, one or more, can be adding or subtracting from a level. The solution interval DT is a parameter of the computing process, not a parameter of the real system that the model represents. The flow rates of the system, measured in units per time unit, are accumulated in steps or batches over the successive time intervals of DT in length. DT, expressed in units of time, converts the flow rates to a quantity of the item following. The solution interval DT should not appear in any equation other than a level equation.

TABLE 3.1

SUMMARY OF DYNAMO POSTSCRIPT CONVENTION

TYPE OF EQUATION	TYPE OF VARIABLE						
	Dependent (Left-Hand Side)	Independent (Right-Hand Side)					
		Level	Rate	Auxiliary	Constant	Initial	Table Name
L: Level	.K	.J	.JK	.J	none	none	n.p.
R: Rate	.KL	.K	.JK	.K	none	none	n.p.
A: Auxiliary	.K	.K	.JK	.K	none	none	none
C: Constant	none	n.p.*	n.p.	n.p.	n.p.	n.p.	n.p.
N: Initial	none	none	none	none	none	none	n.p.
T: Table Name	none	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.

* n.p. = not permitted

The following example (Fig. 3.3) which is an extension of the model introduced in Subsection 3.8.3 illustrates some of these considerations.

3.10 FEEDBACK STRUCTURES

While thinking in terms of causal relationships is necessary in order to conceptualize a problem so that it is amenable to system dynamics it is not sufficient. Causal relationships between variables often close on themselves to form feedback loops. Within a feedback loop, a change in one variable ripples through the entire chain of variables forming the loop until the initial cause becomes an indirect effect of itself. A key aspect of the system analysis of a system is to focus on the feedback loops.

Roberts [74] refers to four hierarchically different levels of feedback system structure: variable, linkage, feedback loop, and feedback system. A variable is a quantity that is changeable as time evolves. The variable may be a decision variable (a system dynamics rate) or it may be a quantity that is affected by such decisions (a level). When the variable is not affected by other variables inside the system, the variable is termed "exogenous" or outside the system. A variable that is subject to effects of other variables inside the system is termed "endogenous".

```
*   AIRCRAFT CARRIER DEFENSE MODEL
NOTE  ***********************************************************************
NOTE  U.S. ARMED FORCES & FOREIGN POLICY  ARE UNIQUE IN THE EXTENT OF      **
NOTE  THE RELIANCE ON AIRCRAFT CARRIERS. THE U.S. POSSESSES 75% OF THE     **
NOTE  WORLD'S 20 CARRIERS; THE SOVIETS HAVE 2 SMALL KIEV CLASS CARRIERS.*
NOTE  UNTIL RECENTLY THE SOVIETS RIDICULED CARRIERS IN A FUTURE WAR AS     **
NOTE  BEING ANTIQUATED, BUT ARE NOW PLANNING SEVERAL LARGER THAN THE       **
NOTE  KIEV CLASS. THE ORIGINAL RESPONSE OF THE U.S.S.R TO U.S. CARRIER     **
NOTE  CAPABILITY WAS  THE AIR-LAUNCHED  CRUISE-MISSILE,  A RELATIVELY      **
NOTE  SMALL DIFFICULT TO DETECT, EXPENDABLE WEAPON SYSTEM,  DELIVERED      **
NOTE  BY SOVIET LAND-BASED AVIATION. THE U.S. COUNTERED WITH THE F-14,     **
NOTE  A CARRIER-BASED AIRCRAFT ARMED WITH AIR-TO-AIR MISSILES CAPABLE      **
NOTE  OF DEFENDING AGAINST  BOTH THE CRUISE MISSILE AND THE AIRCRAFT       **
NOTE  PLATFORM. THE FOLLOWING ATTRITION MODEL IS MEANT TO ILLUSTRATE       **
NOTE  THE DYNAMICS OF  THE INTERACTION -- SIMPLIFIED IN THE SENSE THAT     **
NOTE  F-14 LOSSES  ARE ATTRIBUTED SOLELY TO  CARRIER DAMAGE.  BOTH         **
NOTE  DIRECTLY (EACH HIT ON THE CARRIER WILL DESTROY SOME F-14S ON THE     **
NOTE  CARRIER AT THAT TIME) AND  INDIRECTLY  (EACH HIT ON THE CARRIER      **
NOTE  WILL CREATE DIFFICULTIES FOR F-14S LANDING CAUSING SOME LOSSES).     **
NOTE  SINCE THE SOVIET ATTACK BOMBERS CARRYING THE CRUISE MISSILES DO      **
NOTE  NOT CARRY AIR-TO-AIR MISSILES, THEIR ABILITY TO DESTROY THE          **
NOTE  F-14S INTERCEPTING THEM IS NEGLIGIBLE.                               **
NOTE  ***********************************************************************
NOTE  **********************      SYSTEM  EQUATIONS      ********************
NOTE  ***********************************************************************
L   TF.K=MAX(0,TF.J+(DT)(PRTF.JK-ARTF.JK))                                 **
NOTE                           TF - "TOMCAT" FIGHTER F-14 (AIRCRAFT)       **
N   TF=TFN                                                                 **
N   TFN=A*DPB                                                              **
C   DPB=1800                  DPB - DURATION PEACETIME BUILD-UP (DAYS)     **
R   PRTF.KL=A                PRTF - PROD. RATE F-14 (AIRCRAFT/DAY)         **
R   ARTF.KL=HRAC.K*(DLPH+ILPH) ARTF - ATTRITION RATE F-14(AIRCRAFT/DAY)**
C   DLPH=3                   DLPH - DIRECT LOSS PER HIT (AIRCRAFT/HIT)     **
C   ILPH=1                   ILPH - INDIRECT LOSS PER HIT (AIRCRAFT/HIT)**
A   HRAC.K=LRCM.K*PCMS*PCMH HRAC - HIT RATE ON AC. CARRIER (HITS/DAY)      **
C   PCMS=.5                  PCMS - PROB CRUISE MIS SURVIVING (PROB)       **
N   PCMH=.005             PCMH - PROB CRUISE MIS HITTING CARRIER (PROB)    **
A   LRCM.K=SRABN*AAB*AB.K*NMPB*PCML                                        **
NOTE                   LRCM - LAUNCH RATE CRUISE MISSILE (MISSILES/DAY)    **
C   SRABN=2                 SRABN - SORTIE RATE AB NORMAL (FRACT/DAY)      **
C   AAB=.5                    AAB - AVAILABILITY AB (PROB)                 **
C   NMPB=2                   NMPB - NO. MIS PER BOMBER (MISSILES/AC)       **
C   PCML=.5                  PCML - PROB. CRUISE MIS LAUNCH (PROB)         **
L   AB.K=MAX(0,AB.J+(DT)(PRAB.JK-ARAB.JK))                                 **
NOTE                           AB - ATTACK BOMBER (AIRCRAFT)               **
N   AB=ABN                                                                 **
N   ABN=P*DPB                                                              **
R   PRAB.KL=P                PRAB - PROD. RATE AB (AIRCRAFT/DAY)           **
R   ARAB.KL=SRTFN*ATFN*(1-MSAB)*TF.K                                       **
NOTE                         ARAB - ATTRITION RATE AB (AIRCRAFT/DAY)       **
C   SRTFN=2                 SRTFN - SORTIE RATE F-14 NORMAL (FRACT/DAY)    **
C   ATFN=.5                  ATFN - AVAILABILITY F-14 NORMAL (PROB)        **
C   MSAB=.91                 MSAB - MISSION SURVIVABILITY AB (PROB)        **
C   A=.4                                                                   **
C   P=.6                                                                   **
NOTE  ***********************************************************************
NOTE  **********************     CONTROL   STATEMENTS     *******************
NOTE  ***********************************************************************
SPEC  DT=.5/LENGTH=40/PLTPER=1/PRTPER=1                                    **
PLOT  AB=A,TF=T                                                            **
PRINT AB,TF                                                                **
NOTE  ***********************************************************************
NOTE  **********************      COMPUTER  OUTPUT       ********************
NOTE  ***********************************************************************
   0.                    500.                   1000.                 1500
 .0- - - - - - - - - - - - - - - - - -T- - - - - - - - A - - - - - - - - - -
   |                       |         T             |A                      |
   |                       |         T           A |                       |
   |                       |        T         A    |                       |
   |                       |        T      A       |                       |
   |                       |       T    A          |                       |
   |                       |       T A             |                       |
   |                       |      AT               |                       |
   |                       |   A  T                |                       |
   |                       | A    T                |                       |
10.- - - - - - - - - - - -A- - - -T- - - - - - - - - - - - - - - - - - - -
   |                   A   |      T                |                       |
   |                A      |      T                |                       |
   |              A        |     T                 |                       |
   |           A           |     T                 |                       |
   |        A              |     T                 |                       |
   |     A                 |     T                 |                       |
   |   A                   |     T                 |                       |
   |A                      |     T                 |                       |
   A                       |     T                 |                       |
20.A - - - - - - - - - - - - - - T - - - - - - - - - - - - - - - - - - - - -
```

Fig. 3.3 AIRCRAFT CARRIER DEFENSE MODEL

A linkage is the cause-and-effect relationship between two variables shown by an arrow in the causal diagram. A feedback loop consists of two or more linkages connected in such a way that, beginning with any variable, one can follow the arrows around and return to the starting variable. Implicit in every cause-and-effect illustration of a feedback loop are time delays: delays from each decision to each of its consequences and develop in feeding back information about each consequence to effect the next decision. For simplicity of appearence these time delay notations are omitted from system dynamics causal diagrams. Just as linkages have two possible directions, feedback loops have two possible polarities, positive or negative. A symbol found in the middle of a feedback loop tells its polarity -- a plus sign if the loop acts to reinforce variable changes in the same direction as the change, contributing to sustained growth or decline of variables in the loop; and a minus sign of the loop acts to resists or to counter variable changes, thereby pushing toward a direction opposite to a change, contributing to fluctuation or to maintaining the equilibrium of the loop. A simple way of determining the polarity of a feedback loop is to count the number of negative linkages: if even, the loop is positive; if odd, the loop is negative.

A feedback system is one or more connected feedback loops. The order of a feedback system is determined by the feedback loop with the maximum number of level variables in the loop. The behavior of the variables in each feedback loop can be propagated through the connection to affect other variables in other loops within the feedback system. Complex organizational problems are embedded in such systems composed of many interconnected feedback loops. Formal analytical approaches become difficult to apply as feedback complexity increases. This area of multiloop and higher-order feedback systems is the focus of attention in the remainder of this section.

3.10.1 First-Order Systems

The structure of a feedback loop is determined by the sequence of alternating levels and rates. The order of the loop corresponds to the number of levels in the loop. Since levels accumulate the rates of flow, the level equations are in effect integral equations. Dynamics behavior arises from the process of integration, which can produce a time-shape and time-position different from those of the input rate.

A feedback loop may be either positive or negative. In a positive feedback process, a variable continually feeds back upon itself to reinforce its own growth or collapse. Such terms as "band-wagon effect," "vicious circles" and virtuous circles" characterize positive feedback. Negative feedback is characterized by goal-directed or goal-oriented behavior. Such terms as self-regulating, homeostatic, and adaptive are synonyms for negative feedback.

The generic structure depicted in Fig. 3.4 underlies all human decisions. The components are those that permit one to engage in goal-seeking.

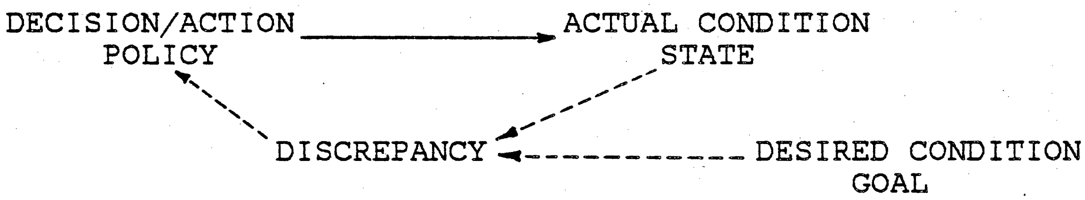


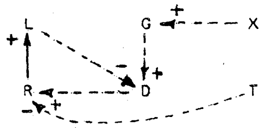
Fig. 3.4 GENERIC STRUCTURE UNDERLYING ALL HUMAN DECISIONS

While the goal-seeking concept displayed in Fig. 3.4 is traditionnaly reserved for negative feedback, positive feedback loops are also part of a goal-seeking process. The difference between negative and positive feedback loops lies only in the nature of the respective goal-seeking process. The goals which positive feedback loops are involved in seeking are receding in the direction of the search, as a consequence of the search. The goals that negative feedback loops seek either are fixed or moving counter to the direction of pursuit [75].

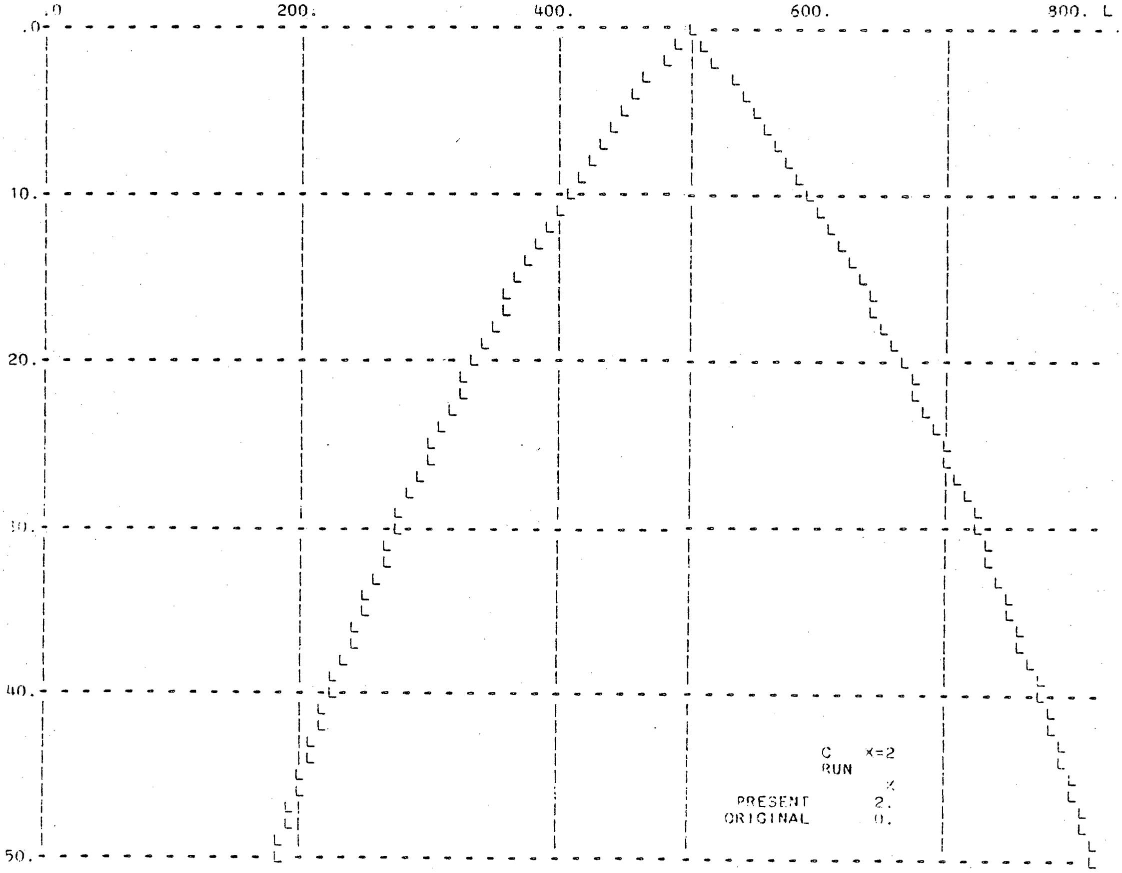
Consider the first order negative feedback system in Fig. 3.5 which consists of a level L, a rate R, the goal G, the discrepancy D, the adjustment time T, and the parameter X. If X is greater than one, L grows asymptotically; if X is less than one, L decays asymptotically; and if X=1, there is no change in L over time. In all cases the actual state of the system, L , approaches the desired state of the system, G, asymptotically. An application of first order negative feedback is explained and illustrated in Fig. 3.6.

Now observe the first order positive feedback system in Fig. 3.7 which consists of the same parameters as in the negative feedback example in Fig. 3.5 -- L, R, G, D, T and X. If X is greater than one, L grows exponentially; if X is less than one, L declines exponentially; and if X=1, there is no change in L over time. In all cases, just as for the negative feedback example, the actual state of the system, L, approaches the desired state, G. The only difference is that the goal is continually changing in the positive feedback example.

To illustrate the concept of goal-seeking positive feedback, consider the classic population model consisting of the level P for population, the rate B for births, and the constant F for fertility. If fertility, which can be measured in the units persons per person per average life



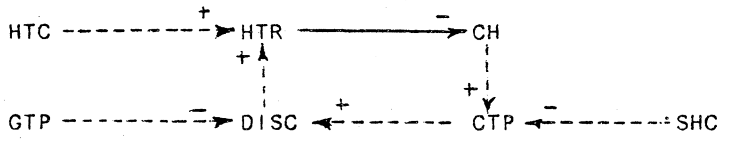
```
*    GENERIC FIRST ORDER NEGATIVE FEEDBACK SYSTEM          DREW W-84   **
NOTE  *****************************************************************
NOTE  *****************************************************************
NOTE  ***   SYSTEM EQUATIONS  ********        CAUSAL DIAGRAM       ***
NOTE  *****************************************************************
L     L.K=L.J+(DT)(R.JK)                **                            **
N     L=N                               **                            **
R     R.KL=D.K/T                        **                            **
A     D.K=G-L.K                         **                            **
N     G=X*N                             **                            **
C     T=50                              **                            **
C     N=500                             **                            **
C     X=0                               **                            **
NOTE  *****************************************************************
NOTE  ****************      CONTROL  STATEMENTS     *******************
NOTE  *****************************************************************
SPEC    DT=.5/LENGTH=100/PLTPER=1/PRTPER=1                            **
PLOT    L=L                                                           **
PRINT   L,R,D                                                         **
NOTE  *****************************************************************
NOTE  ******************      COMPUTER  OUTPUT     ********************
NOTE  *****************************************************************
```



```
C    X=2
RUN
          X
PRESENT         2.
ORIGINAL        0.
```

Fig. 3.5 GENERIC FIRST ORDER NEGATIVE FEEDBACK SYSTEM

```
*    CONCRETE HEAT TRANSFER MODEL                             DREW W-84 ***
NOTE  ****************************************************************
NOTE  ****************     VERBAL  DESCRIPTION     *******************
NOTE  ****************************************************************
NOTE  * THE PRACTICE OF HEATING AGGREGATE OR USING WARM WATER IN THE *
NOTE  * CONCRETE MIX  HAS BEEN SUCCESFULLY EMPLOYED  IN CONSTRUCTION *
NOTE  * PROJECTS DURING PERIODS OF COLD WEATHER. ONE THEORY  IS THAT *
NOTE  * IF THE CONCRETE SETS BEFORE THE TEMPERATURE OF THE MIX DROPS *
NOTE  * BELOW 32  F, THE CONCRETE CAN WITHSTAND THE THERMAL STRESSES *
NOTE  * CAUSED BY THE FREEZING TEMPERATURE. USING A MODEL SIMILAR TO *
NOTE  * THE EXAMPLE DEVELOPED IN CLASS,  FIND THE  MINIMUM ALLOWABLE *
NOTE  * MIX TEMPERATURE  AT THE TIME  THE CONCRETE IS PLACED, X( F), *
NOTE  * IF  THE CONCRETE REQUIRES  2 HOURS  TO SET, AND GROUND-LEVEL *
NOTE  * TEMPERATURE AT  THE CONSTRUCTION SITE  IS 23 F. ASSUMING THE *
NOTE  * FOLLOWING  PROPERTIES  FOR THE  CONCRETE: THE  SPECIFIC HEAT *
NOTE  * CONSTANT IS  4 BTU PER  F AND  THE HEAT TRANSFER CONSTANT IS *
NOTE  * .07 BTU PER MINUTE PER  F.                                   *
NOTE  ****************************************************************
NOTE  ***************       CAUSAL  DIAGRAM        ********************
NOTE  ****************************************************************
```

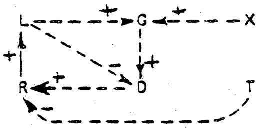


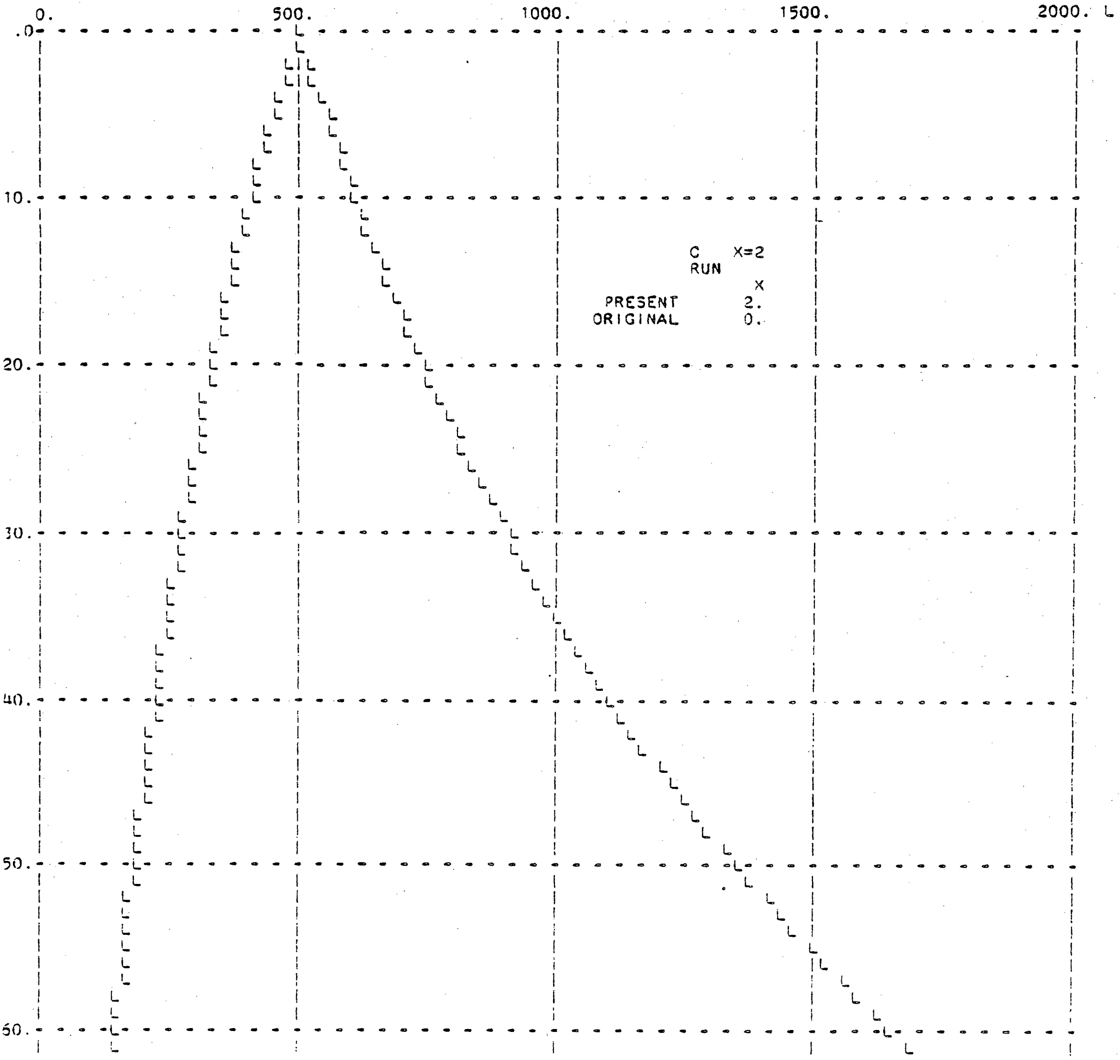
```
NOTE                                                                **
NOTE                                                                **
NOTE                                                                **
NOTE                                                                **
NOTE                                                                **
NOTE                                                                **
NOTE                                                                **
NOTE  ****************************************************************
NOTE  ******************     SYSTEM  EQUATIONS     ********************
NOTE  ****************************************************************
L    CH.K=CH.J-(DT)(HTR.JK)                                         **
N    CH=CTPN*SHC                                                    **
C    CTPN=95                                                        **
C    SHC=4                                                          **
NOTE    CH    - CONCRETE HEAT (BTU)                                 **
NOTE    SHC   - SPECIFIC HEAT CONSTANT (BTU/DEGREE F)               **
A    CTP.K=CH.K/SHC                                                 **
NOTE    CTP   - CONCRETE TEMPERATURE (DEGREE F)                     **
A    DISC.K=CTP.K-GTP                                               **
C    GTP=23                                                         **
NOTE    DISC - DISCREPANCY (DEGREE F)                               **
NOTE    GTP   - GROUND TEMPERATURE (DEGREE F)                       **
R    HTR.KL=DISC.K*HTC                                              **
C    HTC=.07                                                        **
NOTE    HTR   - HEAT TRANSFER RATE (BTU/MIN)                        **
NOTE    HTC   - HEAT TRANSFER CONSTANT (BTU/MIN-DEGREE F)           **
NOTE  ****************************************************************
NOTE  *************       CONTROL  STATEMENTS        *****************
NOTE  ****************************************************************
SPEC    DT=1/LENGTH=120/PLTPER=2/PRTPER=10                          **
PLOT    CTP=C,GTP=G                                                 **
PRINT   CH,CTP,DISC,HTR                                             **
NOTE  ****************************************************************
NOTE  ****************      COMPUTER  OUTPUT      *********************
NOTE  ****************************************************************

TIME=      .0     CH=   380.0    CTP=    95.00    DISC=    72.00    HTR=   5.040
TIME=    10.0     CH=   333.4    CTP=    83.35    DISC=    60.35    HTR=   4.224
TIME=    20.0     CH=   294.3    CTP=    73.58    DISC=    50.58    HTR=   3.541
TIME=    30.0     CH=   261.6    CTP=    65.39    DISC=    42.39    HTR=   2.968
TIME=    40.0     CH=   234.1    CTP=    58.53    DISC=    35.53    HTR=   2.487
TIME=    50.0     CH=   211.1    CTP=    52.78    DISC=    29.78    HTR=   2.085
TIME=    60.0     CH=   191.8    CTP=    47.96    DISC=    24.96    HTR=   1.747
TIME=    70.0     CH=   175.7    CTP=    43.92    DISC=    20.92    HTR=   1.465
TIME=    80.0     CH=   162.1    CTP=    40.54    DISC=    17.54    HTR=   1.228
TIME=    90.0     CH=   150.8    CTP=    37.70    DISC=    14.70    HTR=   1.029
TIME=   100.0     CH=   141.3    CTP=    35.32    DISC=    12.32    HTR=    .862
TIME=   110.0     CH=   133.3    CTP=    33.33    DISC=    10.33    HTR=    .723
TIME=   120.0     CH=   126.6    CTP=    31.65    DISC=     8.65    HTR=    .606
```

Fig. 3.6 CONCRETE HEAT TRANSFER MODEL

```
*    GENERIC FIRST ORDER POSITIVE FEEDBACK SYSTEM           DREW W-84  **
NOTE   ******************************************************************
NOTE   ******************************************************************
NOTE   ***   SYSTEM EQUATIONS  ********          CAUSAL DIAGRAM       ***
NOTE   ******************************************************************
L      L.K=L.J+(DT)(R.JK)             **                               **
N      L=N                            **                               **
R      R.KL=D.K/T                     **                              .**
A      D.K=G.K-L.K                    **                               **
A      G.K=X*L.K                      **                               **
C      T=50                           **                               **
C      N=500                          **                               **
C      X=0                            **                               **
NOTE   ******************************************************************
NOTE   *****************      CONTROL  STATEMENTS     *******************
NOTE   ******************************************************************
SPEC     DT=.5/LENGTH=100/PLTPER=1/PRTPER=1                            **
PLOT     L=L(0,2000)                                                   **
PRINT    L,R,D                                                         **
NOTE   ******************************************************************
NOTE   *******************      COMPUTER  OUTPUT     ********************
NOTE   ******************************************************************
```



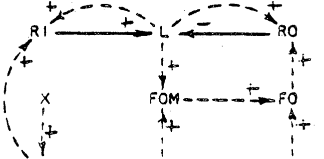


```
C    X=2
RUN
              X
PRESENT       2.
ORIGINAL      0.
```

Fig. 3.7 GENERIC FIRST ORDER POSITIVE FEEDBACK SYSTEM span, is greater than unity, population grows exponentially. In order to frame the problem in the goal seeking terms of Fig. 3.7, think of X as the desired number of children per person and T as the average life span. Thus, if a couple have three children then X=1.5 and the desired population G is greater than the actual population P leading to exponentially growth.

When two or more feedback loops are interconnected, the variables in each loop can propogate through the connections to affect variables in other loops within the feedback system. Coupled feedback loops may or may not have shifts in dominance, a concept that will be illustrated in the example in Fig. 3.8. In this generic model there are two rates, RI and RO for rate-in and rate-out, affecting the level L. RI is determined by L and the parameter FI and RO by L and the parameter FO. FI, however, is a constant and FO is a variable which depends on the constant FON (where "N" stands for "Normal Value") and the multiplier FOM. The parameters X and Y are used to generate the special cases portrayed in the output of Fig. 3.8. A simple real world example of coupled feedback loops producing S-shaped growth is presented in the Industrial Development Model of Fig. 3.9.

```
*     GENERIC FIRST ORDER COUPLED FEEDBACK LOOPS                DREW W-84 **
NOTE  ********************************************************************
NOTE  ********************************************************************
NOTE  ***   SYSTEM EQUATIONS  ********          CAUSAL  DIAGRAM        ***
NOTE  ********************************************************************
L     L.K=L.J+(DT)(RI.JK-RO.JK)        **                                **
N     L=N                              **                                **
R     RI.KL=L.K*FI                     **                                **
R     RO.KL=L.K*FO.K                   **                                **
N     FI=X*FON                         **                                **
A     FO.K=FOM.K*FON                   **                                **
A     FOM.K=(L.K/N)**Y                 **                                **
C     N=100                            **                                **
C     FON=.1                           **                                **
C     X=4                              **                                **
C     Y=1                              **                                **
NOTE  ********************************************************************
NOTE  *****************        CONTROL  STATEMENTS        ****************
NOTE  ********************************************************************
·SPEC   DT=.5/LENGTH=100/PLTPER=.5/PRTPER=1                              **
PLOT    L=L                                                              **
PRINT   L,RI,RO,FOM,FO                                                   **
NOTE  ********************************************************************
NOTE  *****************        COMPUTER  OUTPUT        *******************
NOTE  ********************************************************************
```



```
TIME=      .0     L=   100.0    RI=    40.0    RO=    10.0    FOM=   1.000     FO=   .1000
TIME=     1.0     L=   131.4    RI=    52.6    RO=    17.3    FOM=   1.314     FO=   .1314
TIME=     2.0     L=   167.7    RI=    67.1    RO=    28.1    FOM=   1.677     FO=   .1677
TIME=     3.0     L=   207.1    RI=    82.9    RO=    42.9    FOM=   2.071     FO=   .2071
TIME=     4.0     L=   246.7    RI=    98.7    RO=    60.9    FOM=   2.467     FO=   .2467
TIME=     5.0     L=   283.5    RI=   113.4    RO=    80.4    FOM=   2.835     FO=   .2835
TIME=     6.0     L=   315.0    RI=   126.0    RO=    99.2    FOM=   3.150     FO=   .3150
TIME=     7.0     L=   340.2    RI=   136.1    RO=   115.7    FOM=   3.402     FO=   .3402
TIME=     8.0     L=   359.0    RI=   143.6    RO=   128.9    FOM=   3.590     FO=   .3590
TIME=     9.0     L=   372.5    RI=   149.0    RO=   138.8    FOM=   3.725     FO=   .3725
TIME=    10.0     L=   381.9    RI=   152.8    RO=   145.8    FOM=   3.819     FO=   .3819
TIME=    11.0     L=   388.2    RI=   155.3    RO=   150.7    FOM=   3.882     FO=   .3882
TIME=    12.0     L=   392.3    RI=   156.9    RO=   153.9    FOM=   3.923     FO=   .3923
TIME=    13.0     L=   395.0    RI=   158.0    RO=   156.1    FOM=   3.950     FO=   .3950
TIME=    14.0     L=   396.8    RI=   158.7    RO=   157.5    FOM=   3.968     FO=   .3968
TIME=    15.0     L=   398.0    RI=   159.2    RO=   158.4    FOM=   3.980     FO=   .3980
TIME=    16.0     L=   398.7    RI=   159.5    RO=   158.9    FOM=   3.987     FO=   .3987
TIME=    17.0     L=   399.2    RI=   159.7    RO=   159.3    FOM=   3.992     FO=   .3992
TIME=    18.0     L=   399.5    RI=   159.8    RO=   159.6    FOM=   3.995     FO=   .3995
TIME=    19.0     L=   399.7    RI=   159.9    RO=   159.7    FOM=   3.997     FO=   .3997
TIME=    20.0     L=   399.8    RI=   159.9    RO=   159.8    FOM=   3.998     FO=   .3998
TIME=    21.0     L=   399.9    RI=   159.9    RO=   159.9    FOM=   3.999     FO=   .3999
TIME=    22.0     L=   399.9    RI=   160.0    RO=   159.9    FOM=   3.999     FO=   .3999
TIME=    23.0     L=   399.9    RI=   160.0    RO=   160.0    FOM=   3.999     FO=   .3999
```

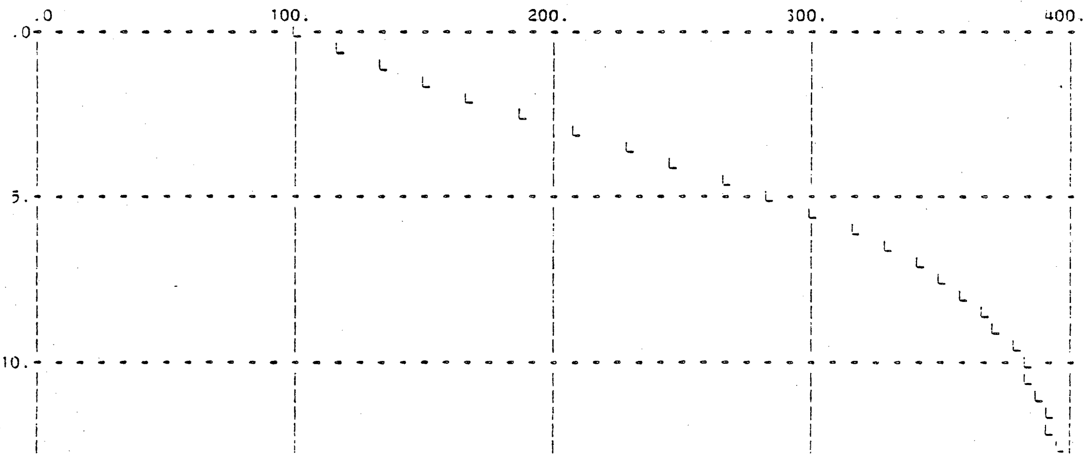
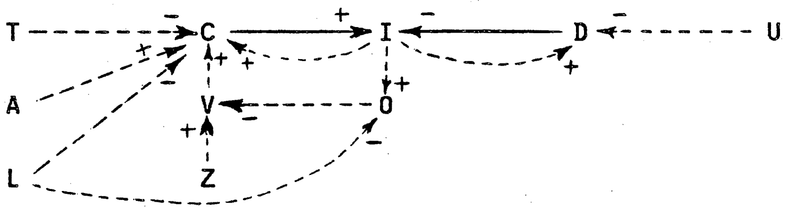


Fig. 3.8 COUPLED FEEDBACK LOOPS

```
*   SIMPLE URBAN INDUSTRIAL DEVELOPMENT MODEL                 DREW W-84 **
NOTE  *****************************************************************
NOTE  *******************       SYSTEM  EQUATIONS      *******************
NOTE  *****************************************************************
L    I.K=I.J+(DT)(C.JK-D.JK)   I - INDUSTRIES (UNITS)                    **
N    I=IN                                                                **
C    IN=10                    IN - INDUSTRIES INITIALLY (UNITS)          **
R    C.KL=I.K*A*V.K/(L*T)      C - CONSTRUCTION (UNITS/YR)               **
C    A=.01                     A - ATTRACTION FACTOR (FRACT/YR)          **
C    L=8                       L - LAND PER INDUSTRY (ACRES/UNIT)        **
C    T=2                       T - TIME FOR CONSTRUCTION (YR)            **
A    V.K=Z-O.K                 V - VACANT LAND (ACRES)                   **
C    Z=400                     Z - LAND ZONED FOR INDUSTRY (ACRES)       **
A    O.K=I.K*L                 O - OCCUPIED LAND (ACRES)                 **
R    D.KL=I.K/U                D - DEMOLITION (UNITS/YR)                 **
C    U=10                      U - USEFUL INDUS LIFETIME (YR)            **
NOTE  *****************************************************************
NOTE  *****************       CAUSAL  DIAGRAM     ***********************
NOTE  *****************************************************************
```



```
NOTE  *****************************************************************
NOTE  ****************      CONTROL  STATEMENTS      *********************
NOTE  *****************************************************************
SPEC  DT=1/LENGTH=50/PLTPER=2/PRTPER=2                                  **
PLOT  I
PRINT I,C,D,V,O                                                          **
NOTE  *****************************************************************
NOTE  ******************      COMPUTER  OUTPUT     ***********************
NOTE  *****************************************************************
RUN

TIME=     .00     I=   10.00    C=   2.000    D=   1.000    V=   320.0    O=    80.0
TIME=    2.00     I=   12.04    C=   2.286    D=   1.204    V=   303.6    O=    96.4
TIME=    4.00     I=   14.23    C=   2.545    D=   1.423    V=   286.1    O=   113.9
TIME=    6.00     I=   16.48    C=   2.762    D=   1.648    V=   268.2    O=   131.8
TIME=    8.00     I=   18.69    C=   2.926    D=   1.869    V=   250.5    O=   149.5
TIME=   10.00     I=   20.76    C=   3.035    D=   2.076    V=   234.0    O=   166.0
TIME=   12.00     I=   22.61    C=   3.097    D=   2.261    V=   219.1    O=   180.9
TIME=   14.00     I=   24.22    C=   3.122    D=   2.422    V=   206.3    O=   193.7
TIME=   16.00     I=   25.55    C=   3.123    D=   2.555    V=   195.6    O=   204.4
TIME=   18.00     I=   26.63    C=   3.112    D=   2.663    V=   187.0    O=   213.0
TIME=   20.00     I=   27.47    C=   3.094    D=   2.747    V=   180.2    O=   219.8
TIME=   22.00     I=   28.12    C=   3.076    D=   2.812    V=   175.0    O=   225.0
TIME=   24.00     I=   28.61    C=   3.060    D=   2.861    V=   171.1    O=   228.9
TIME=   26.00     I=   28.98    C=   3.046    D=   2.898    V=   168.1    O=   231.9
TIME=   28.00     I=   29.26    C=   3.034    D=   2.926    V=   165.9    O=   234.1
TIME=   30.00     I=   29.46    C=   3.026    D=   2.946    V=   164.3    O=   235.7
TIME=   32.00     I=   29.61    C=   3.019    D=   2.961    V=   163.1    O=   236.9
TIME=   34.00     I=   29.71    C=   3.014    D=   2.971    V=   162.3    O=   237.7
TIME=   36.00     I=   29.79    C=   3.010    D=   2.979    V=   161.7    O=   238.3
TIME=   38.00     I=   29.85    C=   3.007    D=   2.985    V=   161.2    O=   238.8
TIME=   40.00     I=   29.89    C=   3.005    D=   2.989    V=   160.9    O=   239.1
TIME=   42.00     I=   29.92    C=   3.004    D=   2.992    V=   160.6    O=   239.4
TIME=   44.00     I=   29.94    C=   3.003    D=   2.994    V=   160.5    O=   239.5
TIME=   46.00     I=   29.96    C=   3.002    D=   2.996    V=   160.3    O=   239.7
TIME=   48.00     I=   29.97    C=   3.001    D=   2.997    V=   160.2    O=   239.8
TIME=   50.00     I=   29.98    C=   3.001    D=   2.998    V=   160.2    O=   239.8
```

Fig. 3.9 INDUSTRIAL DEVELOPMENT MODEL

3.10.2 Steady State Analysis

The unchanging state of a system is called its "steady state." Although the given system may have an input and output, the value of the state variable does not change. An example is body temperature: it remains in a steady state even though there is continuous metabolism and heat is continually lost to the environment. It is important to note that not all the elements of a system reach the steady state at the same time. Thus, a person grows in height and weight while his body temperature stays at 37°C.

The growth pattern of a system (or its state) usually shows two phases: transient and steady. The transient state may be regarded as a state of continual change. During the transient, all quantities that can vary are in the process of varying. The steady state represents a condition of dynamic or state equilibrium: the state of a system does not change over time. The steady state may also be thought of as the limit of the transient state.

In the previous paragraph, reference is made to "equilibrium." Equilibrium is the equivalent to steady state. The term is used traditionally in dealing with a closed system and refers to change in the system and no interaction with the environment technically, the term steady state applies to an open system. However, when applied to system dynamics modeling for our purpose no distinction will be made.

Steady state analysis is a technique for finding the values of the variables in a system when they no longer change over time. These steady state values or equilibium values of the variables occur when the values of the variables in question are independent of time. Given the complete mathematical description of the system in the time domain, the steady state may be found by taking the limiting values of the variables as time approaches infinity. For example, the solutions to models expressed as differential equations are often expressed in two parts: the transient and the steady state. In the limit the transient becomes zero leaving the steady state solution. Since it is a simple manner to convert the difference equations of system dynamics models to equivalent differential equations, solving these differential equations at time equals infinity affords one way of obtaining the steady state.

In difference equation terminology, any level variable L_i is expressed as functions of rate varables R_j and the previous value of the level

$$L_i(t) = L_i(t-1) + dt \sum_{j=1}^{n} R_j\ (t-1) \qquad i=1, \ldots, m \qquad (3.1)$$

with the R_j's assumed to be constant over the interval time from t-dt to t.

The rate variables are of the form

$$R_j(t) = f\ [L_i(t),\ E_k(t),\ A_{ij}(t),\ A_{kj}(t)] \qquad (3.2)$$

where E_k are the set of exogenous inputs that affect R_j directly and A_{ij} and A_{kj} are the impacts of auxiliary variables in the causal streams from the ith level variable and kth exogenous input, respectively.

Using Eq. 3.1, the differential equation is formed as follows:

$$\lim_{t\to 0} \frac{L_i(t) - L_i(t-1)}{dt} = \sum_{j=1}^{n} R_j\ (t-1) \qquad (3.3)$$

A much simpler way of obtaining the steady state solution to a system dynamics model is to work directly with the difference equations. Thus, referring again to Eq. 3.1, we are looking for the value of the levels L_i when $L_i(t) = L_i(t-1)$. The levels on each side of Eq. 3.1 are obviously equal when

$$\sum_{j=1}^{n} R_j(t-1) = 0 \qquad (3.4)$$

Repeated substitution in Eq. 3.4 permits one to find the parameters $A_{ij}(t)$, $A_{kj}(t)$ and $L_i(t)$ from Eq. 3.2.

Applying the analytical concepts of Eqs. 3.3 and 3.4 to some of the simple feedback structures considered in the previous section is instructive. Consider the first order negative feedback system in Fig. 3.5. First, converting the level equation to continuous notation yields

$$L_t = L_{t-1} + (DT)\ (R_t) \qquad (3.5)$$

Forming the differential equation and substituting for R_t gives

$$dL_t/dt = R_t = (G-L_t)/T \qquad (3.6)$$

Separating variables and integrating both sides,

$$\int_{L_o}^{L_t} dL_t/(G-L_t) = \int_{o}^{t} dt/T$$

we obtain the solution

$$L_t = G - (G-N)e^{-t/T} \qquad (3.7)$$

where G and N are the desired and initial values of L_t. As t approaches infinity, L_t approaches L_e where L_e is the steady state values of the level variable:

$$L_e = G \qquad (3.8)$$

Now, using the much simpler procedure indicated by Eq. 3.5,

$$R_e = 0 \qquad (3.9)$$

Repeated substitution in the left hand side gives

$$D_e/T = 0 \qquad (3.10)$$

$$(G-L_e)/T = 0 \qquad (3.11)$$

and $L_e = G$ (3.12)

Consider now the more complex model of Fig. 3.8. The differential equation of the system for Y=1 is

$$\frac{dL_t}{dt} = RI_t - RO_t = L_t(FI-FO_t)$$
$$= L_t \times FON\ (X-\frac{L_t}{N}) \qquad (3.13)$$

The solution of Eq. 3.13 is

$$L_t = (NxX)/[1+(X-1)e^{-(X)(FON)(t)}] \qquad (3.14)$$

As t approaches infinity, we find the steady state solution to be

$$L_e = N \times X \qquad (3.15)$$

Using the alternative, simpler steady state analysis taken from Eq. 3.5:

$$RI_e = RO_e$$
$$L_e \times FI = L_e \times FO_e$$
$$(FON)(X) = (FON)(FOM_e) \qquad (3.16)$$
$$X = \frac{L}{N}$$
$$L_e = N \times X \qquad (3.17)$$

The concept of steady state equilibrium developed in this section is pervasive in the real-world: the need for its understanding is crucial in that it makes possible the establishment of the determinate conditions for a system. Only when the conditions of equilibrium are known can the analyst deduce all the various properties of the system. This was first understood in the physical sciences where such sciences as mechanics, thermodynamics, and physical chemistry took shape within a framework based on equilibrium. Now, in economics as well as in physics, equilibrium can be accurately specified at the level of theory, whether or not it can be found to be present empirically. For example the economists, with the aid of his supply and demand schedules, defines a given equilibrium as the point at which the two lines intersect. The thrust toward equilibrium is continually being thwarted by factors of population growth, technology, entrepreneurial innonation, etc.

3.10.3 Second-Order Systems

All positive feedback loops and first-order, negative-feedback loops generate a time response of exponential shape. Higher-order (second-order and above) negative feedback loops can generate sinusoidal behavior. In the remainder of the chapter these second-order systems will be discussed starting with the simpler and moving to the more complex.

To begin with, the behavior of a second-order, positive feedback loop will be examined using the following model:

$$L1.K=L1.J+(DT)(R1.JK) \qquad (3.18)$$

L1=N1

R1.KL=L2.K/A1 (3.19)

L2.K=L2.J+(DT)(R2.JK) (3.20)

L2=N2

R2.KL=L1.K/A2 (3.21)

Representing the two level equations by differential equations,

$$dL1_t/dt = L2_t/A1 \qquad dL2_t/dt = L1_t/A2$$

Differentiating $L1_t$ with respect to time again,

$$\frac{d^2L1_t}{dt^2} = \frac{1}{A1}\ \frac{dL2_t}{dt} \tag{3.22}$$

Substituting into the right-hand side of (3.22), one obtains the second-order differential equation for this system to be:

$$\frac{d^2L1_t}{dt^2} = \frac{L1_t}{A1XA2} \tag{3.23}$$

Since $\frac{d}{dt}\left(\frac{dL1_t}{dt}\right)^2 = 2\ \frac{dL1_t}{dt}\left(\frac{d^2L1_t}{dt^2}\right)$, (3.24)

multiplying both sides of (3.23) by $2dL1_t/dt$ gives

$$2\ \frac{d^2L1_t}{dt^2}\ \frac{dL1_t}{dt} = \frac{2}{A1xA2}\ L1_t\ \frac{dL1_t}{dt} \tag{3.25}$$

Separating variables and integrating

$$\left(\frac{dL1_t}{dt}\right)^2 = \frac{2}{A1xA2} \int L1_t\ dL1_t = L1_t^2\ \omega^2 \tag{3.26}$$

where $\omega^2 = 1/(A1)(A2)$. Then

$$\int \frac{dL1_t}{L1_t} = \pm\ \omega t \tag{3.27}$$

and the general solution to the equation for the system, equation 3.23, is

$$Ll_t = C_1 e^{\omega t} + C_2 e^{-\omega t} \qquad (3.28)$$

If either, but not both, of the constants A1 and A2 are negative, the feedback loop changes from positive to negative, and equation 3.23 becomes

$$\frac{d^2 Ll_t}{dt} + Ll_t \times \omega^2 = 0 \qquad (3.29)$$

Since the roots are now $\pm\sqrt{-\omega^2}$ or ωi and $-\omega i$, the general solution is

$$Ll_t = C_3 e^{\omega i t} + C_4 e^{-\omega i t} \qquad (3.30)$$

Since

$$e^{\omega i t} = \cos \omega t + i \sin \omega t$$

and $$e^{-\omega i t} = \cos \omega t - i \sin \omega t$$

the solution may be put in the form

$$Ll_t = (C_3 + C_4) \cos \omega t + i(C_3 - C_4) \sin \omega t$$

or, for convenience,

$$Ll_t = C_1 \sin \omega t + C_2 \cos \omega t \qquad (3.31)$$

The parameter ω is the frequency of oscillation measured in radians per unit of time.

The constants C_1 and C_2 for the general solutions to the second-order systems, equation 3.28 for positive and equation 3.31 for negative, are evaluated from initial conditions as follows:

Considering the positive case first,

$$\frac{dL1_t}{dt} = C_1\omega\ e^{\omega t} - C_2\omega\ e^{-\omega t} = \frac{L2_t}{A1} \tag{3.32}$$

At time zero,

$$C_1\omega - C_2\omega = N2/A1 \tag{3.33}$$

and, from (3.28),

$$C_1 + C_2 = N1 \tag{3.34}$$

Solving (3.33) and (3.34) simultaneously,

$$C_1 = \frac{N1}{2} + \frac{N2}{2}\sqrt{\frac{A2}{A1}} \tag{3.35}$$

and $$C_2 = \frac{N1}{2} - \frac{N2}{2}\sqrt{\frac{A2}{A1}} \tag{3.36}$$

For the second-order negative feedback case, we differentiate (3.31) to obtain

$$\frac{dL1_t}{dt} = C_1\omega \cos \omega t - C_2\omega \sin \omega t = \frac{L2_t}{A1} \tag{3.37}$$

At time zero

$$C_1 = N2\sqrt{A2/A1} \tag{3.38}$$

and from (3.31),

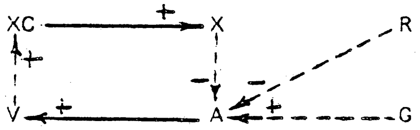
$$C_2 = N1 \tag{3.39}$$

A simple application of the second-order negative feedback system discussed above is presented in the model of Fig. 3.10.

3.10.4 Second-Order Negative Feedback with Rates In and Out

Referring to Fig. 3.10, it is evident that the equilibrium values of the level variables are equal to zero.

```
*     GRAVITRAIN TUBEWAY MODEL                                   DREW W-84
NOTE  ********************************************************************
NOTE  ********************  VERBAL DESCRIPTION  **************************
NOTE  ********************************************************************
NOTE  AS HIGHER SPEEDS ARE ATTAINED WITH GROUND TRANSPORTATION SYSTEMS,**
NOTE  THE PROBLEM OF SAFETY, ENVIRONMENTAL POLLUTION AND RIGHT-OF-WAY   **
NOTE  ACQUISITION ARE AMPLIFIED. ONE METHOD OF ALLEVIATING THESE        **
NOTE  PROBLEMS IS THE USE OF THE GRAVITRAIN CONCEPT IN WHICH A CAPSULE  **
NOTE  WOULD TRAVEL THROUGH A TUBEWAY FAR BENEATH THE EARTH'S SURFACE.   **
NOTE  THE CAPSULE WOULD BE ACCELERATED AND DECELERATED BY GRAVITY. TO   **
NOTE  ILLUSTRATE THE CONCEPT, ASSUME THAT NEW YORK AND SAN FRANCISCO    **
NOTE  ARE CONNECTED BY A TUBEWAY WITHIN A TUNNEL CONSTRUCTED ON A CHORD  *
NOTE  THROUTH THE EARTH. THE EQUATIONS OF MOTION FOR THE SYSTEM WITH    **
NOTE  THE CAPSULE INITIALLY IN SAN FRANCISCO WRITTEN IN DYNAMO ARE      **
NOTE  GIVEN BELOW.                                                      **
NOTE  ********************************************************************
NOTE  ********************  SYSTEM EQUATIONS  ****************************
NOTE  ********************************************************************
R     A.KL=(-X.K)*(G/R)      A-ACCELERATION OF THE CAPSULE (FT/SEC-SEC) **
C     G=32.2                 G-ACCELERATION OF GRAVITY (FT/SEC-SEC)     **
N     R=4000*CF              R-RADIUS OF THE EARTH (FT)                 **
L     V.K=V.J+(DT)(A.JK)     V-VELOCITY OF THE CAPSULE (FT/SEC)         **
N     V=0                                                               **
R     XC.KL=V.K              XC-POSITION CHANGE OF THE CAPSULE (FT/SEC) **
L     X.K=X.J+(DT)(XC.JK)    X-POSITION OF THE CAPSULE (FT)             **
N     X=-1500*CF                                                        **
C     CF=5280                CF-COVERSION FACTOR (FT/MI)                **
NOTE  ********************************************************************
NOTE  **********************  CAUSAL DIAGRAM  ****************************
NOTE  ********************************************************************
```



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NOTE                                                                    **
NOTE                                                                    **
NOTE                                                                    **
NOTE                                                                    **
NOTE                                                                    **
NOTE                                                                    **
NOTE                                                                    **
NOTE  ********************************************************************
NOTE  ********************  CONTROL STATEMENTS  **************************
NOTE  ********************************************************************
SPEC  DT=30/LENGTH=6000/PLTPER=300                                      **
PLOT  X=X(0,20E6)/V=V(0,20E3)                                           **
NOTE  ********************************************************************
NOTE  *********************  SYSTEM BEHAVIOR  ****************************
NOTE  ********************************************************************
RUN
```

```
     .0                     5.M                    10.M                    15.M
     .0                     5.T                    10.T                    15.T
   0.V - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
     |                V      |                       |                       |
     |                       |       V               |                       |
     |                       |                  V    |                       |
     |                       |                       V                       |
     |          X            |                      V|                       |
     |                       X              V        |                       |
     |                       | V       X             |                       |
     |        V              |               X       |                       |
     |                       |               X       |                       |
3000.- - - - - - - - - - - - - - - - - X - - - - - - - - - - - - - - - - - - - -
     |                       X                       |                       |
     |          X            |                       |                       |
     |                       |                       |                       |
     |                       |                       |                       |
     |                       |                       |                       |
     |                       |                       |                       |
     |V                      |                       |                       |
     |                   V   |                       |                       |
     |                       |            V          |                       |
6000.- - - - - - - - - - - - - - - - - - - - - - - - -V- - - - - - - - - - - - -
```

Fig. 3.10 GRAVITRAIN TUBEWAY MODEL

This is a condition that rarely exists outside of the realm of mechanical systems. It is far more common in most real world systems for the equilibrium values of the levels to have positive values. Consider the system represented by the following equations:

$$L1.K=L1.J+(DT)(RI.JK-RO.JK) \tag{3.40}$$

$$L1=N1$$

$$RO.KL=E2/A1 \tag{3.41}$$

$$RI.KL=L2.K/A1 \tag{3.42}$$

$$L2.K=L2.J+(DT)(R2.JK) \tag{3.43}$$

$$L2=N2$$

$$R2.KL=(E1-L1.K)/A2 \tag{3.44}$$

The system is illustrated in Fig. 3.11 in the form of a causal diagram comprised of two levels, three rates and four constants.

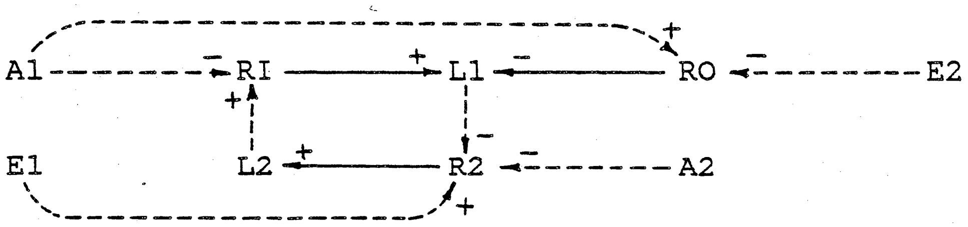

Fig. 3.11

Execution of steady state analysis serves to provide the significance of two of these parameters, E1 and E2:

$$RI_e = RO_e \qquad R2_e = 0$$

$$L2_e/A1 = E2/A1 \qquad (E1-L1_e)/A2 = 0$$

$$E2 = L2_e \qquad E1 = L1_e \tag{3.45}$$

The first-order differential equation representation of the system consists of the following two equations:

$$\frac{dL1_t}{dt} = RI_t - RO_t = \frac{L2_t}{A1} - \frac{E2}{A1} \qquad (3.46)$$

$$\frac{dL2_t}{dt} = R2_t = \frac{E1}{A2} - \frac{L1_t}{A2} \qquad (3.47)$$

The equivalent second-order differential equation is

$$\frac{d^2L2_t}{dt^2} = -\frac{1}{(A1)(A2)} (L2_t - E2) \qquad (3.48)$$

Placing equation 3.48 in a form for which we already have a general solution,

$$\frac{d^2}{dt}(L2_t - E2) + \frac{1}{(A1)(A2)} (L2_t - E2) = 0 \qquad (3.49)$$

The general solution is:

$$(L2_t - E2) = C_1 \sin \omega t + C_2 \cos \omega t \qquad (3.50)$$

Differentiating twice,

$$\frac{d(L2_t - E2)}{dt} = C_1\omega \cos \omega t - C_2 \omega \sin \omega t \qquad (3.51)$$

$$\frac{d^2(L2_t - E2)}{dt^2} = - C_1\omega^2 \sin \omega t - C_2\omega^2 \cos \omega t \qquad (3.52)$$

Substituting (3.50) and (3.52) in (3.49),

$$(C_1 \sin \omega t + C_2 \cos \omega t)(-\omega^2 + \frac{1}{A1 \times A2}) = 0 \qquad (3.53)$$

from which ω, the frequency, is

$$\omega = \frac{1}{\sqrt{(A1)(A2)}} \qquad (3.54)$$

The reciprocal of the frequency is the period of oscillation, P -- a parameter that has been found to be very useful in describing harmonic motion.

$$P = 2\pi/\omega = 2\pi\sqrt{(A1)(A2)} \qquad (3.55)$$

where A1 and A2 are the "coupling time constants".

To evaluate the constants of integration, use is made of (3.50) and (3.51) at time zero as follows:

$$C_2 = N2 - E2 \qquad (3.56)$$

and $C_1 = (E1 - N1)/(\omega \times A2) = (E1 - N1)\sqrt{A1/A2}$ (3.57)

An illustration of the type of system developed in this section is the supply and demand model presented in Fig. 3.12. The two levels in this system are inventory and production capacity which combine to form the second-order supply loop. Demand is assumed to be constant in this model. In Fig. 3.13 we see a supply-demand example with a second-order negative feedback demand loop with constant supply.

```
*   SUPPLY-CONSTANT DEMAND MODEL
NOTE  **************************************************************
NOTE  ******************    SYSTEM  EQUATIONS   ********************
NOTE  **************************************************************
L   I.K=I.J+(DT)(PR.JK-CR.JK)    I-INVENTORY (UNITS)              **
N   I=IN                                                          **
N   IN=X*DI                                                       **
C   X=1.5                        X-CONSTANT (DIM)                 **
N   DI=D*DC                     DI-DESIRED INVENTORY (UNITS)      **
C   D=1000                       D-DEMAND (UNITS/MO)              **
C   DC=12                       DC-DESIRED COVERAGE (MO)          **
R   PR.KL=PC.K/A1               PR-PRODUCTION RATE (UNITS/MO)     **
C   A1=1                        A1-CONSTANT (DIM)                 **
R   CR.KL=D                     CR-CONSUMPTION RATE (UNITS/MO)    **
L   PC.K=PC.J+(DT)(CCR.JK)      PC-PRODUCTION CAPACITY (UNITS/MO) **
N   PC=DPC                                                        **
N   DPC=D*A1                DPC-DESIRED PROD. CAPACITY (UNITS/MO) **
R   CCR.KL=(DI-I.K)/A2      CCR-CAPACITY CHANGE RATE (UNITS/MO-MO) **
N   A2=CCD*DI/DPC               A2-CONSTANT (MO )                 **
C   CCD=10                     CCD-CAPACITY CHANGE DELAY (MO)     **
NOTE  **************************************************************
NOTE  ******************    CAUSAL   DIAGRAM    ********************
NOTE  **************************************************************
NOTE                                                              **
NOTE                                                              **
NOTE                                                              **
NOTE                                                              **
NOTE                                                              **
NOTE                                                              **
NOTE                                                              **
NOTE                                                              **
NOTE                                                              **
NOTE                                                              **
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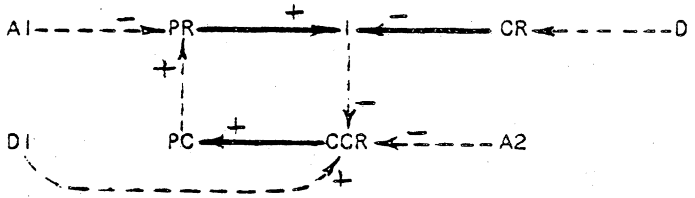

```
NOTE  **************************************************************
NOTE  *****************   CONTROL  STATEMENTS     ******************
NOTE  **************************************************************
SPEC  DT=.1/LENGTH=100/PLTPER=5/PRTPER=10                         **
PLOT  I=I(0,30000)/PC=P(0,2000)                                   **
PRINT I,PC                                                        **
NOTE  **************************************************************
NOTE  ******************    COMPUTER  OUTPUT    ********************
NOTE  **************************************************************
```

I=I, PC=P

```
       .0                     7.5T                    15.T                   22.5T I
       0.                     500.                   1000.                   1500. P
     .0-- - - - - - - - - - - - - - - - - - - - - - - P - - - - I - - - - - - - - - -
        |                       |           P           |       I               |
        |                       |  P                    | I                     |
        |                     P |                 I     |                       |
        |                     P |         I             |                       |
        |                       | I P                   |                       |
        |                    I  |             P         |                       |
        |                  I    |                       |P                      |
        |                    I  |                       |            P          |
        |                       |  I                    |                     P |
    50.-- - - - - - - - - - - - - - - - - - I - - - - - - - - - - - - - - - - - -P- -
        |                       |                   I   |                       | P
        |                       |                       |   I              P    |
        |                       |                       |        I              |
        |                       |                    P  |         I             |
        |                       |         P             |      I                |
        |                       |P                      |I                      |
        |                    P  |               I       |                       |
        |                     P |      I                |                       |
        |                       |    P                  |                       |
  99.99-- - - - - - - - - -I- - - - - - - - - P - - - - - - - - - - - - - - - - - -
```

Fig. 3.12 SUPPLY - CONSTANT DEMAND MODEL

```
FILE:5002   CONSTANT SUPPLY- DEMAND MODEL

*    CONSTANT SUPPLY- DEMAND MODEL
NOTE ***************************************************************
NOTE *****************       SYSTEM  EQUATIONS    ******************
NOTE ***************************************************************
L    I.K=I.J+(DT)(PR.JK-CR.JK)      I-INVENTORY (UNITS)              **
N    I=IN                                                            **
N    IN=DI                                                           **
N    DI=DC*PC                     DI-DESIRED INVENTORY (UNITS)       **
C    DC=1.0                       DC-DESIRED COVERAGE (MO)           **
N    PC=PCCN*P                    PC-PRODUCTION CAPACITY (UNITS/MO)  **
C    P=100000                      P-POPULATION (PERSONS)            **
C    PCCN=100                 PCCN-PER CAP CONSUMP NORM (UNITS/MO-PER)**
R    PR.KL=PC                     PR-PRODUCTION RATE (UNITS/MO)      **
R    CR.KL=PCC.K*P                CR-CONSUMPTION RATE (UNITS/MO)     **
L    PCC.K=PCC.J+(DT)(PCCCR.JK) PCC-PER CAPITA CONSUMP (UNITS/MO-PER)**
N    PCC=PCCI                                                        **
N    PCCI=Y*PCCN                                                     **
C    Y=1.5                         Y-CONSTANT (DIM)                  **
R    PCCCR.KL=(I.K-DI)/A2       PCCCR-PER CAP CONSUMP CHANGE RATE    **
C    A2=.4E6                           (UNITS/PER-MO**2)             **
NOTE ***************************************************************
NOTE *****************       CAUSAL   DIAGRAM     ******************
NOTE ***************************************************************
NOTE                                                                 **
NOTE                                                                 **
NOTE                                                                 **
NOTE                                                                 **
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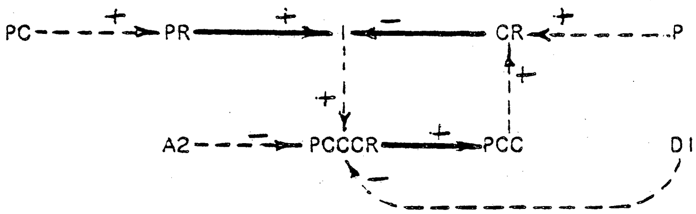


```
NOTE ***************************************************************
NOTE ****************       CONTROL  STATEMENTS     *****************
NOTE ***************************************************************
SPEC  DT=.2/LENGTH=20/PLTPER=1/PRTPER=1                              **
PLOT  I=I(0,20E6)/PCC=C(0,200)                                       **
PRINT I,PCC                                                          **
NOTE ***************************************************************
NOTE *****************       COMPUTER  OUTPUT     ******************
NOTE ***************************************************************
RUN

23 SYMBOL TABLE ENTRIES
```

Fig. 3.13 CONSTANT SUPPLY - DEMAND MODEL

3.10.5 Second Order Positive Feedback with Rates In and Out

This system can be represented by two levels, two rates, and six constants combined as follows:

L1.K=L1.J+(DT)(R1I.JK-R1O.JK) (3.58)

L1=N1

R1I.KL=1/A1I (3.59)

R1O.KL=L2.K/A1O (3.60)

L2.K=L2.J+(DT)(R2I.JK-R2O.JK) (3.61)

L2=N2

R2I.KL=1/A2I (3.62)

R2O.KL=L1.K/A2O (3.63)

The causal diagram corresponding to these equations is presented in Fig. 3.14.

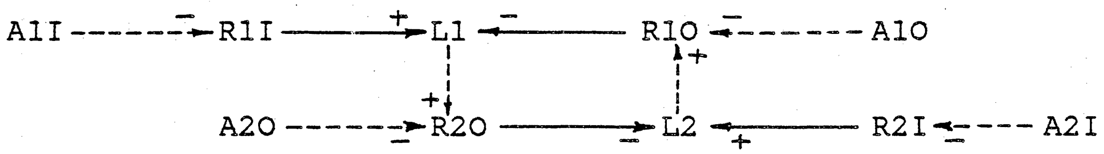


FIG. 3.14

Referring to the causal diagram in the figure for this system, one sees that the feedback loop contains two levels making it second-order. The two rates in the loop are rates-out giving two negative relationships around the loop, making the polarity of the feedback loop positive. The rates in, R1I and R2I, are constant.

As is usual with our approach, steady state analysis is performed. Equating R1I to R1O and R2I to R2O at equilibrium yields the values of the level variables at equlibrium, E1 and E2. They are found to be

$$E1 = A2O/A2I \text{ and } E2 = A1O/A1I \qquad (3.64)$$

The first step in obtaining an analytical solution is the formation of the differential equations of the system. Converting the two level equations to first-order differential equations,

$$dL1_t/dt = R1I_t - R1O_t \text{ and } dL2_t/dt = R2I_t - R2O_t \qquad (3.65)$$

Substituting for the rates and making use of the equations in (3.64) to express the differential equations in terms of the equilibrium parameters,

$$\frac{dL1_t}{dt} = \frac{E2 - L2_t}{A1O} \quad \text{and} \quad \frac{dL2_t}{dt} = \frac{E1 - L1_t}{A2O}$$

Differentiating $L1_t$ with respect to time again, and substituting for $dL2_t/dt$,

$$\frac{d^2L1_t}{dt^2} = -\frac{dL2_t}{dt}\,\frac{1}{A1O} = \frac{L1_t - E1}{A1O\text{x}A2O} \qquad (3.66)$$

Expressing the left side of the equation in more convenient, but equivalent, form, the second-order differential equation representing the system is

$$\frac{d^2(L1_t - E1)}{dt^2} - \frac{(L1_t - E1)}{(A1O\text{x}A2O)} = 0 \qquad (3.67)$$

The general solution of equation 3.67 is

$$(L1_t - E1) = C_1e^{\omega t} + C_2e^{-\omega t} \tag{3.68}$$

Repeated differentiation of the solution yields:

$$\frac{d(L1_t - E1)}{dt} = C_1\omega e^{\omega t} - C_2\omega e^{-\omega t} \tag{3.69}$$

and

$$\frac{d^2(L1_t - E1)}{dt^2} = C_1\omega^2e^{\omega t} - C_2\omega^2e^{-\omega t} \tag{3.70}$$

Substitution of (3.68) and (3.70) in the differential equation (3.67) serves to evaluate the parameter ω, which is

$$\omega = 1 / \sqrt{A10 \times A20} \tag{3.71}$$

Referring to the figure for this system, the next step is the evaluation of the constants C_1 and C_2 from the initial conditions. Taking equation 3.68 at time zero,

$$C_1 + C_2 = N1 - E1, \tag{3.72}$$

gives us one equation containing the two unknown constants. Now working with equation 3.68, and equating it to the original first-order differential equation,

$$\frac{dL1_t}{dt} = C_1\omega e^{\omega t} - C_2\omega e^{-\omega t} = \frac{E2 - L2_t}{A10} \tag{3.73}$$

At time zero we are left with,

$$C_1 - C_2 = (E2 - N2)/(\omega \times A10) \tag{3.74}$$

Solving (3.72) and (3.74) simultaneously gives

$$C_1 = \frac{(E2 - N2) + (\omega \times A1O)(N1 - E1)}{2\omega \times A1O} \qquad (3.75)$$

$$C_2 = \frac{(N1 - E1)(\omega \times A1O) - (E2 - N2)}{2\omega \times A1O} \qquad (3.76)$$

The final solution is obtained by substituting for C_1 and C_2 in the general solution and its derivatives. First, taking equation 3.68

$$L1_t = E1 + \frac{(E2-N2)+(\omega \times A1O)(N1-E1)}{2\omega \times A1O} e^{\omega t} + \frac{(N1-E1)(\omega \times A1O)-(E2-N2)}{2\omega \times A1O} e^{-\omega t} \qquad (3.77)$$

Now, solving equation 3.73 for $L2_t$,

$$L2_t = E2 - \frac{(E2-N2)+(\omega \times A1O)(N1-E1)}{2} e^{\omega t} + \frac{(N1-E1)(\omega \times A1O)-(E2-N2)}{2} e^{-\omega t} \qquad (3.78)$$

Now if the second-order positive feedback loop is formed about the rates-in instead of the rates-out, the causal diagram changes from Fig. 3.14 to Fig 3.14.

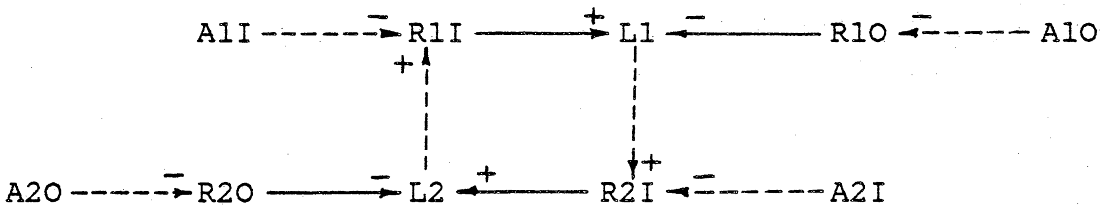


FIG. 3.15

The system equations are:

$$\mathrm{L1.K=L1.J+(DT)(R1I.JK-R1O.JK)} \tag{3.79}$$

$$\mathrm{L1=N1}$$

$$\mathrm{R1I.KL=L2.K/A1I} \tag{3.80}$$

$$\mathrm{R1O.KL=1/A1O} \tag{3.81}$$

$$\mathrm{L2.K=L2.J+(DT)(R2I.JK-R2O.JK)} \tag{3.82}$$

$$\mathrm{L2=N2}$$

$$\mathrm{R2I.KL=L1.K/A2I} \tag{3.83}$$

$$\mathrm{R2O.KL=L2.K/A2O} \tag{3.84}$$

Equating rates-in and rates-out for the subsystems defines the equilibrium values of the level variables to be

$$\mathrm{EI = A2I/A2O} \quad \text{and} \quad \mathrm{E2 = A1I/A1O} \tag{3.85}$$

The two first-order differential equations of the system formed the level equations are

$$\frac{d\mathrm{L1}_t}{dt} = \frac{\mathrm{L2}_t - \mathrm{E2}}{\mathrm{A1I}} \quad \text{and} \quad \frac{d\mathrm{L2}_t}{dt} = \frac{\mathrm{L1}_t - \mathrm{E1}}{\mathrm{A2I}} \tag{3.86}$$

Substitution of one into the second derivative of the other permits us to develop the second-order differential equation of the system,

$$\frac{d^2(\mathrm{L1}_t - \mathrm{E1})}{dt^2} - \frac{(\mathrm{L1}_t - \mathrm{E1})}{(\mathrm{A1I} \times \mathrm{A2I})} = 0 \tag{3.87}$$

The forms of the general solution are:

$$(L1_t - E1) = C_1 e^{\omega t} + C_2 e^{-\omega t} \tag{3.88}$$

$$\frac{d(L1_t - E1)}{dt} = C_1 \omega e^{\omega t} - C_2 \omega e^{-\omega t} \tag{3.89}$$

and $$\frac{d^2(L1_t - E1)}{dt^2} = C_1 \omega^2 e^{\omega t} - C_2 \omega^2 e^{-\omega t} \tag{3.90}$$

The evaluation of the parameters in the usual manner gives the values of ω, C_1, and C_2:

$$\omega = 1/\sqrt{A1I \times A2I} \tag{3.91}$$

$$C_1 = \frac{(N2 - E2) + (\omega \times A1I)(N1 - E1)}{2\omega \times A1I} \tag{3.92}$$

$$C_2 = \frac{(N1 - E1)(\omega \times A1I) - (N2 - E2)}{2\omega \times A1I} \tag{3.93}$$

The final solution is

$$L1_t = E1 + \frac{(N2-E2)+(\omega x A1I)(N1-E1)}{2\omega \times A1I} e^{\omega t} + \frac{(N1-E1)(\omega x A1I)-(N2-E2)}{2\omega \times A1I} e^{-\omega t} \tag{3.94}$$

and

$$L2_t = E2 + \frac{(N2-E2)+(\omega x A1I)(N1-E1)}{2} e^{\omega t} + \frac{(N1-E1)(\omega x A1I)-(N2-E2)}{2} e^{-\omega t} \tag{3.95}$$

In order for pure exponential growth to appear immediately at time equals zero, the last terms of the final solutions must equal zero. For this to be true, it is necessary that

$$N2 = E2 + (N1 - E1) \sqrt{A1I/A2I} \qquad (3.96)$$

For this special case

$$L1_t = E1 + (N1 - E1)\, e^{\omega t} \qquad (3.97)$$

and

$$L2_t = E2 + (N2 - E2)\, e^{\omega t} \qquad (3.98)$$

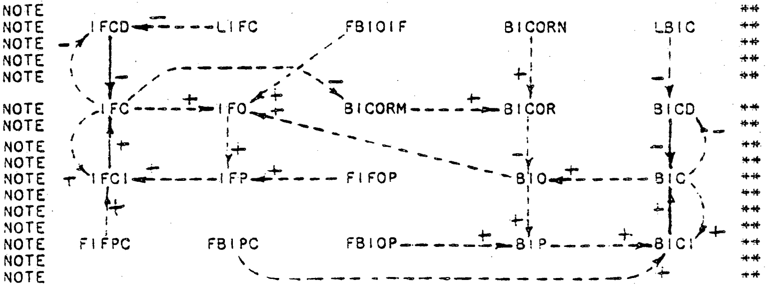
A practical application of the second-order positive feedback concepts described in this solution is presented in the model of Fig. 3.16.

3.10.6 Second-Order Systems with First-Order Loops

Consider the interdependence of two species, the first of which serves as food for the second. To make the discussion more objective, assume the first species as consisting of deer, the second of wolves. Models of this type are referred to as preditor-prey models and they are of interest in analyzing ecological balance. Another similar class of models are host-parasite models, in which one of the species might be humans and the other bacteria with the idea being to investigate the spread of a fatal disease.

Let us consider the first species in isolation. If there are no wolves to kill the deer, than the deer population

```
*    INFRASTRUCTURE INDUCED DEVELOPMENT MODEL
NOTE  *****************************************************************
NOTE  ******************      SYSTEM EQUATIONS      ********************
NOTE  *****************************************************************
L    BIC.K=BIC.J+(DT)(BICI.JK-BICD.JK)                               **
N    BIC=BICN                                                        **
NOTE  BIC  - BASIC INDUS CAPITAL                                     **
C    BICN=.5E9                                                       **
NOTE  BICN - BASIC INDUS CAPITAL INITIAL                             **
R    BICD.KL=BIC.K/LBIC                                              **
NOTE  BICD - BASIC INDUS CAPITAL DEPRECIATION                        **
C    LBIC=20                                                         **
NOTE  LBIC - LIFETIME BASIC INDUS CAPITAL                            **
R    BICI.KL=BIP.K*FBIPC                                             **
NOTE  BICI - BASIC INDUS CAPITAL INVESTMENT                          **
C    FBIPC=.2                                                        **
NOTE FBIPC - FRACT BASIC INDUS PROD TO CAPITAL                       **
A    BIP.K=BIO.K*FBIOP                                               **
NOTE  BIP  - BASIC INDUS PRODUCT                                     **
C    FBIOP=.5                                                        **
NOTE FBIOP - FRACT BASIC INDUS OUTPUT TO PROD                        **
A    BIO.K=BIC.K/BICOR.K                                             **
NOTE  BIO  - BASIC INDUS OUTPUT                                      **
A    BICOR.K=BICORN*BICORM.K                                         **
NOTE BICOR - BASIC INDUS CAPITAL OUTPUT RATIO                        **
C    BICORN=1.0                                                      **
NOTE BICORN - BASIC INDUS CAPITAL OUTPUT RATIO NORMAL                **
A    BICORM.K=IFCN/IFC.K                                             **
NOTE BICORM - BASIC INDUS CAPITAL OUTPUT RATIO MULT                  **
A    IFO.K=BIO.K*FBIOIF                                              **
NOTE  IFO  - INFRASTRUCTURE OUTPUT                                   **
C    FBIOIF=.2                                                       **
NOTE FBIOIF - FRACT BASIC INDUS OUTPUT TO INFRA                      **
A    IFP.K=IFO.K*FIFOP                                               **
NOTE  IFP  - INFRASTRUCTURE PRODUCT                                  **
C    FIFOP=.25                                                       **
NOTE FIFOP - FRACT INFRA OUTPUT TO PRODUCT                           **
R    IFCI.KL=IFP.K*FIFPC                                             **
NOTE  IFCI - INFRA CAPITAL INVESTMENT                                **
C    FIFPC=.1                                                        **
NOTE FIFPC - FRACT INFRA PRODUCT TO CAPITAL                          **
L    IFC.K=IFC.J+(DT)(IFCI.JK-IFCD.JK)                               **
N    IFC=IFCN                                                        **
NOTE  IFC  - INFRASTRUCTURE CAPITAL                                  **
C    IFCN=.1E9                                                       **
NOTE  IFCN - INFRA CAPITAL NORMAL                                    **
R    IFCD.KL=IFC.K/LIFC                                              **
NOTE  IFCD - INFRA CAPITAL DEPRECIATION                              **
C    LIFC=50                                                         **
NOTE  LIFC - LIFETIME INFRA CAPITAL                                  **
NOTE  *****************************************************************
NOTE  ********************      CAUSAL  DIAGRAM      ******************
NOTE  *****************************************************************
```



```
NOTE  *****************************************************************
NOTE  ********************      CONTROL  STATEMENTS      **************
NOTE  *****************************************************************
SPEC  DT=1/LENGTH=100/PLTPER=2/PRTPER=5                              **
PLOT  BIC=I/IFC=F                                                    **
PRINT BIC(1,6),BIO(1,6),BIP(1,6),IFC(1,6),IFO(1,6),IFP(1,6)          **
```

Fig. 3.16 INFRASTRUCTURE INDUCED DEVELOPMENT will expand. If we let R1I stand for the natural rate of increase of the first species and L1, the number of that species, then it is realistic to assume that the rate of increase of the deer population is proportional to the size of the population:

R1I.KL=L1.K*G1I (3.99)

where G1I is a constant. Similarly, the rate of decrease of the wolf population depends on its size,

R2O.KL=L2.K*G2O (3.100)

where L2 is the size of the wolf population, R2O is the rate of decrease of that population and G2O is a constant.

Having considered the species separately, we must now take their interaction into account. We shall assume that the number of kills of deer by wolves is proportional to the product of the two populations,

R1O.KL=L1.K*L2.K*G1O (3.101)

and that the wolf population fluorishes in a similar manner,

R2I.KL=L1.K*L2.K*G2I (3.102)

The system equations are completed by writing the state equations for the deer and wolf subsystems:

L1.K=L1.J+(DT)(R1I.JK-R1O.JK) (3.103)

L1=N1

L2.K=L2.J+(DT)(R2I.JK-R2O.JK) (3.104)

L2=N2

We have thus arrived at a system dynamics model for the interaction of the two species. The initial values, N1 and N2, are obtained by counting the number of each at a given time. The purpose of the model is to determine the sizes of the two populations for the future.

Consider now a second model, similar in form, but leading to quite different solutions. This model involves two groups of preditors, instead of preditors and preys as in the first model. In this second model, the preditor species are in competition with each other, so that members of one often killed members of the other. The system equations are:

L1.K=L1.J+(DT)(R1I.JK-R1O.JK) (3.105)

L1=N1

R1I.KL=G1I*L1.K (3.106)

R1O.KL=L1.K*L2.K*G1O (3.107)

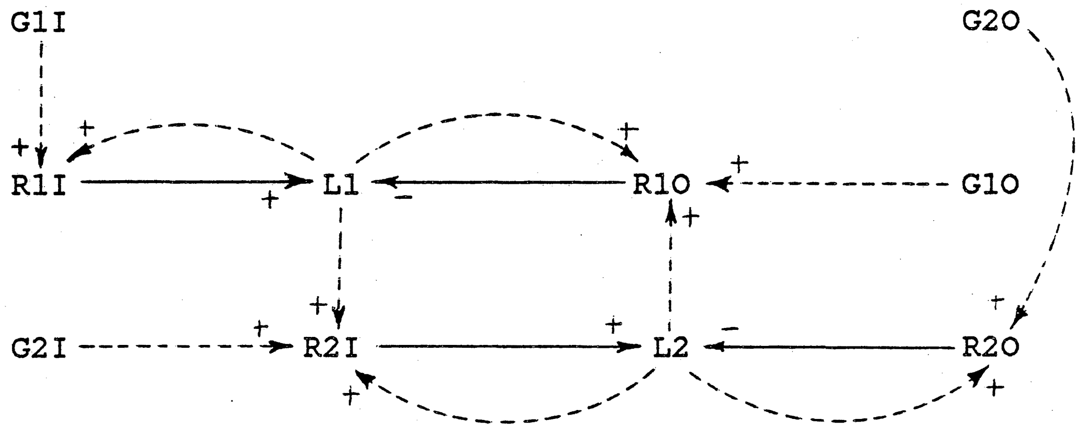
L2.K=L2.J+(DT)(R2I.JK-R2O.JK) (3.108)

L2=N2

R2I.KL=L2.K*G2I (3.109)

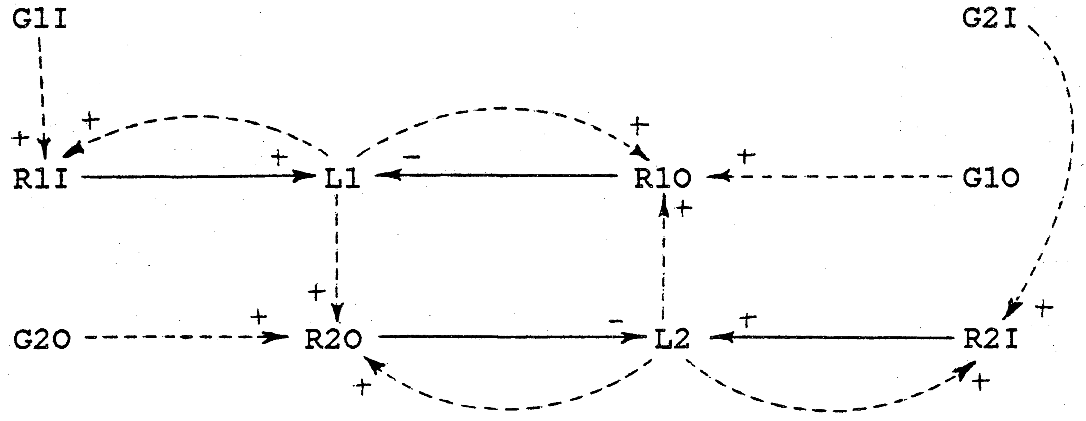
R2O.KL=L1.K*L2.K*G2O (3.110)

The causal diagram for these two models appear in Figs. 3.17 and 3.18. We see that the preditor-prey model is second-order negative and that the two-preditor model is second-order positive. The differential equations for the first model are:



SECOND-ORDER NEGATIVE FEEDBACK WITH FIRST-ORDER LOOPS

Fig. 3.17



SECOND-ORDER POSITIVE FEEDBACK WITH FIRST-ORDER LOOPS

Fig. 3.18

$$\frac{dL1_t}{dt} = G1I \times L1_t - G1O \; X \; L1_t \times L2_t \qquad (3.111)$$

$$\frac{dL2_t}{dt} = G2I \times L1_t \times L2_t - G2O \times L2_t \qquad (3.112)$$

The simplest model representing the two-preditor case is

$$\frac{dL1_t}{dt} = G1I \times L1_t - G1O \; X \; L1_t \times L2_t \qquad (3.113)$$

$$\frac{dL2_t}{dt} = G2I \times L2_t - G2O \times L1_t \times L2_t \qquad (3.114)$$

The differential equations of these models (and indeed all of the second-order models that we consider in this chapter) are examples of a particularly interesting type of simultaneous first-order differential equations in that time does not enter into them explicitly. As a matter of fact, time can be eliminated by dividing the second equation by the first for each case to get equations of the form,

$$\frac{dL2}{dL1} = f\ (L1,\ L2) \qquad (3.115)$$

Often we are more interested in knowing the values of the state variables with respect to each other rather than knowing the exact times the values occur. The locus of the positions of L1 and L2 on a graph, known as a "trajectory," must be a solution of the first-order differential equation of (3.113).

Such equations have been studied extensively by Lefschetz [76]. An important result of his work is the following existence and uniqueness theorem:

> If $(L1_o, L2_o)$ is a point of the plane near which the partial derivatives of f(L1,L2) is continuous, then there is a unique solution of the differential equations $(dL1_t/dt$ and $dL2_t/dt)$ passing through $(L1_o, L2_o)$ at t=0. The solutions $(L1_t$ and $L2_t)$ describe a simple curve which depends on the initial position.

Many useful conclusions can be drawn from this theorem.

First of all, we note that in our two cases the trajectories do not depend on the starting time. Hence, there is a unique trajectory through each point on the L1, L2 plane. As Lefschetz points out, an immediate consequence is that two trajectories cannot cross, for we would have two different trajectories through the same point. Similarly, a trajectory cannot cross itself.

We must now discuss the relations between initial conditions and equilibrium. If the starting point is in equilibrium, we have a one-point trajectory. If the starting point is not an equilibrium point, then the trajectory is a simple curve. Thus, an equilibrium point can never be reached if we start out of equilibrium, although the trajectory can approach it assymptotically. In summary, three kinds of behavior are possible for a trajectory in the neighborhood of an equilibrium point:

1. stable equilibrium, in which whenever we start near the equilibrium, we approach equilibrium,
2. unstable equilibrium, in which whenever we start near equilibrium, we proceed away from it, and
3. harmonic equilibrium, in which whenever the trajectory is a closed curve with equilibrium inside, we move cyclically around the equilibrium.

With this understanding of the trajectories, curves of the solutions of the models, we are ready to derive these solutions. First we will concentrate on the negative feedback model of Fig. 3.17. Employing steady state analysis:

$$R1I_e = R1O_e \qquad\qquad R2I_e = R2O_e$$

$$L1_e x G1I = L1_e x L2_e x G1O \qquad\qquad L1_e x L2_e x G2I = L2_e x G2O$$

$$L2_e = G1I/G1O = E2 \quad (3.116) \qquad\qquad L1_e = G2O/G2I = E1 \quad (3.117)$$

Another equilibrium point exists at (0,0) which is, of course, trivial. Therefore, we shall concentrate on determining the nature of the trajectories (the solutions) near E1, E2. Let U = L1 - E1 and V = L2 - E2. Then

$$\frac{dU}{dt} = \frac{dL1}{dt} = (U+E1)[G1I-G1O(V+E2)]=(U+E1)(-G1OxV) \qquad (3.118)$$

$$\frac{dV}{dt} = \frac{dL2}{dt} = (V+E2)[G2I(U+E1)-G2O]=(V+E2)(+G2IxU) \qquad (3.119)$$

Now a major tool in arriving at a useful solution is given in the following theorem:

> The nature of a trajectory near an equilibrium point may be determined by expanding L1 = f(L1,L2) and L2 = f(L1,L2) in a Taylor series around the equilibrium, and keeping only linear terms. The solutions of these linear equations near the equilibrium will have the same general nature as the exact solutions [76].

The linear parts of (3.118) and (3.119) are:

$$\frac{dU}{dt} \sim -G1O \text{ x } E1 \text{ x } V \qquad (3.120)$$

$$\frac{dV}{dt} \sim +G2I \text{ x } E2 \text{ x } U \qquad (3.121)$$

Treating these as exact equations in accordance with the theorem above, it follows that

$$d^2U/dt^2 = -\ (G1I)(G2O)(U) \qquad (3.122)$$

We have seen in previous sections that the most general solution of this second-order differential equation is

$$U = C_1 \sin \omega t + C_2 \cos \omega t \qquad (3.123)$$

$$V = -r\, C_1 \cos \omega t + r\, C_2 \sin \omega t \qquad (3.124)$$

where $r = \omega/(G1O \text{ x } E1)$ and $\omega = \sqrt{(G1I)(G2O)}$ (3.125)

the motion is, of course, periodic. Since the starting time is unimportant, let us start at a time when U = 0, requiring that $C_2 = 0$, giving

$$U = C_1 \sin \omega t \qquad (3.126)$$

$$V = -r\, C_1 \cos \omega t \qquad (3.127)$$

Since $U^2/C_1^2 + V^2/(r^2C_1^2) = 1$ is the equation for an ellipse, the trajectories are elliptical with period,

$$P = 2\pi/\omega \tag{3.128}$$

It should be noted that unlike the forms used in (3.54) and (3.55) for the frequency and the period in which both are expressed as functions of the coupling time-constants, the models in this section have their rates written with the constants in the numerators (3.99 to 3.102). When so done these constants are called "gain" or "amplification" coefficients.

To find the exact trajectories -- the exact solution, that is -- we form the equation corresponding to (3.115) from (3.111) and (3.112) as follows:

$$\frac{dL2}{dL1} = \frac{dL2_t/dt}{dL1_t/dt} = \frac{G2I \times L1_t\ L2_t - G2O \times L2_t}{G1I \times L1_t - G1O \times L1_t\ L2_t} \tag{3.129}$$

Separating variables and integrating

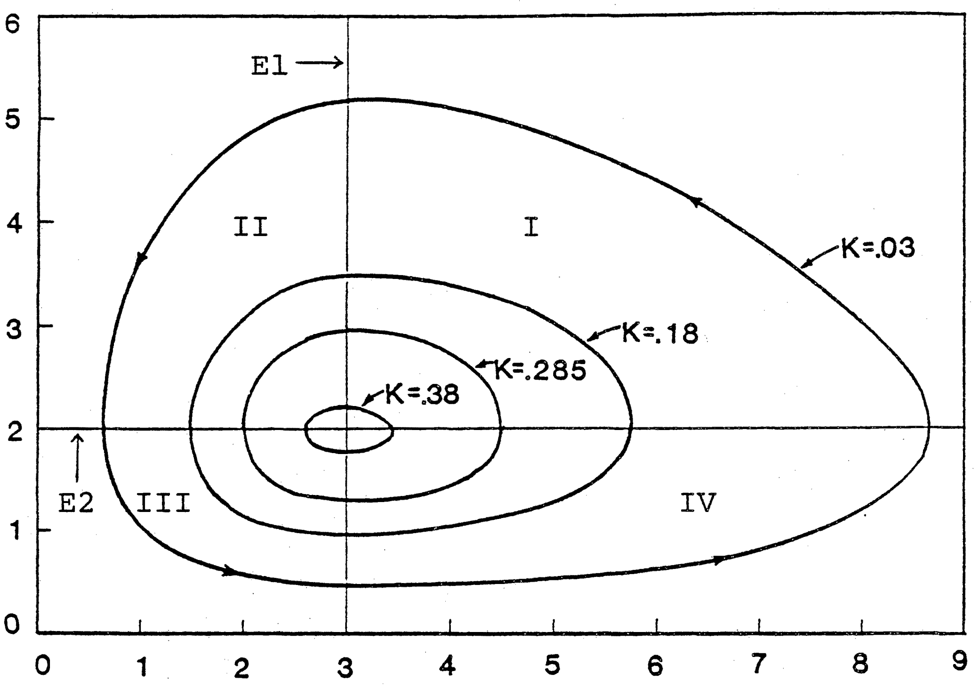
$$\int \frac{G1I-G1O x L2}{L2}\, dL2 = \int \frac{G2I x L1-G2O}{L1}\, dL1 \tag{3.130}$$

and $G1I \ln L2 - G1O x L2 = G2I x L1 - G2O \ln L1 + \ln K$ (3.131)

where ln K is the constant of integration to be evaluated from the initial conditions. The final solution is

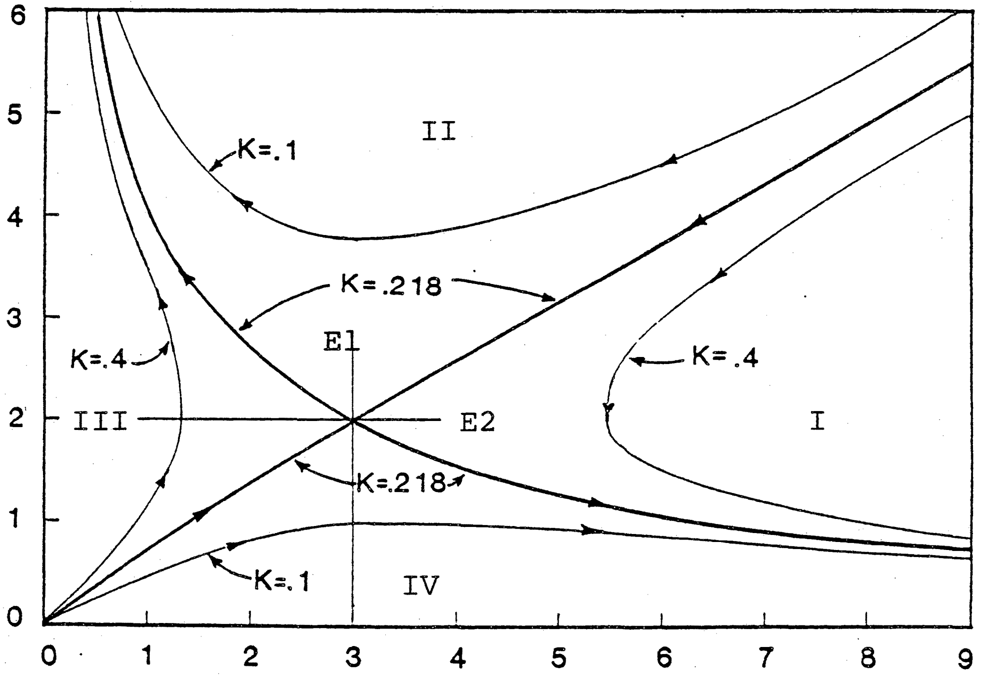
$$K = L1^{G2O} L2^{G1I} e^{-(G21xL1+G1OxL2)} = N1^{G2O} N2^{G1I} e^{-(G2IxN1+G1OxN2)} \tag{3.132}$$

Using the value of G1I=4, G1O=2, G2I=1 and G2O=3, this equation is graphed in Fig. 3.19.



TRAJECTORIES FOR SECOND-ORDER NEGATIVE FEEDBACK SYSTEM

Fig. 3.19



TRAJECTORIES FOR SECOND-ORDER POSITIVE FEEDBACK SYSTEM

Fig. 3.20

Let us now turn to the second model, the second-order positive feedback system depicted in Fig. 3.18. The major difference arises when we find the behavior near (E1,E2). Following the steps from (3.118) to (3.122) we obtain

$$d^2U/dt^2 = (G1I)(G2I)(U) \qquad (3.133)$$

in this case the solution is not periodic. The most general solution of this equation we have found to be in previous sections is

$$U = C_1e^{\omega t} + C_2e^{-\omega t} \qquad (3.134)$$

where $\omega = \sqrt{(G1I)(G2I)}$ (3.135)

If we differentiate this, we can use it to obtain

$$V = -r\ C_1e^{\omega t} + r\ C_2e^{-\omega t} \qquad (3.136)$$

where $r = \omega/(G1O \times E1)$ (3.137)

From these solutions we find the relation

$$U^2 - (V/r)^2 = 4\ C_1\ C_2\ ; \qquad (3.138)$$

hence, the first approximation trajectories are hyperbolas, with (E1,E2) as center.

To obtain more information concerning the trajectories we carry out the method of (3.129 - 3.132) to find a parametric solution in L1 and L2:

$$\frac{dL2}{dL1} = \frac{L2\ (G2I - G2O \times L1)}{L1\ (G1I - G1O \times L2)} \qquad (3.139)$$

with solution

$$L1^{-G2I}\ L2^{G1I}\ e^{(G2O \times L1 - G1O \times L2)} \qquad (3.140)$$

where $K = N1^{-G2I}\ N2^{G1I}\ e^{(G2O \times N1 - G1O \times N2)}$ (3.141)

Particularly interesting are the curves passing through (E1,E2) where

$$K=E1^{-G2I}E2^{G1I}e^{(G2O\mathrm{x}E1-G1O\mathrm{x}E2)}=E1^{-G2I}E2^{G1I}e^{(G2I-G1I)} \qquad (3.142)$$

Using the value of G1I=4, G1O=2, G2I=3 and G2O=1, these are shown by heavy lines on the graph of Fig. 3.20. Since trajectories cannot cross, and since (E1,E2) is a point trajectory, the remainder of these curves must actually represent four separate trajectories and, indeed, serve to divide the positive quadrant into four regions.

We shall conclude this section by interpreting the results of the models introduced. This discussion will center on Figs. 3.19 and 3.20. In Fig. 3.19 we have cyclic behavior. Our cycle always starts with a positive number of deer, L1, and wolves, L2, and passes through four stages:

1. Deer are in abundance. The number of wolves increases, cutting down on the number of deer.
2. When the deer drop to E1, the wolves find insufficient food and hence start declining in number. Deer continue to decline.
3. When the wolves drop to E2 in number, deer can start increasing in number. Wolves continue to decline.
4. When deer climb back to E1, wolves start increasing again, until they reach a level E2. At this point Stage I is reentered. Since neither species dies out,

we have a type of cyclic equilibrium. The numbers the graph can be thought of as being expressed in ten-thousands of dear and thousands of wolves.

In the model of Fig. 3.20, we see that although neither preditor species dies out in finite time, one tends to vanish asymptotically amounting to the eventual extinction of one of the species. There are again four separate regions, but this time they determine the long-term outcome:

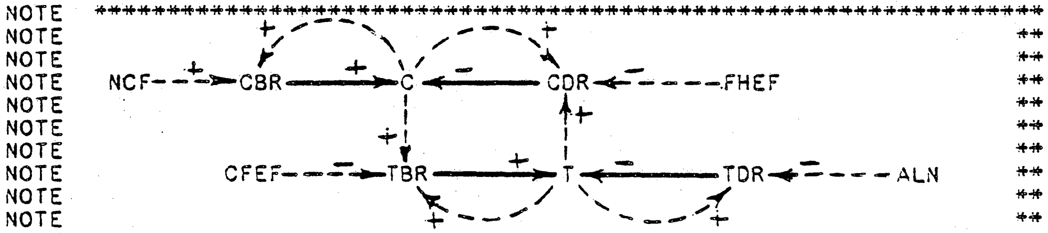
1. There are a large number of both species to start with causing a large number of kills and steady decrease until the second species drops to the critical level of E2. Then the first species starts to increase again and to wipe its enemy out.
2. This is like I, except that the critical level is E1 and it is the first species to be eliminated.
3. There are small numbers to start with and hence relatively little conflict. Thus each species can increase, until the second species reaches the critical level of E2. Then it begins to dominate the first species, and eventually eliminates it.
4. This is like Region III, except for the fact that the critical level is E1 and it is the second species that dies out.

A simple illustration of each of the two systems developed in this section is presented in Fig. 3.21 and Fig. 3.22.

3.10.7 Damped Second-Order Negative Feedback Systems

Up to now the second-order negative feedback systems discussed have the following characteristic: if initially in equilibrium, they remain in equilibrium; if not in equlibrium, initially, they oscillate about the equilibrium point indefinitely. This is true of the gravitrain capsule (see Fig 3.10), an example of the second-order system developed in Subsection 3.10.3; the supply and demand models (see Figs. 3.12 and 3.13, examples of the second-order system derived in Subsection 3.10.4; and the TseTse Fly-Cattle Model (see Fig. 3.21), an illustration of the systems developed in Subsection 3.10.6. However, most second-order negative feedback systems do not exhibit this type of behavior. Rather, their response is one of gradual return to equilibrium rather than sustained oscillation -- what we call "cyclic equilibrium" in the preceeding subsection.

```
*    TSETSE FLIES - CATTLE MODEL                               DREW W-84 **
NOTE ******************************************************************
NOTE ******************        SYSTEM  EQUATIONS      *********************
NOTE ******************************************************************
L    C.K=C.J+(DT)(CBR.JK-CDR.JK)        C - CATTLE                     **
N    C=CN                                                              **
C    CN=1000                                                           **
R    CBR.KL=C.K*NCF                   CBR - CATTLE BIRTH RATE          **
C    NCF=.005                         NCF - NORMAL CATTLE FERTILITY    **
R    CDR.KL=C.K*T.K/FHEF              CDR - CATTLE DEATH RATE          **
C    FHEF=1E9                        FHEF - FLY-HOST ENCOUNTER FACTOR  **
L    T.K=T.J+(DT)(TBR.JK-TDR.JK)        T - TSETSE                     **
N    T=TN                                                              **
C    TN=5E6                                                            **
R    TDR.KL=T.K/ALN                   TDR - TSETSE DEATH RATE          **
C    ALN=10                           ALN - AVERAGE LIFETIME NORMAL    **
R    TBR.KL=C.K*T.K/CFEF              TBR - TSETSE BIRTH RATE          **
C    CFEF=1E4                        CFEF - CATTLE-FLY ENCOUNTER FACTOR **
NOTE ******************************************************************
NOTE ********************      CAUSAL DIAGRAM      **********************
NOTE ******************************************************************
```



```
NOTE ******************************************************************
NOTE ******************        CONTROL  STATEMENTS    *******************
NOTE ******************************************************************
SPEC   DT=.5/LENGTH=300/PLTPER=10/PRTPER=20                            **
PLOT   C=C(800,1200)/T=T(0,12E6)                                       **
PRINT  C,T                                                             **
NOTE ******************************************************************
NOTE *********************     COMPUTER  OUTPUT      *******************
NOTE ******************************************************************
```

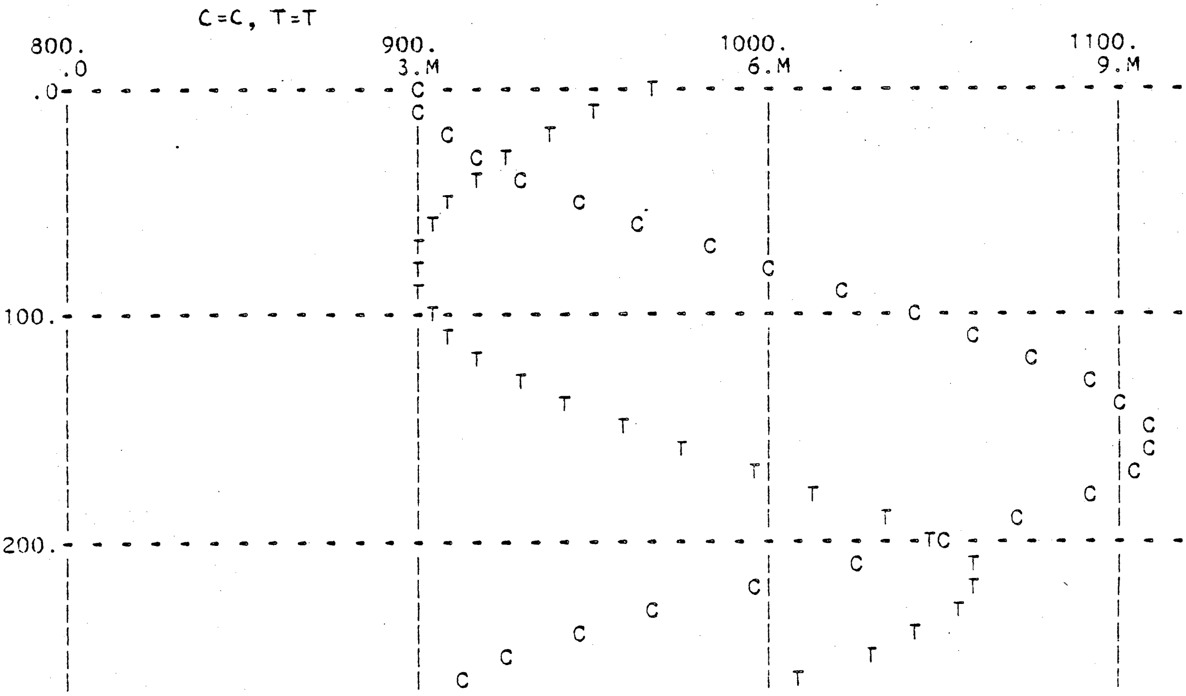


Fig. 3.21 TSETSE FLIES - CATTLE MODEL

```
*    AIRCRAFT COMBAT ATTRITION MODEL                          DREW W-84 ***
NOTE  *****************************************************************
NOTE  ******************    SYSTEM  EQUATIONS    **********************
NOTE  *****************************************************************
L    SS.K=SS.J+(DT)(PRSS.JK-ARSS.JK)                                   **
N    SS=A*DPB                                                          **
NOTE  SS   - U.S. AIRCRAFT (PLANES)                                    **
C    DPB=1000                                                          **
NOTE  DPB  - DURATION OF PEACETIME BUILDUP (DAYS)                      **
R    PRSS.KL=A                                                         **
NOTE  PRSS - PROCUREMENT RATE FOR U.S. AIRCRAFT (PLANES/DAY)           **
R    ARSS.KL=CLIP(B*XX.K,0,XX.K,0)                                     **
NOTE  ARSS - ATTRITION RATE FOR U.S. AIRCRAFT (PLANES/DAY)             **
N    B=SRXX*AVXX*(1-MSSS)                                              **
NOTE   B - EFFECTIVENESS PARAMETER FOR U.S.S.R. AIRCRAFT (FRACT/DAY) **
C    SRXX=2                                                            **
NOTE  SRXX - SORTIE RATE FOR U.S.S.R. AIRCRAFT (FRACT/DAY)             **
C    AVXX=.5                                                           **
NOTE  AVXX - AVAILABILITY OF U.S.S.R. AIRCRAFT (PROB)                  **
C    MSSS=.98                                                          **
NOTE  MSSS - MISSION SURVIVABILITY OF U.S. AIRCRAFT (PROB)             **
L    XX.K=XX.J+(DT)(PRXX.JK-ARXX.JK)                                   **
N    XX=P*DPB                                                          **
NOTE   XX  - U.S.S.R. AIRCRAFT (PLANES)                                **
R    PRXX.KL=P                                                         **
NOTE  PRXX - PROCUREMENT RATE FOR U.S.S.R. AIRCRAFT (PLANES/DAY)       **
R    ARXX.KL=CLIP(C*SS.K,0,SS.K,0)                                     **
NOTE  ARXX - ATTRITION RATE FOR U.S.S.R. AIRCRAFT (PLANES/DAY)         **
N    C=SRSS*AVSS*(1-MSXX)                                              **
NOTE   C   - EFFECTIVENESS PARAMETER FOR U.S. AIRCRAFT (FRACT/DAY)    **
C    SRSS=2                                                            **
NOTE  SRXX - SORTIE RATE FOR U.S. AIRCRAFT (FRACT/DAY)                 **
C    AVSS=.5                                                           **
NOTE  AVSS - AVAILABILITY OF U.S. AIRCRAFT (PROB)                      **
C    MSXX=.92                                                          **
NOTE  MSXX - MISSION SURVIVABILITY OF U.S.S.R. AIRCRAFT (PROB)         **
C    A=1.0                                                             **
C    P=2.0                                                             **
NOTE  *****************************************************************
NOTE  ******************    CONTROL  STATEMENTS    ********************
NOTE  *****************************************************************
SPEC  DT=0.25/LENGTH=100/PLTPER=5/PRTPER=5                             **
PLOT  SS=S,XX=X(0,2000)                                                **
PRINT SS,XX,L1,L2                                                      **
NOTE  *****************************************************************
NOTE  ******************    COMPUTER  OUTPUT    ***********************
NOTE  *****************************************************************
```

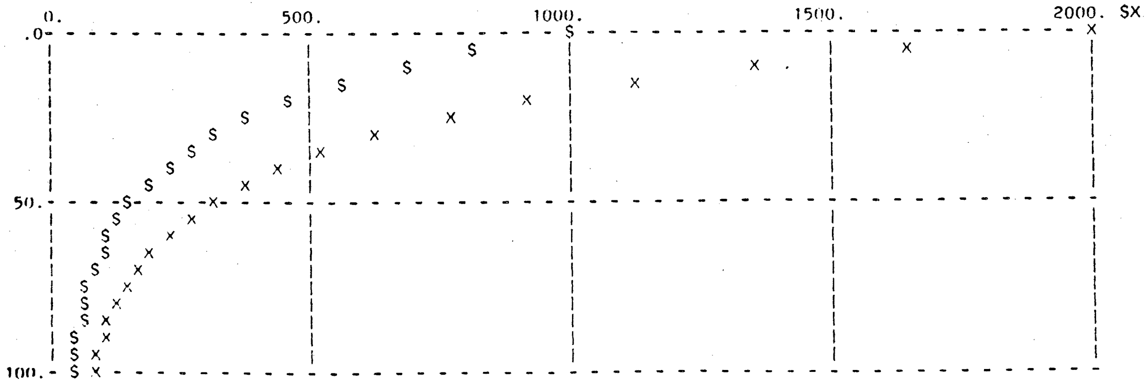


Fig. 3.22 AIR COMBAT ATTRITION MODEL

Consider the second-order negative feedback system described by the following DYNAMO equations:

L1.K=L1.J+(DT)(RI.JK-RO.JK) (3.143)

L1=N1

N1=X1*E1

RO.KL=L1.K/A3 (3.144)

RI.KL=L2.K/A1 (3.145)

L2.K=L2.J+(DT)(R2.JK) (3.146)

L2=N2

N2=E2

R2.KL=(E1-L1.K)/A2 (3.147)

The system is depicted in Fig 3.23 in the form of a causal diagram comprised of a second-order negative feedback loop and a first-order negative feedback loop.

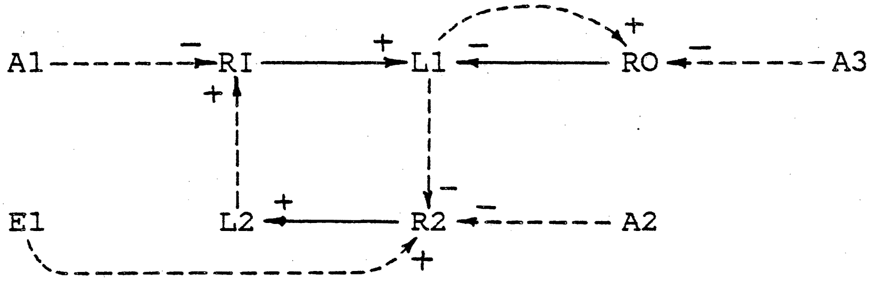


Fig. 3.23

Execution of steady state analyses serves to provide the significance of the parameters A3, E1, and E2:

$RI_e = RO_e$

$L2_e/A1 = L1_e/A3$

$A3 = (A1)(E1/E2)$ (3.148)

$R2_e = 0$

$(E1 - L1_e)/A2 = 0$

$E1 = L1_e$ (3.149)

The first-order differential equation representation of the system consists of the following two equations:

$$\frac{dL1_t}{dt} = \frac{L2_t}{A1} - \frac{L1_t}{A3} \qquad (3.150)$$

$$\frac{dL2_t}{dt} = \frac{E1}{A2} - \frac{L1_t}{A2} \qquad (3.151)$$

A useful tool for solving simultaneous ordinary differential equations is the Laplace transform. The procedure is summarized in Fig 3.24.

$$sL1(s) - N1 = \frac{L2(s)}{A1} - \frac{L1(s)}{A3} \qquad (3.152)$$

$$sL2(s) - N2 = \frac{E1}{A2}\,\frac{1}{s} - \frac{L1(s)}{A2} \qquad (3.153)$$

Solving (3.153) for L2(s),

$$L2(s) = \frac{N2}{s} + \frac{E1}{A2}\,\frac{1}{s^2} - \frac{L1(s)}{A2}\,\frac{1}{s} \qquad (3.154)$$

Substituting (3.154) in (3.152),

$$sL1(s) + \frac{L1(s)}{A3} = N1 + \frac{1}{A1}\left[\frac{N2}{s} + \frac{E1}{A2}\,\frac{1}{s^2} - \frac{L1(s)}{A2}\,\frac{1}{s}\right] \qquad (3.155)$$

Collecting L1(s) terms on the left-hand side,

$$L1(s)\left[s^2 + \frac{s}{A3} + \frac{1}{A1xA2}\right] = N1 \times s + \frac{N2}{A1} + \frac{E1}{A1xA2}\,\frac{1}{s} \qquad (3.156)$$

Solving (3.156) for L1(s), expressed in terms of the parameters ω, δ and α gives

$$L1(s) = \frac{N1 \times s + N2/A1 + E1 \times \omega^2/s}{s^2 + 2\alpha s + \omega^2} \qquad (3.157)$$

1. Let f(t) be a function of the variable t, then

   $$\mathcal{L}[f(t)] = F(s) = \int_0^\infty f(t)\, e^{-st} dt$$

   is called the Laplace transform of f(t)

2. For example, if f(t) = c where c is a constant, then $\mathcal{L}[c] = \frac{c}{s}$

3. The Laplace transform of a derivative $\frac{d}{dt}$ f(t) is

   $$\mathcal{L}[\frac{d}{dt} f(t)] = s\,F(s) - f(t=o)$$

   where f(t=o) is the initial value of f(t).

4. The transformation from the s- domain into the t domain is called the inverse Laplace transform, written $\mathcal{L}^{-1}$

   Thus $\mathcal{L}^{-1}[F(s)] = f(t)$

5. A short table of Laplace transforms of use in the analysis of dynamic systems appear below. Complete tables appear in the appendices of most math books.

	f(t)		F(s)
1.	e^{-xt}	1.	$\frac{1}{s+x}$
2.	sin yt	2.	$\frac{y}{s^2+y^2}$
3.	cos yt	3.	$\frac{s}{s^2+y^2}$
4.	e^{-xt} sin yt	4.	$\frac{y}{(s+x)^2+y^2}$
5.	e^{-xt} cos yt	5.	$\frac{s+x}{(s+x)^2+y^2}$
6.	$(1/y^2)(1-\cos yt)$	6.	$\frac{1}{s(s^2+y^2)}$
7.	$(1/x)(1-e^{-xt})$	7.	$\frac{1}{s(s+x)}$
8.	$\frac{e^{-\delta\omega t}}{\omega\sqrt{1-\delta^2}} \sin \omega\sqrt{1-\delta^2}\, t$	8.	$\frac{1}{s^2+2\delta\omega s+\omega^2}$
9.	$\frac{1}{\omega^2} - \frac{e^{-\delta\omega t}}{\omega^2\sqrt{1-\delta^2}} \sin(\omega\sqrt{1-\delta^2}\, t+\cos^{-1}\delta)$	9.	$\frac{1}{s(s^2+2\delta\omega s+\omega^2)}$
10.	$(1/x^2)(1-e^{-xt}-xt\, e^{-xt})$	10.	$\frac{1}{s(s+x)^2}$
11.	$(1/x^2)(xt-1+e^{-xt})$	11.	$\frac{1}{s^2(s+x)}$

FIVE STEP APPLICATION OF LAPLACE TRANSFORMS

Fig. 3.24

where ω is the natural frequency, δ is the damping ratio and α is the damping coefficients -- all defined as follows:

$$\alpha = \delta\omega = 1/2A3 \qquad (3.158)$$

$$\omega = 1/\sqrt{(A1)(A2)} \qquad (3.159)$$

$$\delta = \sqrt{(A1)(A2)}/2A3 \qquad (3.160)$$

Noting that $N2/A1 = E2/A1$, we can express (3.157) as

$$L1(s) = \frac{(s \times X1 \times E1) + (E1/A3) + E1 \times \omega^2/s}{s^2 + 2\alpha s + \omega^2} . \qquad (3.161)$$

Referring to Fig. 3.20, it is convenient to express the three terms of (3.157) in the transform format provided:

$$L1(s) = \frac{(s+\alpha)X1xE1}{(s+\alpha)^2+\omega^2-\alpha^2} + \frac{X1xE1(2/X1-1)\alpha}{(s+\alpha)^2+\omega^2-\alpha^2} + \frac{E1 \times \omega^2}{s(s^2+2\delta\omega s+\omega^2)} \qquad (3.162)$$

Equation 3.158 is the transform of the solution. Taking the inverse,

$$\begin{aligned} L1_t &= (X1xE1)e^{-\alpha t} \cos\sqrt{\omega^2-\alpha^2}\, t \\ &+ \frac{\underline{(X1xE1)(2/X1 - 1)\alpha e^{-\alpha t} \sin\sqrt{\omega^2-\alpha^2}\, t}}{\sqrt{\omega^2-\alpha^2}} \\ &+ E1 \left[1 - \frac{e^{-\delta\omega t} \sin(\omega\sqrt{1-\delta^2}\, t + \cos^{-1}\delta)}{\sqrt{1-\delta^2}}\right] \end{aligned} \qquad (3.163)$$

Equation 3.163 is the solution for L1 in the time domain -- our answer.

Now we can execute the same procedure to find $L2_t$. The transform is found to be

$$L2(s)\left[s^2 + \frac{s}{A3} + \frac{1}{A1xA2}\right] = \frac{E1-N1}{A2} + N2 \times s + \frac{N2}{A3} + \frac{E1}{A2xA3}\,\frac{1}{s}$$

$$= \frac{(1-X1)E1}{A2} + \left[N2\left(s+\frac{1}{2A3}\right) + \frac{N2}{2A3}\right] + \frac{E2x\omega^2}{s} \qquad (3.164)$$

$$L2(s) = \frac{\alpha xN2+E1(1-X1)/A2}{s^2+2\delta\omega s-\omega^2} + \frac{E2 \; x \; \omega^2}{s(s^2+2\delta\omega s+\omega^2)} + \frac{N2(s+\alpha)}{(s+\delta)^2+\omega^2-\delta^2}$$

Taking the inverse, the solution to L2 is found as

$$L2_t = \frac{\alpha xN2+E1(1-X1)/A2}{\omega\sqrt{(1-\delta^2)}} e^{-\delta\omega t} \sin \omega\sqrt{1-\delta^2}\, t$$

$$E2\left[1-\frac{e^{-\delta\omega t}\sin(\omega\sqrt{1-\delta^2}t + \cos^{-1}\delta)}{\sqrt{1-\delta^2}}\right] + N2\; e^{-\alpha t}\cos\sqrt{\omega^2-\alpha^2}t$$

(3.165)

The period for this system is

$$P = \frac{2\pi}{\omega_d} = \frac{2\pi}{\omega\sqrt{1-\delta^2}} \qquad (3.166)$$

where ω_d is the damped natural frequency.

An example of this system in the supply-demand area is presented in the model of Fig. 3.25.

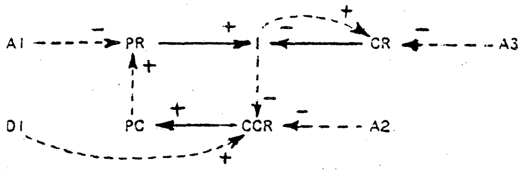
A special case of the system of this section that is of interest is obtained by letting $\delta = 0$. The equations corresponding to (3.163), (3.165) and (3.166) of the general area are:

$$L1_t = E1\;[1 - (1-X1)\cos \omega t] \qquad (3.167)$$

$$L2_t = E2\;\left[1 + \frac{(1-X1)E1}{A2x\omega xE2}\sin \omega t\right] \qquad (3.168)$$

$$P = 2\pi/\omega \qquad (3.169)$$

```
*    DAMPED SUPPLY AND DEMAND MODEL  -     3-.
NOTE  *************************************************************
NOTE  ******************      SYSTEM  EQUATIONS     ******************
NOTE  *************************************************************
L    I.K=I.J+(DT)(PR.JK-CR.JK)       I - INVENTORY (UNITS)          **
N    I=IN                                                           **
N    IN=X*DI                                                        **
C    X=.8                            X - CONSTANT (DIM)             **
N    DI=D*DC                        DI - DESIRED INVENTORY (UNITS)  **
C    D=1000                          D - DEMAND (UNITS/MO)          **
C    DC=12                          DC - DESIRED COVERAGE (MO)      **
R    PR.KL=PC.K/A1                  PR - PRODUCTION RATE (UNITS/MO) **
C    A1=1                           A1 - CONSTANT (DIM)             **
R    CR.KL=I.K/A3                   CR - CONSUMPTION RATE (UNITS/MO)  **
L    PC.K=PC.J+(DT)(CCR.JK)         PC - PRODUCTION CAPACITY (UNITS/MO)**
N    PC=DPC                                                         **
N    DPC=D*A1                   DPC-DESIRED PROD. CAPACITY (UNITS/MO)  **
R    CCR.KL=(DI-I.K)/A2         CCR-CAPACITY CHANGE RATE (UNITS/MO-MO) **
N    A2=CCD*DI/DPC                  A2 - CONSTANT (MO²)             **
C    CCD=10                        CCD - CAPACITY CHANGE DELAY (MO) **
N    A3=DC                          A3 - CONSTANT (MO)              **
NOTE  *************************************************************
NOTE  ******************      CAUSAL   DIAGRAM      ******************
NOTE  *************************************************************
```



```
NOTE  *************************************************************
NOTE  ******************     CONTROL  STATEMENTS     ******************
NOTE  *************************************************************
SPEC  DT=.1/LENGTH=100/PLTPER=5/PRTPER=10                           **
PLOT  I=I(0,30000)/PC=P(0,2000)                                     **
PRINT I,PC                                                          **
NOTE  *************************************************************
NOTE  ******************      COMPUTER  OUTPUT      ******************
NOTE  *************************************************************
I=I,PC=P
```

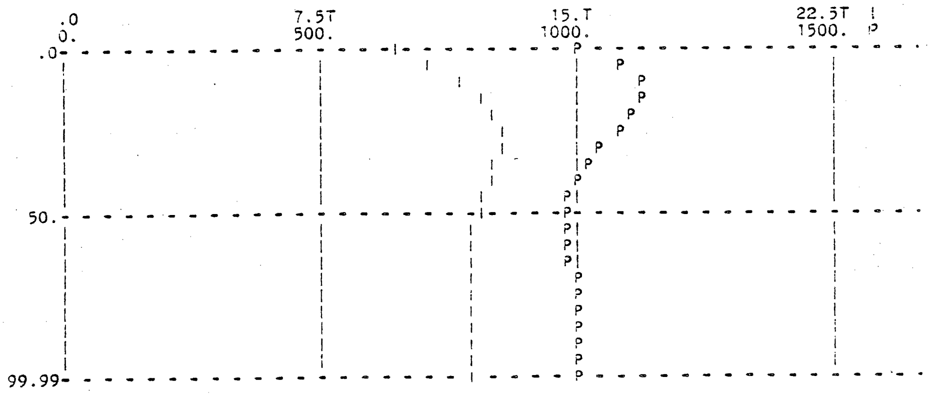
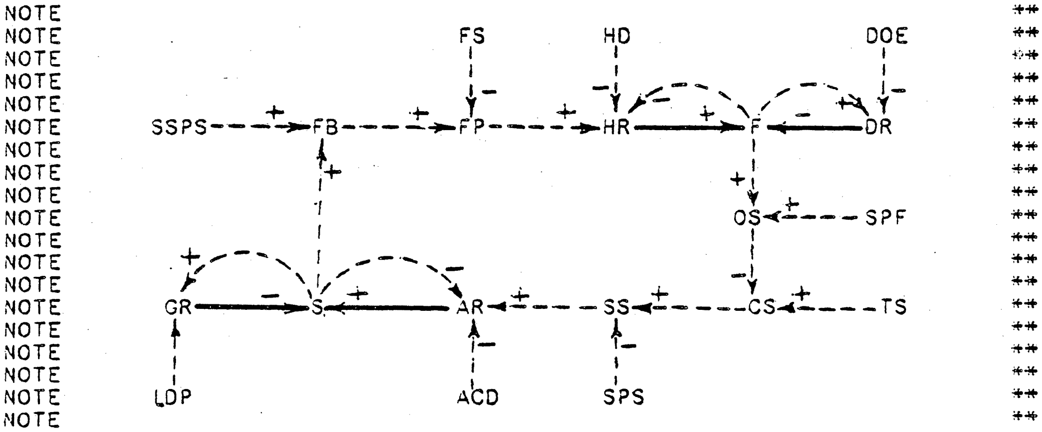


Fig. 3.25 DAMPED SUPPLY DEMAND MODEL

Somewhere between the second-order negative feedback systems presented in Subsection 3.10.6 (those containing four minor first-order loops leading to cyclic equilibrium) and the second-order negative feedback system described in this section (with first-order negative feedback loop leading to damped equilibrium) is the "constrained" second-order negative feedback system. Two examples are depicted in the models of Figs. 3.26 and 3.27.

```
*   UNIVERSITY  RESOURCE  ALLOCATION  MODEL               DREW  W-84 **
NOTE  ****************************************************************
NOTE  ****************      SYSTEM  EQUATIONS       ******************
NOTE  ****************************************************************
L   F.K=F.J+(DT)(HR.JK-DR.JK)   F - FACULTY (PERSONS)                **
N   F=FN                                                             **
C   FN=1600                                                          **
A   OS.K=F.K*SPF               OS - OFFICE SPACE (SQ.FT.)            **
C   SPF=200                   SPF - SPACE PER FACULTY (SQ.FT/PERSON) **
A   CS.K=TS-OS.K               CS - CLASSROOM SPACE (SQ.FT)          **
C   TS=1E6                     TS - TOTAL SPACE (SQ.FT)              **
A   SS.K=CS.K/SPS              SS - STUDENT SLOTS (PERSONS)          **
C   SPS=25                    SPS - SPACE PER STUDENT (SQ.FT/PERSON) **
R   AR.KL=(SS.K-S.K)/ACD       AR - ADMISSION CHANGE DELAY (YR)      **
C   ACD=2                     ACD - ADMISSION CHANGE DELAY (YR)      **
L   S.K=S.J+(DT)(AR.JK-GR.JK)   S - STUDENTS (PERSONS)               **
N   S=SN                                                             **
C   SN=16000                                                         **
R   GR.KL=S.K/LDP              GR - GRADUATION RATE (PERSONS/YR)     **
C   LDP=4                     LDP - LENGTH DEGREE PROGRAM (YR)       **
A   FB.K=S.K*SSPS              FB - FACULTY BUDGET (S/YR)            **
C   SSPS=7000          SSPS - STATE SUPPORT PER STUDENT(S/YR-PER)    **
A   FP.K=FB.K/FS               FP - FACULTY POSITIONS (PERSONS)      **
C   FS=40000                   FS - FACULTY SALARIES (S/YR-PERSON)   **
R   HR.KL=(FP.K-F.K)/HD        HR - HIRING RATE (PERSONS/YR)         **
C   HD=2                       HD - HIRING DELAY (YR)                **
R   DR.KL=F.K/DOE              DR - DEPARTURE RATE (PERSONS/YR)      **
C   DOE=5                     DOE - DURATION OF EMPLOYMENT (YR)      **
NOTE  ****************************************************************
NOTE  ******************      CAUSAL  DIAGRAM      *******************
NOTE  ****************************************************************
```



```
NOTE  ****************************************************************
```

Fig. 3.26 UNIVERSITY RESOURCE ALLOCATION

```
*    URBAN LAND USE MODEL
NOTE  *************************************************************
NOTE  *******************    SYSTEM  EQUATIONS    *******************
NOTE  *************************************************************
L    BS.K=BS.J+(DT)(BC.JK-BD.JK) BS - BUSINESS STRUCTURES (UNITS)      **
N    BS=BSI                                                            **
C    BSI=1000                   BSI - BUSIN STRUCT INITIAL             **
A    J.K=JBS*BS.K                J  - JOBS (PERSONS)                   **
C    JBS=18                    JBS - JOBS PER BUSIN STRUCT (PERSONS/UNIT) **
A    LF.K=LFJR*J.K               LF - LABOR FORCE (PERSONS)            **
C    LFJR=1.2                  LFJR - LABOR FORCE JOB RATIO (DIM)      **
A    P.K=LF.K/LPF                 P - POPULATION (PERSONS)             **
C    LPF=.4                     LPF - LABOR PARTICIPATION FRACT (DIM)  **
A    HDD.K=P.K/HS               HDD - HOUSING DEMAND (UNITS)           **
C    HS=4                        HS - HOUSEHOLD SIZE (PERSONS/UNIT)    **
R    HC.KL=(HDD.K-H.K)/HAT       HC - HOUSING CONSTRUCTION (UNITS/YR)  **
C    HAT=5                      HAT - HOUSING ADJUSTMENT TIME (YR)     **
R    HD.KL=H.K*HDN               HD - HOUSING DEMOLITION (UNITS/YR)    **
C    HDN=.02                    HDN - HOUSING DEMO NORMAL (FRACT/YR)   **
L    H.K=H.J+(DT)(HC.JK-HD.JK)   H  - HOUSES (UNITS)                   **
N    H=HI                                                              **
C    HI=10000                                                          **
A    LOH.K=H.K*LPH              LOH - LAND OCCUPIED BY HOUSING (ACRES) **
C    LPH=.1                     LPH - LAND PER HOUSE (ACRES/HOUSE)     **
A    LAB.K=AREA-LOH.K           LAB - LAND AVAIL FOR BUSINESS (ACRES)  **
C    AREA=10000                AREA - LAND AREA (ACRES)                **
R    BC.KL=((LAB.K/LBS)-BS.K)/BAT BC- BUSINESS CONSTRUCTION (UNITS/YR) **
C    LBS=.2                LBS - LAND PER BUSINESS STRUCT (ACRES/STRUCT) **
C    BAT=10                     BAT - BUSINESS ADJUST TIME (YR)        **
R    BD.KL=BS.K*BDN              BD - BUSINESS DEMOLITION (UNITS/YR)   **
C    BDN=.025                   BDN - BUSINESS DEMO NORMAL (FRACT/YR)  **
NOTE  *************************************************************
NOTE  *******************    CAUSAL DIAGRAM    **********************
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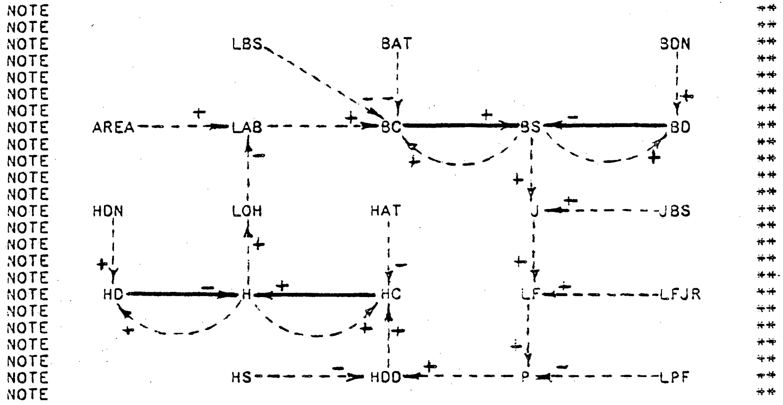


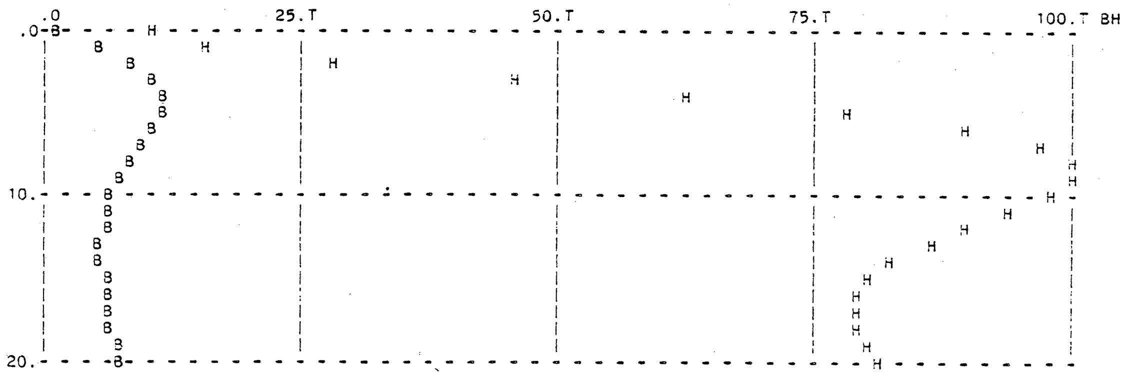


Fig. 3.27 URBAN LAND USE MODEL

Chapter IV

OVERVIEW OF THE MODEL

4.1 ORGANIZATION OF THE RESEARCH

In the performance of Phase 1, aircraft survivability management was conceptualized as consisting of two decision-making dimensions or orientations -- the hierarchical and the chronological. Regarding the former, three policy levels of national security planning and defense management are identified: (1) the quantity of resources available to the nation, in general, and to the defense establishment, in particular; (2) the allocation of these resources within the Department of Defense both by service -- Army, Air Force, Navy and Marines, and function -- Procurement; Operations and Maintenance; Research, Development, Test and Evaluation; Personnel; and Construction; and (3) the allocation of RDT&E resources within the JTCG/AS. Regarding the chronological dimension, there are the decision nodes throughout the aircraft system life cycle -- from mission requirements to research to design (conceptual, preliminary, baseline, and final) to development to procurement to maintenance to modification to retirement and/or attrition. In consideration of these two dimensional requirements, three complementary responses have been formulated and have been termed as follows: (1) the "Top-Down" Approach, (2) the "Bottom-Up" Approach, and (3) the "Mission Scenario" Approach [77].

The "Top-Down" Approach, described in Section 4.2, consists of five submodels; (1) Economy Submodel, (2) Budget Submodel, (3) Procurement Submodel, (4) Attrition Submodel, (5) Survivability Submodel. Whereas the "Top-Down" Approach starts at the top of the hierarchy, the "Bottom-Up" Approach starts with the Subgroups in the JTCG/AS and works up the hierarchy. The "Mission Scenario" Approach addresses itself to survivability trade-offs performed during the aircraft systems' life cycle [77].

In executing the "Bottom-Up" Approach explained in Section 4.8, the Survivability Submodel was disaggregated into the following Subsystems: (1) Engine Susceptibility, (2) Airframe Susceptibility, (3) Aircraft Structure, (4) Engine Vulnerability, (5) Electrical Power Systems, (6) Flight Control Systems, (10) Personnel Station, (11) Propulsion Systems, (12) Armament Systems, (13) Armor Systems, (14) Power Train Systems, (15) Fluid Power Systems, (16) Environmental Control Systems, (17) Oxygen Systems, (18) Launch and Recovery Systems. To effect the "Mission Scenario" Approach the portions of the procurement Submodel and the Attrition Submodel dealing with Navy Aircraft were extended to construct scenarios dealing with typical combat missions -- the subject of Chapter VI.

4.2 ORGANIZATION OF THE MODEL [77]

Fig. 4.1 is a conceptualization of the JTCG Aircraft Survivability Model developed in Phase 1 of this research. The JTCG/AS Model is comprised of five submodels: (1) Economy Submodel, (2) Budget Submodel, (3) Procurement Submodel, (4) Attrition Submodel, and (5) Survivability Submodel. Throughout this report, visual representations or "causal diagrams" consistent with the system dynamics methodology as described in Section 3.8 are used to communicate the underlying structure of the survivability phenomenon.

Starting in the upper left corner of Fig. 4.1, the Economy Submodel generates the annual Gross National Product of the U.S. which, in turn, determines the size of the Federal Government Budget. The two arrows leading into "Federal Government Budget" from "Gross National Product" and "Fraction of GNP to Government Budget" means that the Budget is a function of the GNP and the fraction of the GNP that is taxed to generate the budget. The plus signs on the arrows mean that the Federal Government Budget increases (or decreases) as the GNP increases (or decreases), etc. for "Fraction of GNP to Government Budget."

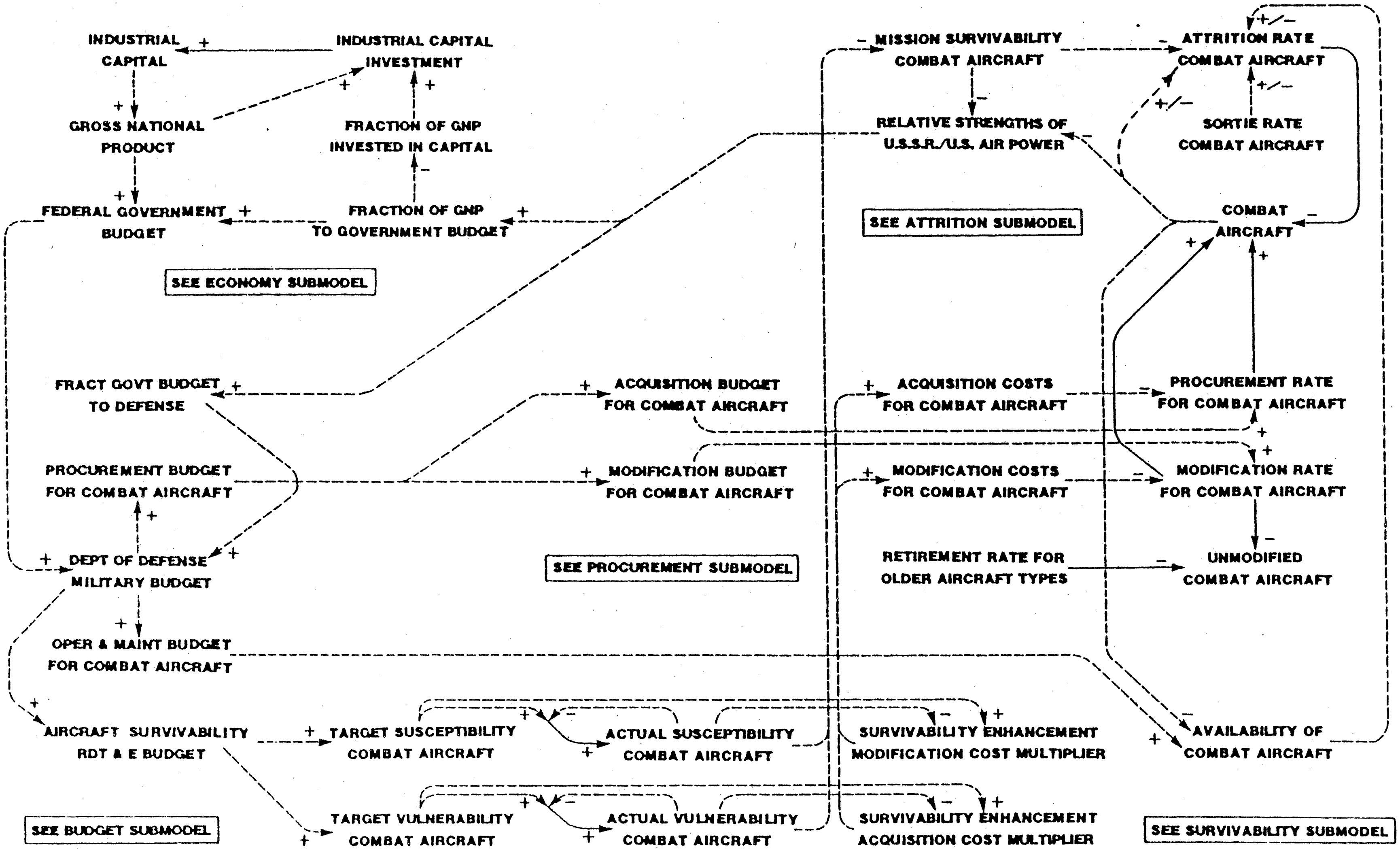


Fig. 4.1 STRUCTURE OF JTCG AIRCRAFT SURVIVABILITY MODEL

The Budget Submodel uses the output of the Economy Submodel to determine the "Department of Defense Military Budget" each year. In this submodel, the DOD budget is broken down by service (Army, Navy, Marines, and Air Force) and function (Procurement; Operations and Maintenance; and Research, Development, Test and Evaluation).

In the Procurement Submodel, the "Procurement Budget for Combat Aircraft" determined in the Budget Submodel is used to generate "Acquisition Budget for Combat Aircraft" and "Modification Budget for Combat Aircraft." The outputs of this submodel are the "Procurement Rate for Combat Aircraft" and "Modification Rate for Combat Aircraft."

The Attrition Submodel acts on the inventory of "Combat Aircraft" in the event of war. The number of "Combat Aircraft" increased over the peacetime years by the outputs of the procurement Submodel are reduced in wartime through the "Attrition Rate for Combat Aircraft." The "Attrition Rate" depends on the number of "Combat Aircraft," the "Sortie Rate for Combat Aircraft," the "Mission Survivability for Combat Aircraft" and the "Availability of Combat Aircraft."

The key variable, "Mission Survivability for Combat Aircraft" depends on the outputs of the Survivability Submodel. In turn, the "Availability of Combat Aircraft" calculated in this submodel influences the "Attrition Rate for Combat Aircraft" in the Attrition Submodel above. Focusing on the Survivability Submodel in Fig. 4.1, survivability is a function of both susceptibility and vulnerability. Susceptibility takes into account those factors that determine whether the aircraft will be detected and hit by a threat and vulnerability takes into account those factors that determine whether the aircraft is killed by the threat mechanisms if it is hit. The magnitude of the "Aircraft Survivability RDT&E Budget" calculated in the Budget Submodel determines "Actual Susceptibility of Combat Aircraft" and "Actual Vulnerability of Combat Aircraft." The product of these gives "Mission Survivability for Combat Aircraft" in the Attrition Submodel. However, reduced susceptibility and reduced vulnerability increase acquisition and modification costs which is accomplished in the model through the "Survivability Enhancement Modification Cost Multiplier" and the "Survivability Enhancement Acquisition Cost Multiplier."

The feedback between submodels is completed by monitoring the "Relative Strengths of U.S.S.R./U.S. Airpower" (see Attrition Submodel). As U.S.S.R. airpower increases with respect to U.S. air power, an increasing "Function of Government Budget to Defense" (see Budget Submodel) takes place, and eventually, possibly, an increase in the "Fraction of GNP to Government Budget" (see Economy Submodel).

The five submodels interact to form a series of interacting positive and negative feedback loops. The positive feedback loops reinforce themselves leading to increased air power. The negative feedback loops which are coming more and more into play act through spiraling costs and have already served to begin to reduce the increase in the combat aircraft inventory.

In the following sections the five submodels identified in Fig. 4.1 are treated individually and in more detail.

4.3 ECONOMY SUBMODEL

National security depends upon many factors--military, human, technological and economic. In this submodel we try to interpret and define the economic strength of the nation, as contrasted with its military forces. As a beginning let us identify three levels of defense economics: (1) the quantity of national resources available, now and in the future; (2) the proportion of these resources allocated to national security purposes; and (3) the efficiency with which the resources so allocated are used. The first, or highest level, is considered in this submodel.

For purposes of this model, GNP statistics are divided into mutually exclusive, collectively exhaustive categories. The most commonly used scheme for subdivision is that based on the International Standard Industrial Classification (ISIC) [78]. The major ISIC categories, which are Agriculture, Mining, Manufacturing, Utilities/ Transportation, Construction, Trade and Services, did not lend themselves well to the requirements of this research and were therefore broken-down and reassembled to form four more relevant categories: Aerospace Industry, Defense Industry (other than aerospace), Air Transportation Industry, and Non-Defense Industry (other then air transportation) [79] [80]. Principal parameters for representing the dynamics of economic growth for each category are shown in Fig. 4.2. In the figure the four industries are developed in parallel starting at the top with the parameter "capital" and ending at the bottom of the page with "product" or value added by each industry category. The four product values are summed to give the GNP, the Gross National Product of the U.S. The "Fraction of the GNP to the Government Budget," FGNPGB, when multiplied by the GNP determines the parameter FGB, the "Federal Government Budget." Inflation is treated as a variable, IGR, the "Inflationary Growth Rate" [81].

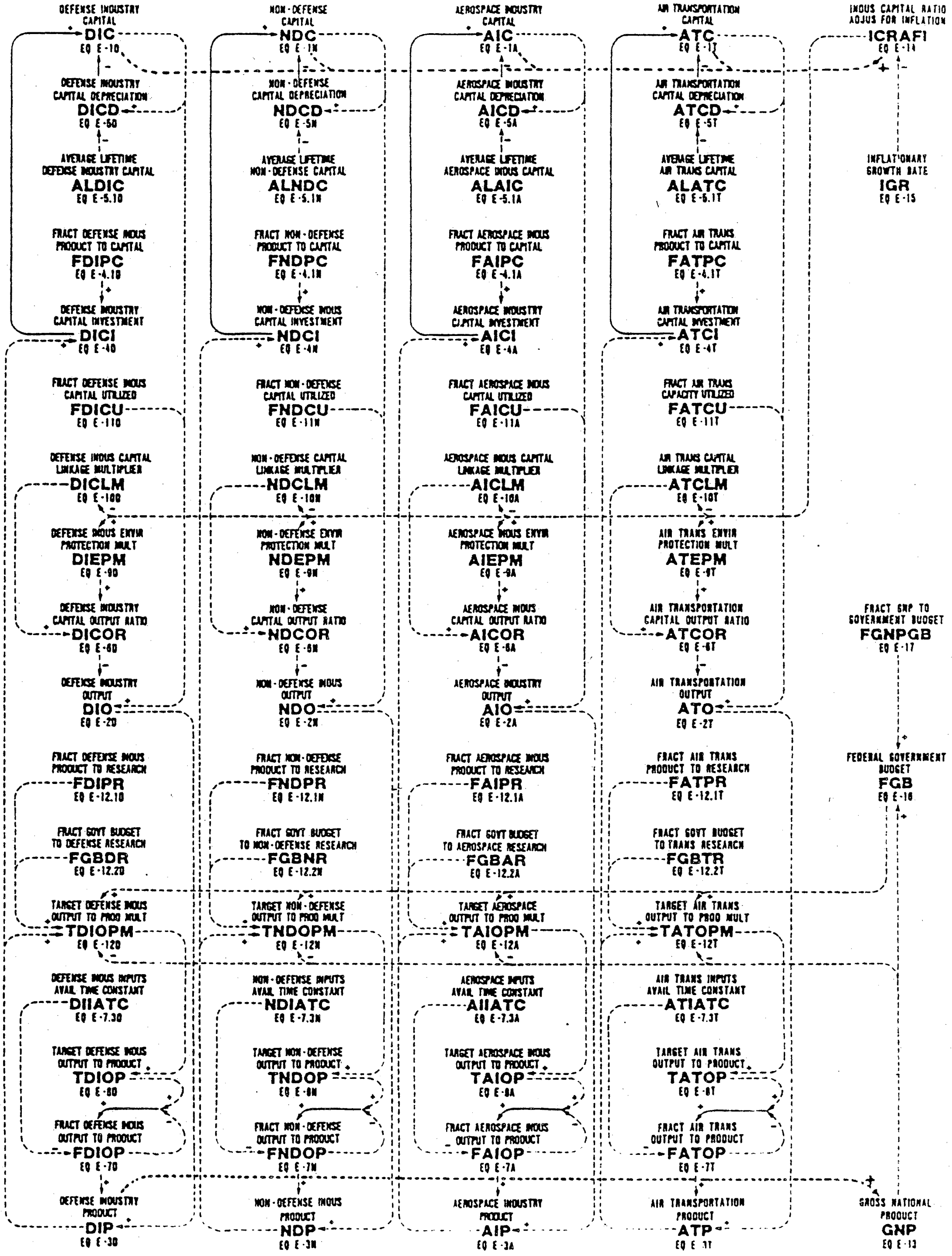


Fig. 4.2 ECONOMY SUBMODEL

An important function of the Economy Submodel is to account for the critical need of a national research and development policy to sustain a healthy economic and military preparedness.

4.4 BUDGET SUBMODEL

In the previous section, organized around the Economy Submodel, we considered the highest hierarchy of defense economics -- the quantity of national resources available. In this section, organized around the Budget Submodel, the questions of the proportion of these resources allocated to national security and the efficiency with which these resources are so used -- levels two and three in the hierarchy -- are addressed. Problems at the second level are the special responsibility of the Bureau of the Budget and the Appropriations Committees of Congress, although all executive departments are deeply involved [82]. In the Budget Submodel (see Figs 4.3 and 4.4) the second level decision parameter is FGBDOD, the "Fraction of the Government Budget to DOD." When this fraction is multiplied by the size of the federal budget we obtain DODMB, the "Department of Defense Military Budget" in the model.

The remaining parameters in the Budget Submodel (some 116 of them from DB-3 to DB-118) apply to the third or lowest

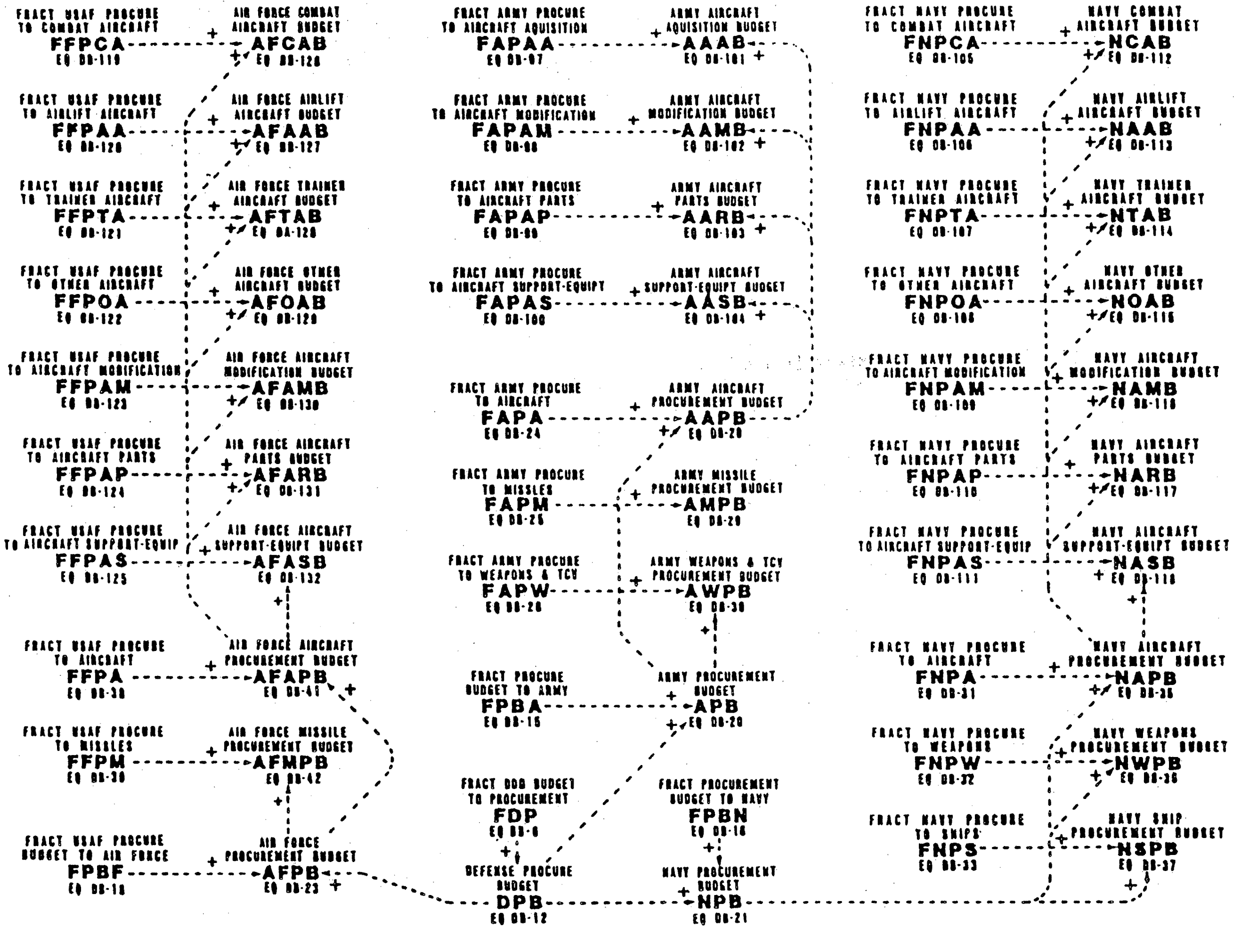


Fig. 4.3 DEFENSE BUDGET SUBMODEL - A

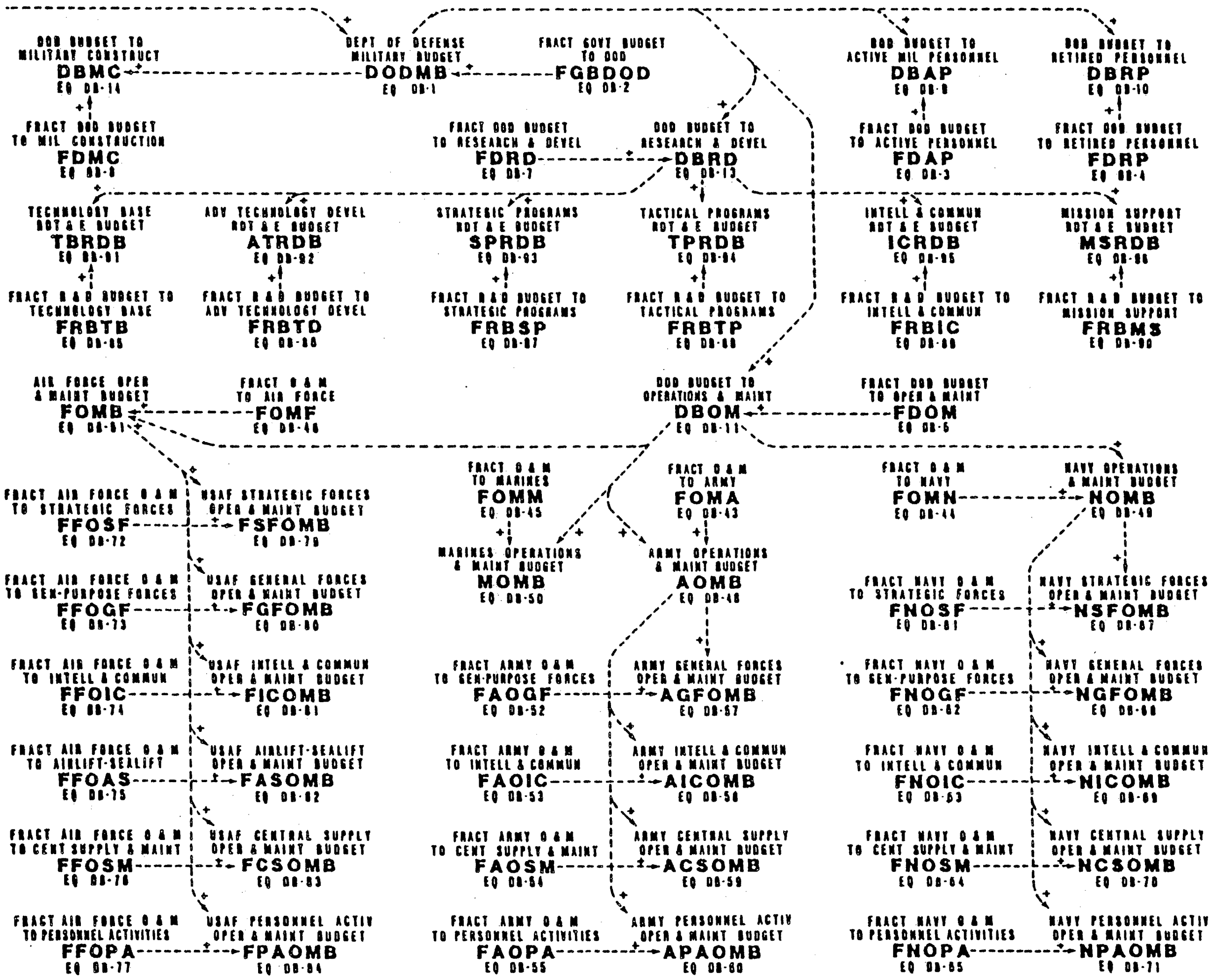


Fig. 4.4 DEFENSE BUDGET SUBMODEL - B

level of the hierarchy. Problems at this level -- the efficient use of the resources allocated for defense -- are primarily internal problems of the defense departments and agencies. The problems consist in choosing efficiently, or economically, among the alternative methods of achieving military tasks, objectives, or missions. These alternative methods may be different strategies, different tactics, various forces, or different weapons [77].

The organization of the Budget Submodel reflects the breakdown of the DOD Military Budget into service and activity categories described above. Fig. 4.3 depicts the Procurement Subsystem and Fig. 4.4 the Operations & Maintenance and the RDT&E Subsystems. Each of the 118 parameters in the figure are expressed in equation form in the model. Viewed as a multivariable optimization problem, the task is to find the fraction of the total budget that should be allocated to the scores of such categories so as to maximize military effectiveness, subject to the constraints that all the fractional allocations add up to unity [77].

4.5 PROCUREMENT SUBMODEL

The processes of combat aircraft procurement as they are conceived in the model are depicted in Figs. 4.5 and 4.6. Twenty-three combat aircraft organized according to Army, Navy, and Air Force are shown in the two figures and ten parameters for each aircraft describe the manner in which they are procured. Basically the inventory of each aircraft is increased by acquisition of new aircraft or modification of an older version of the same type aircraft. Older version inventories are reduced by retirement and modification to improved versions. Both the acquisition and modifications rates depend directly on the acquisition and modification budgets and inversely with acquisition and modification costs. The acquisition and modification budgets are determined from the outputs of the Budget Submodel from Figs. 4.3 and 4.4 [77].

As to the future, procurement costs are projected to rise somewhat more rapidly than the projected rate of inflation. The non-inflationary increase is attributable to three factors: maximum technological substitution, obsolescence, and procurement stretch-out [83].

Analysis focused on procurement decisions, of necessity, will have to consider technological developments and design alternatives on the one hand and operations -- the strategy

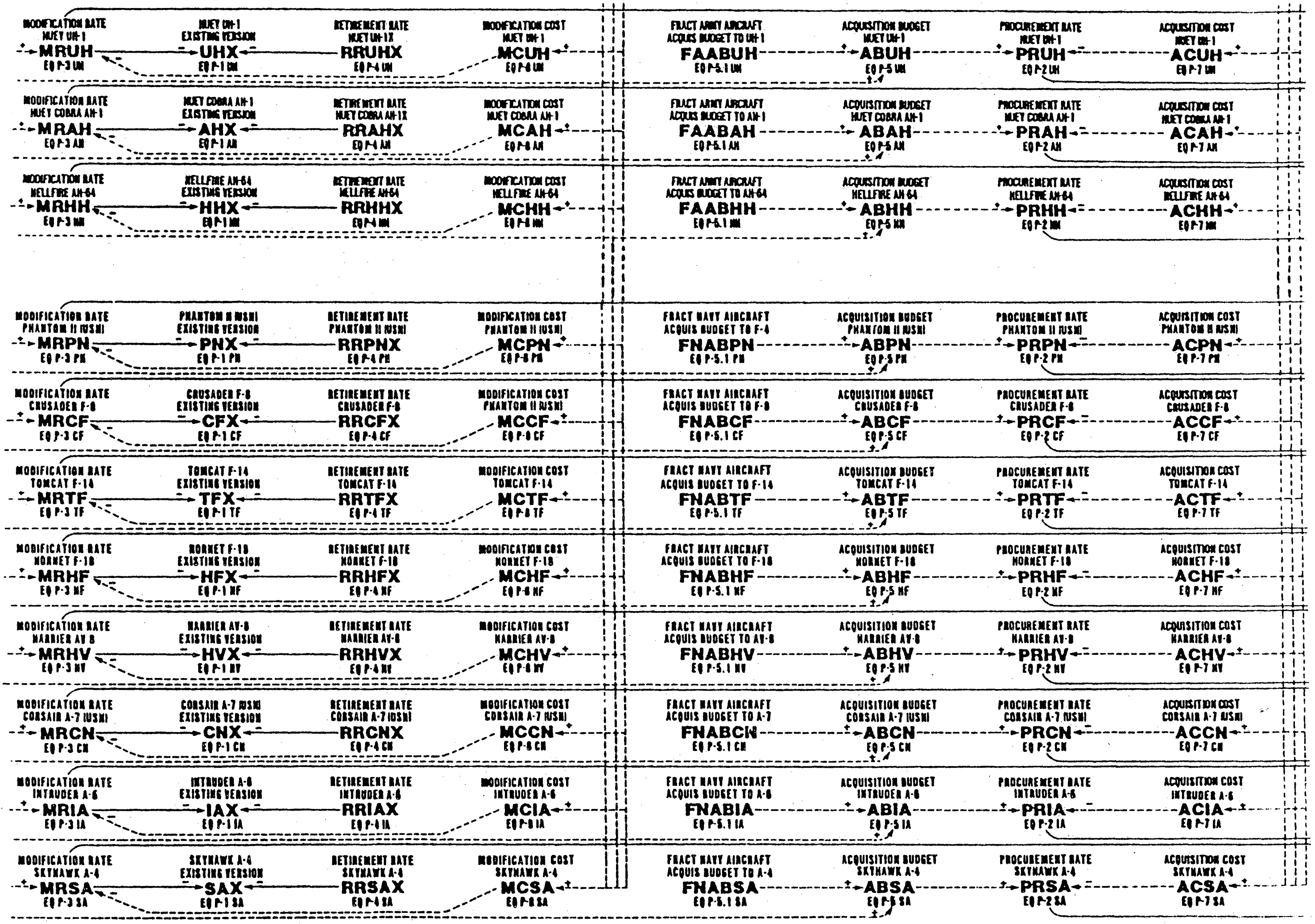


Fig. 4.5 PROCUREMENT SUBMODEL - 1

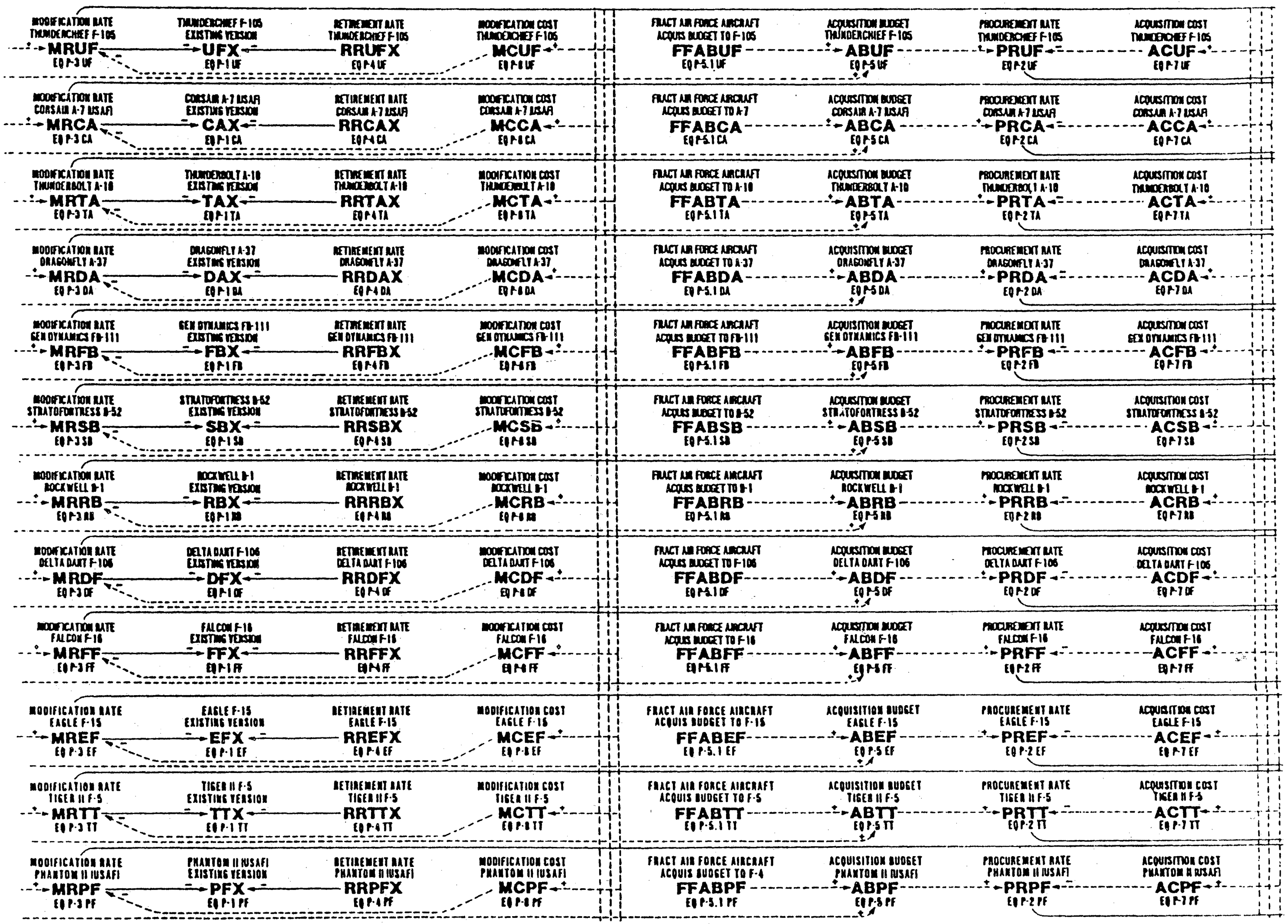


Fig. 4.6 PROCUREMENT SUBMODEL - 2

and tactics with which each aircraft will be used when it is deployed -- on the other. In the modeling effort this is accomplished by tying the Procurement Submodel (Figs. 4.5 and 4.6) to the Attrition Submodels and the Survivability Submodel. The Survivability Submodel establishes the magnitudes of the multipliers affecting acquisition and modification costs in the Procurement Submodel [77]. As to the Procurement-Attrition interaction, referring to Fig. 4.1, we see they are merely different aspects of the aircraft inventory adjustment process. Attrition is considered in the next section.

4.6 ATTRITION SUBMODEL

The Attrition Submodel is used to describe and to quantify the survivability of combat aircraft in encounters with hostile forces. Military Standards and Military Handbooks identify numerous descriptors and summary measures used to define the results of engagements between aircraft and various threats [22][28]. In general, these measures address the probability of survival per shot from a given weapon, probability of survival per encounter with a given weapon, and probability of survival per sortie or mission during which an aircraft may have multiple engagements with the various weapons of a zone defense. Aircraft probability of survival is a summary measure that an aircraft will survive a defined level of damage or kill category -- attrition, forced landing, mission abort, and mission available. In the model the kill category used is attrition, which covers those aircraft with combat damage so extensive that it is neither reasonable nor economical to repair.

In Fig. 4.7 and 4.8, combat attrition for 23 U.S. aircraft is modeled using seven parameters. Taking a row in the figure, the number of aircraft is reduced by the attrition rate (aircraft/day). The attrition rate is the product of the sortie rate (sorties per day), the number of aircraft available (aircraft), and mission survival (fraction per sortie). The sortie rate varies directly with the fraction of aircraft remaining. Aircraft available is a function of the number of aircraft and fraction that are combat ready, which is calculated in the Survivability Submodel under "availability." Mission survival depends on survivability versus air threat platforms and survivability versus surface threat platforms.

The Attrition Submodel treats Soviet aircraft combat losses in an identical manner as seen in Figs. 4.9 and 4.10. Again 23 aircraft types have been chosen. The U.S. aircraft and the U.S.S.R. aircraft shown were selected to cover a variety of missions for the different services [84]. The

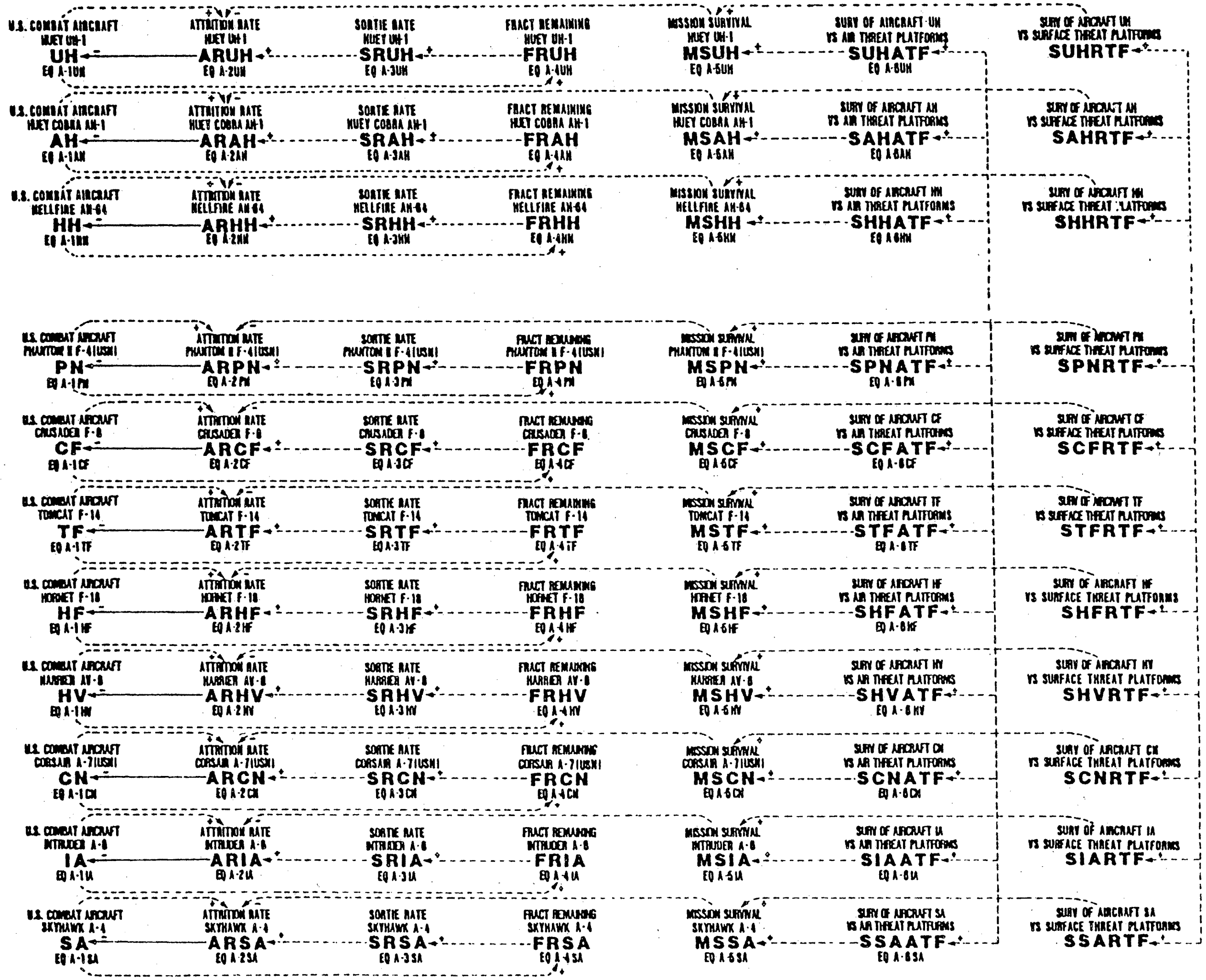


Fig. 4.7 ATTRITION SUBMODEL - A1

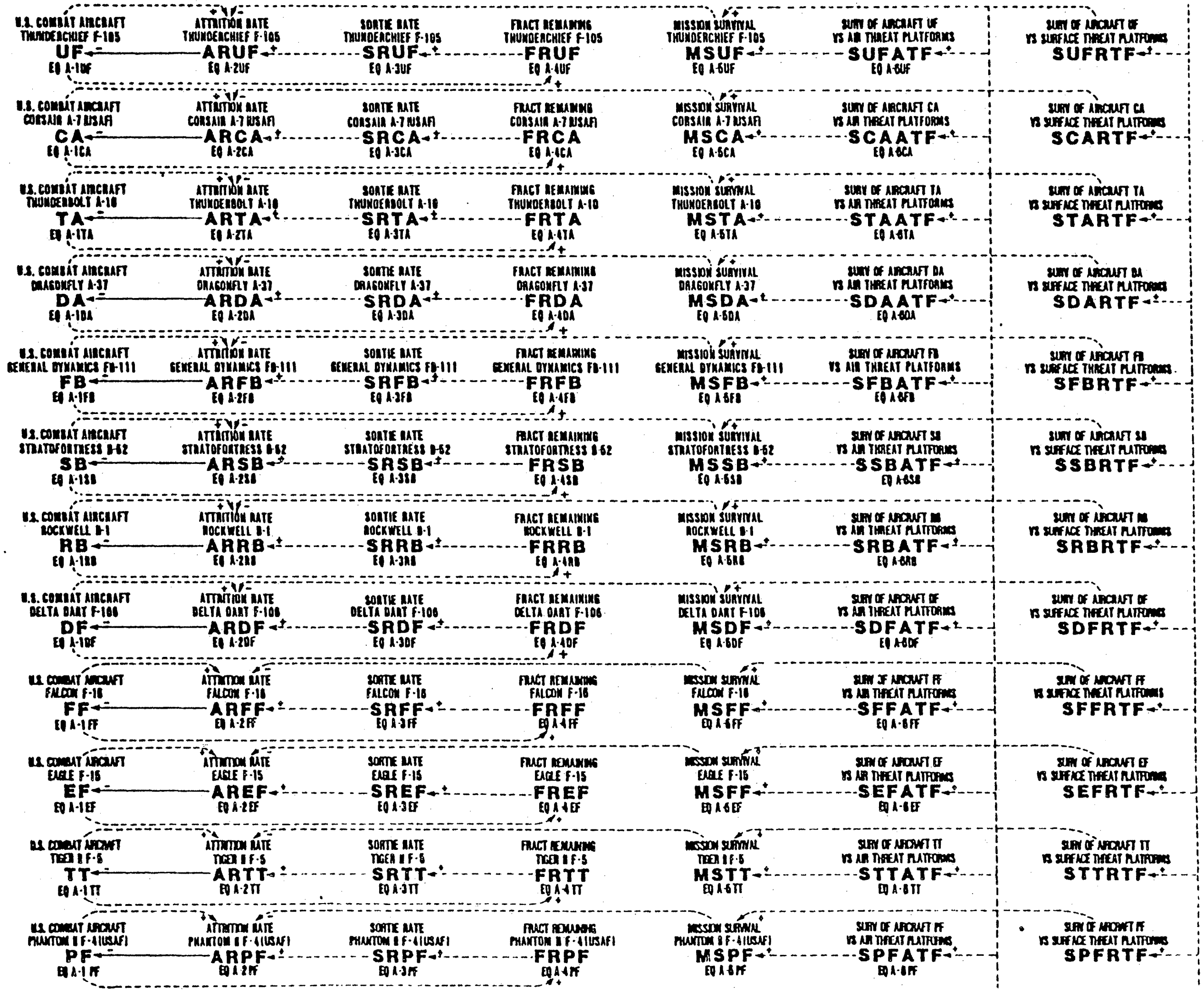


Fig. 4.8 ATTRITION SUBMODEL - A2

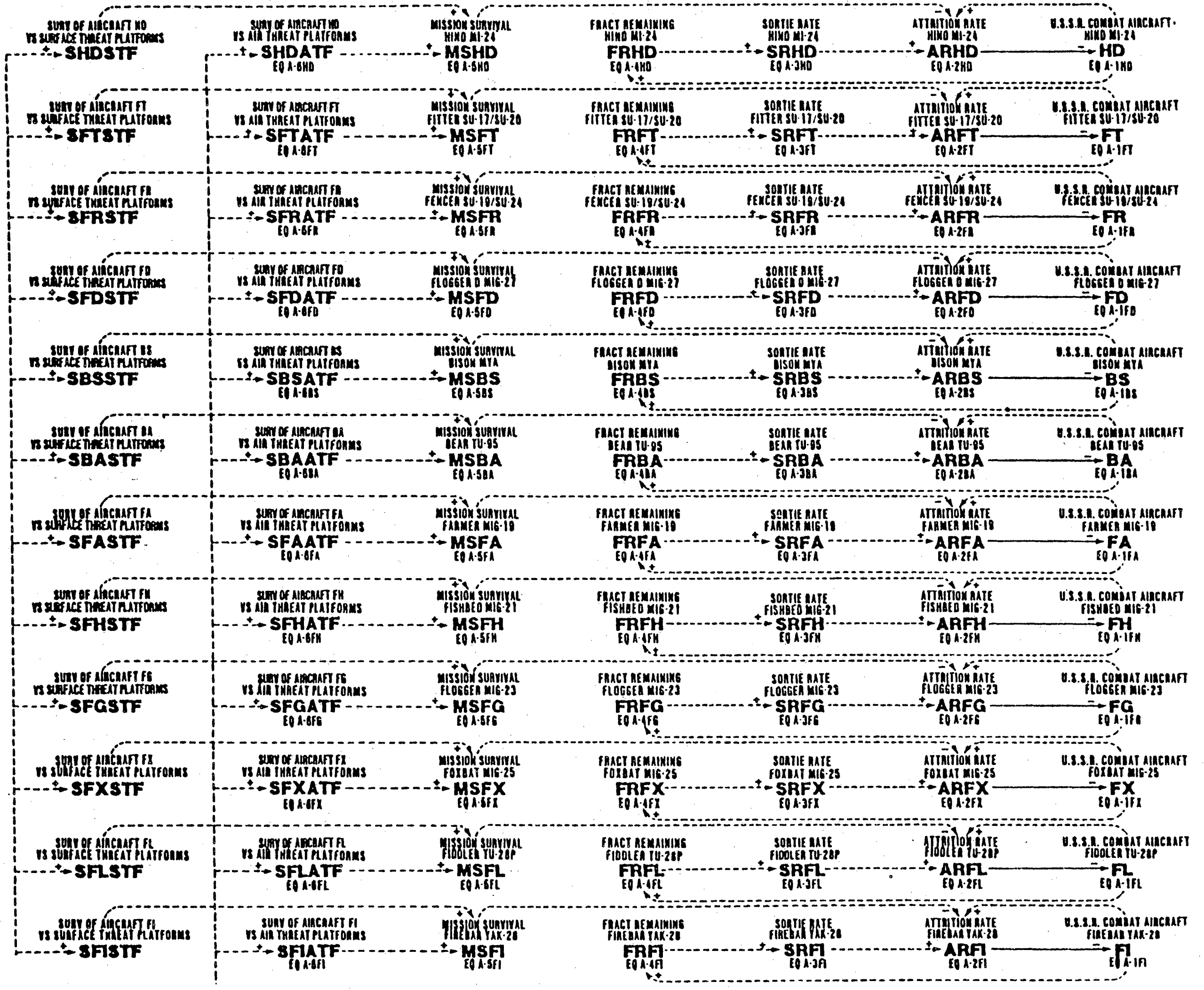


Fig. 4.9 ATTRITION SUBMODEL - SI

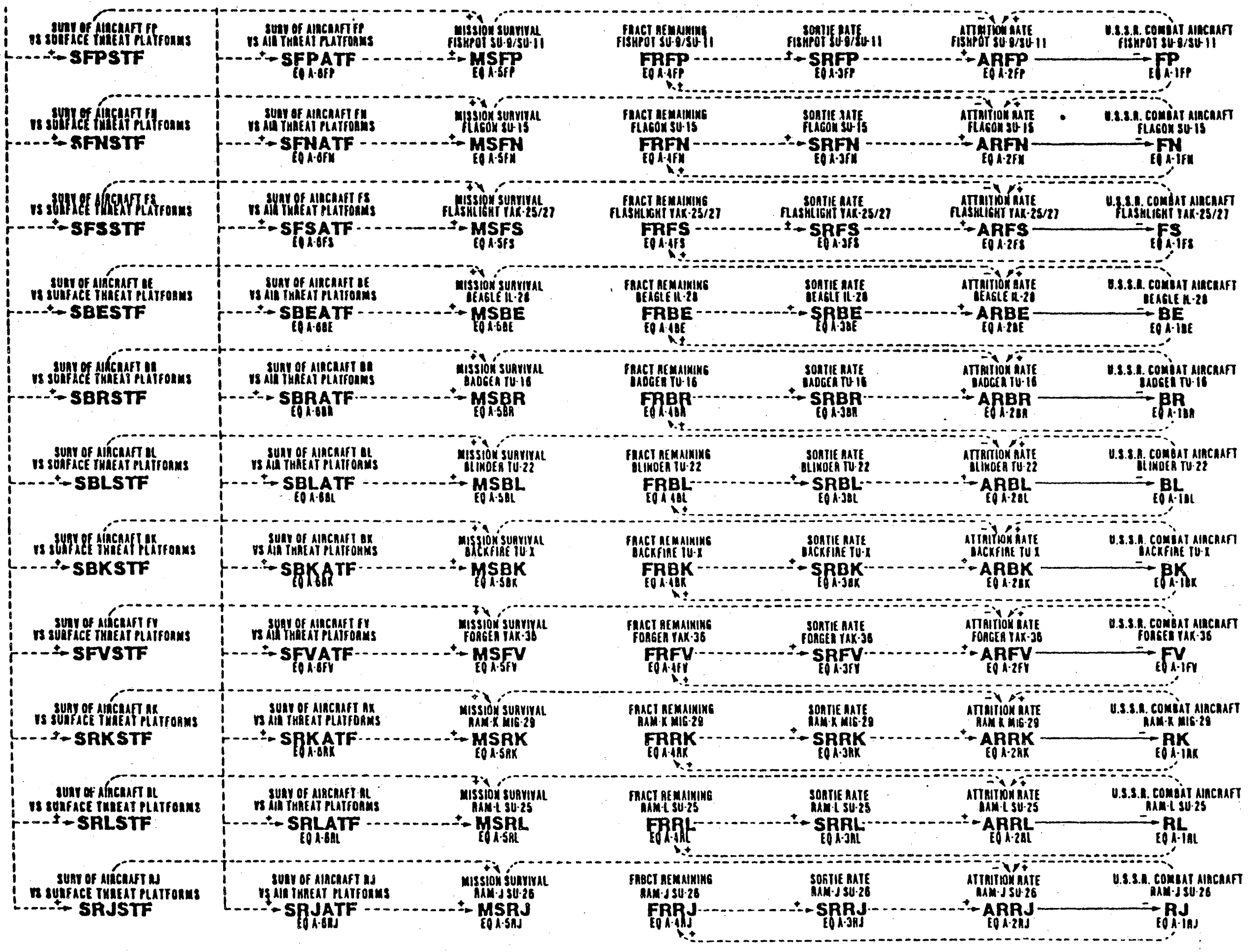


Fig. 4.10 ATTRITION SUBMODEL - S2

demands of air combat tend to force distinct designs on aircraft intended for differing tactical roles. Basically, tactical airpower can be divided into two groups: planes that attack ground targets (attack aircraft and bombers) and those that engage other airplanes (fighters). Each group can further be divided into a longand short-range component.

In air combat, as in a chess game, there is no guarantee that similar pieces will match-up. One aircraft's target will be another's threat. Antiground aircraft will be shot down by antiair aircraft and vice versa; both are vulnerable to surface-based air defenses. In the model air-to-air combat is simulated using the interactions shown in Figs. 4.7 & 4.8 and 4.9 & 4.10. Air-to-Surface and Surface-to-Air warfare aspects are incorporated when Figs 4.11, 4.12, 4.13 and 4.14, 4.15, 4.16 are considered.

In a survivability - methodology context, the Attrition Submodel represents a classification of threats -- "those elements of a man-made environment designed to reduce the ability of an aircraft to perform mission-related functions by inflicting damaging effects, forcing undesirable maneuvers or degrading systems effectiveness" [22]. Terminal threats consist of a firing platform (e.g., interceptor, launcher, etc.) and propagators (e.g., projectiles, missiles, etc.). Missiles are, by far, the most significant.

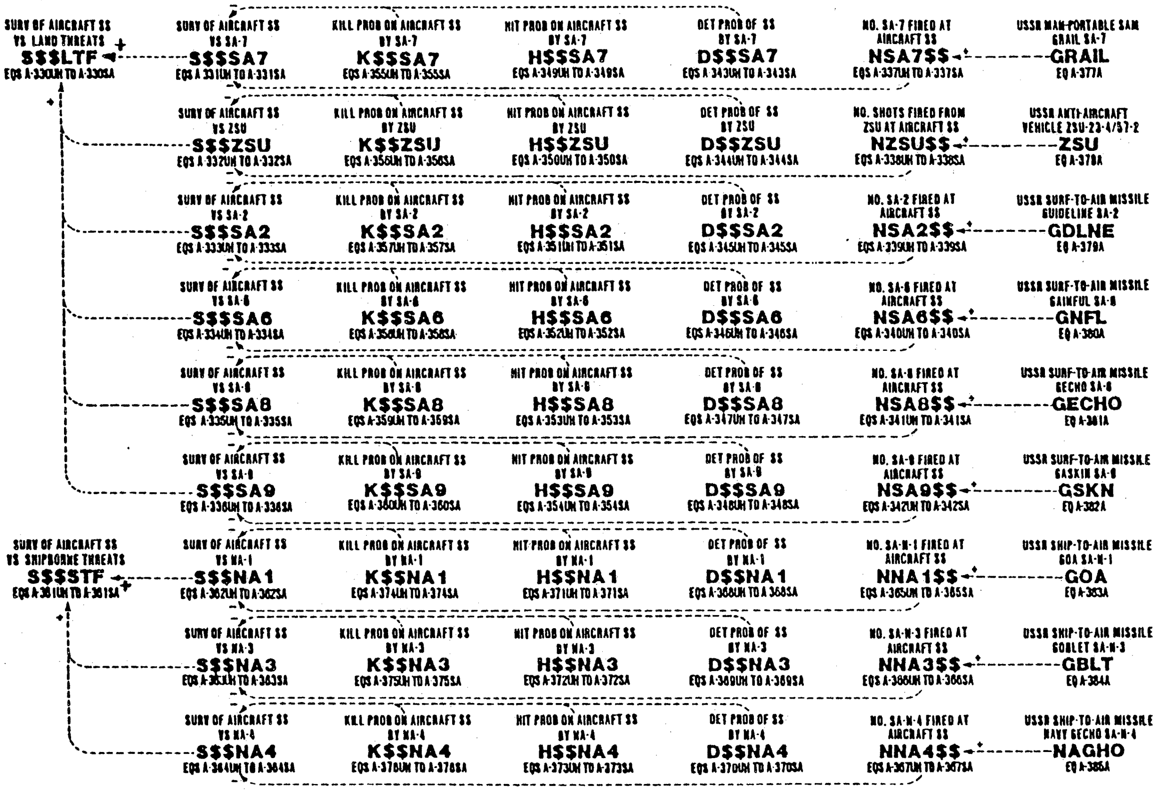


Fig. 4.11 ATTRITION SUBMODEL - A3

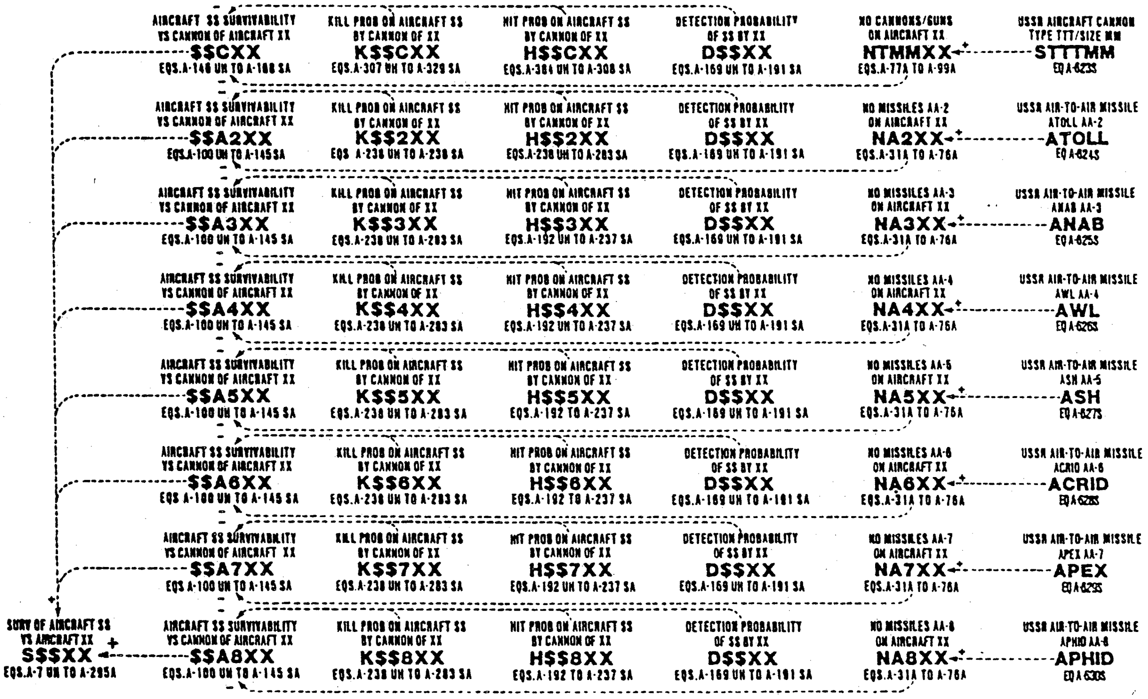


Fig. 4.12 ATTRITION SUBMODEL - A4

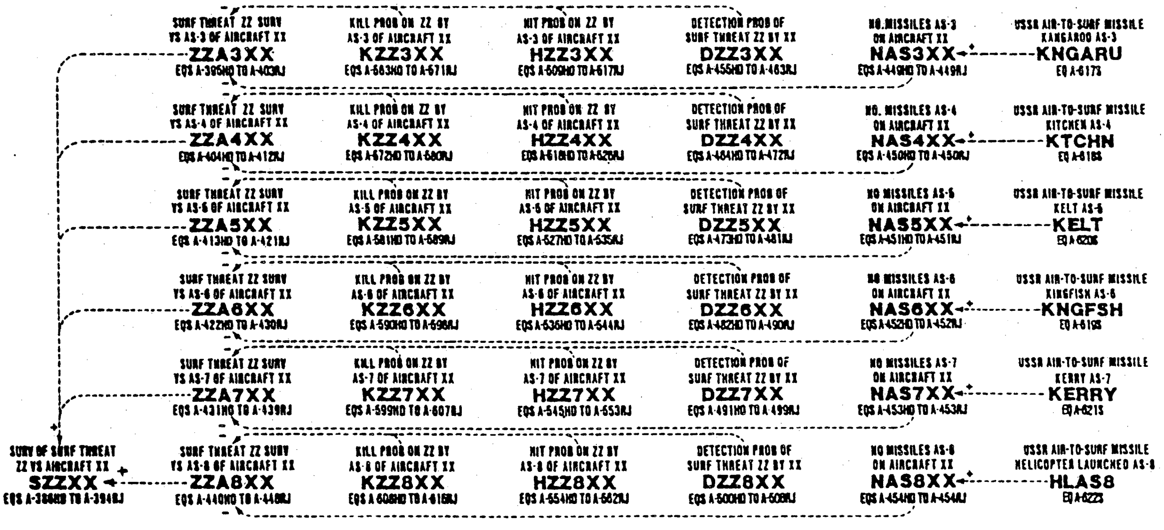


Fig. 4.13 ATTRITION SUBMODEL - A5

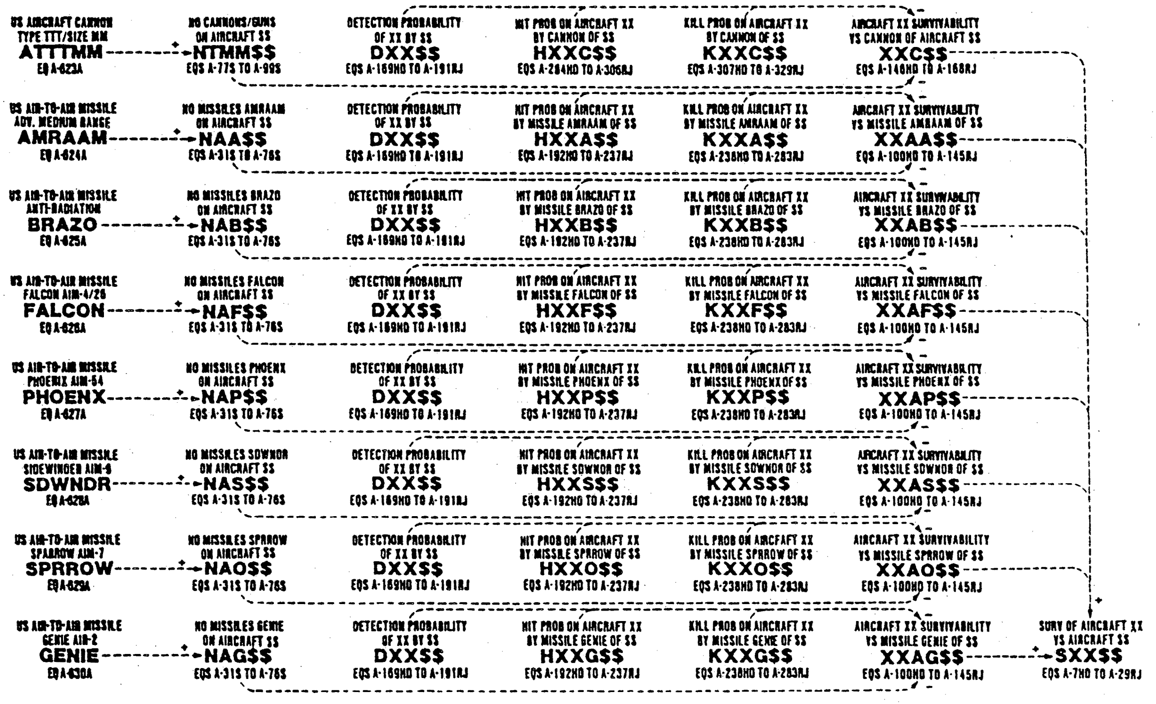


Fig. 4.14 ATTRITION SUBMODEL - S3

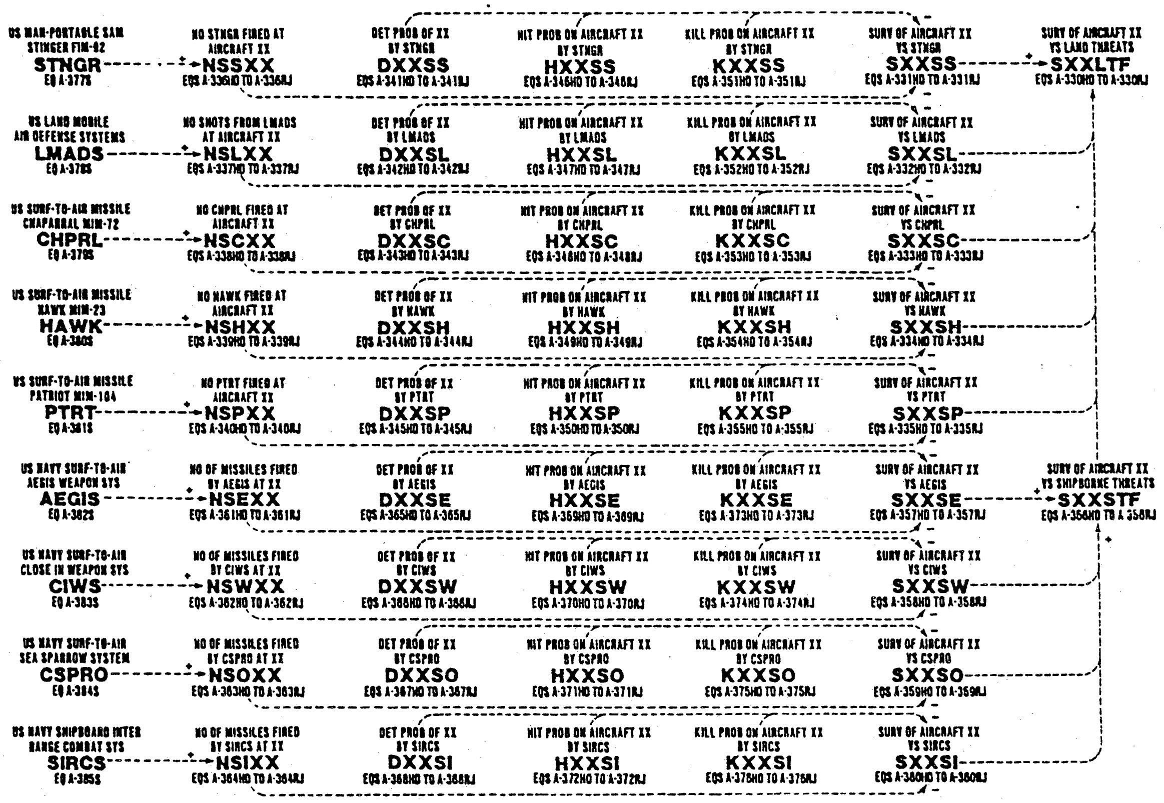


Fig. 4.15 ATTRITION SUBMODEL - S4

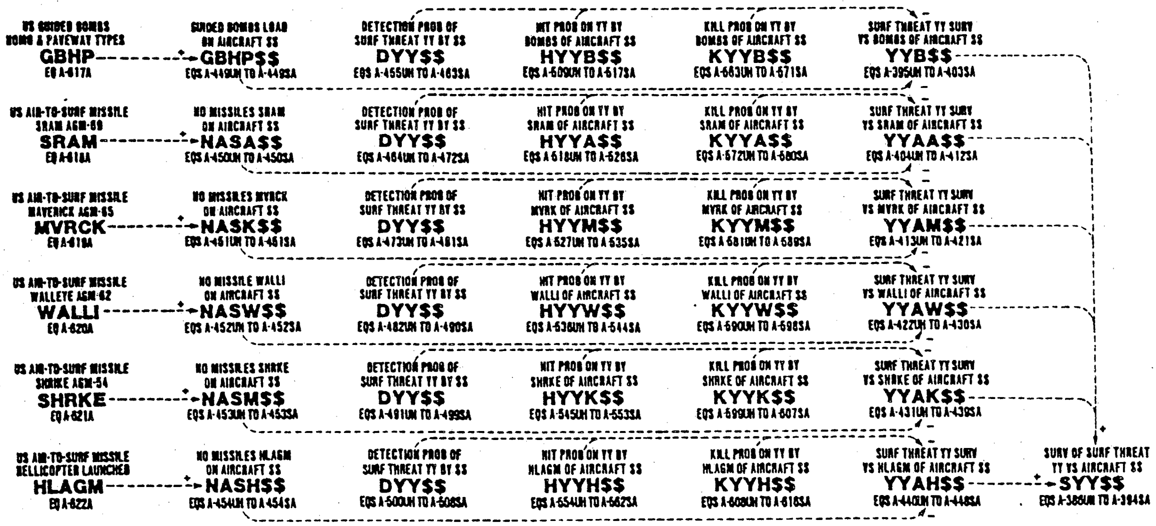


Fig. 4.16 ATTRITION SUBMODEL - S5

They are self-propelled, possess varying guidance capabilities, and are fabricated for air-to-air, surface-to-air, air-to-surface, or surface-to-surface roles. All contain a propulsion system, warhead section, sensor/antenna, and guidance system which ranges from self-contained to launch-dependent [85]. In the model, in addition to air-to-air, air-to-surface, and surface-to-air missiles, aircraft cannon/machine guns and anti-aircraft artillery systems are considered.

The three-step process by which aircraft are destroyed by hostile forces in combat is through "detection", "hit" and "kill". The probability of an aircraft not surviving an encounter is the probability of being detected multiplied by the probability of being hit if detected multiplied by the probability of being killed if hit. This convolution of conditional probabilities has been incorporated into the model for all air-to-air, surface-to-air, and air-to-surface encounters in the model (see Figs. 4.11, 4.12, 4.13 and 4.14, 4.15, 4.16). Surface-to-surface interchanges, while important, are beyond the scope of this research [77].

4.7 SURVIVABILITY SUBMODEL

The design and operation of air weapons based on consideration given to survivability is a relatively new philosophy for waging war. As late as World War II, it made sense, in time and dollars, to simply boost production and training inputs to resolve problems created by attrition. Most advances in survivability that occurred in WWII and the post WWII era were either "crew pacifiers" or unintended side-effects from efforts directed to other ends -- increased strength, performance, load carrying capacity, reliability, etc. [86].

The survivability of an aircraft can be increased by reducing its susceptibility to being detected and hit by a threat weapon system and/or by reducing its vulnerability to damage once hit. In Fig. 4.17 the methods of detection, hit, and kill reduction incorporated into the model are shown. These provide the baseline for survival enhancement.

Regarding detection, aircraft -- no matter how large -- are small objects in the vastness of the airspace in which they operate. Detection reduction involves reducing the target aircraft signatures (audio, visual, radar and infrared) that are used by threat systems for acquisition, tracking, and warhead guidance/homing. Use of minimum engine noise levels, low visibility paint, low radar cross section,

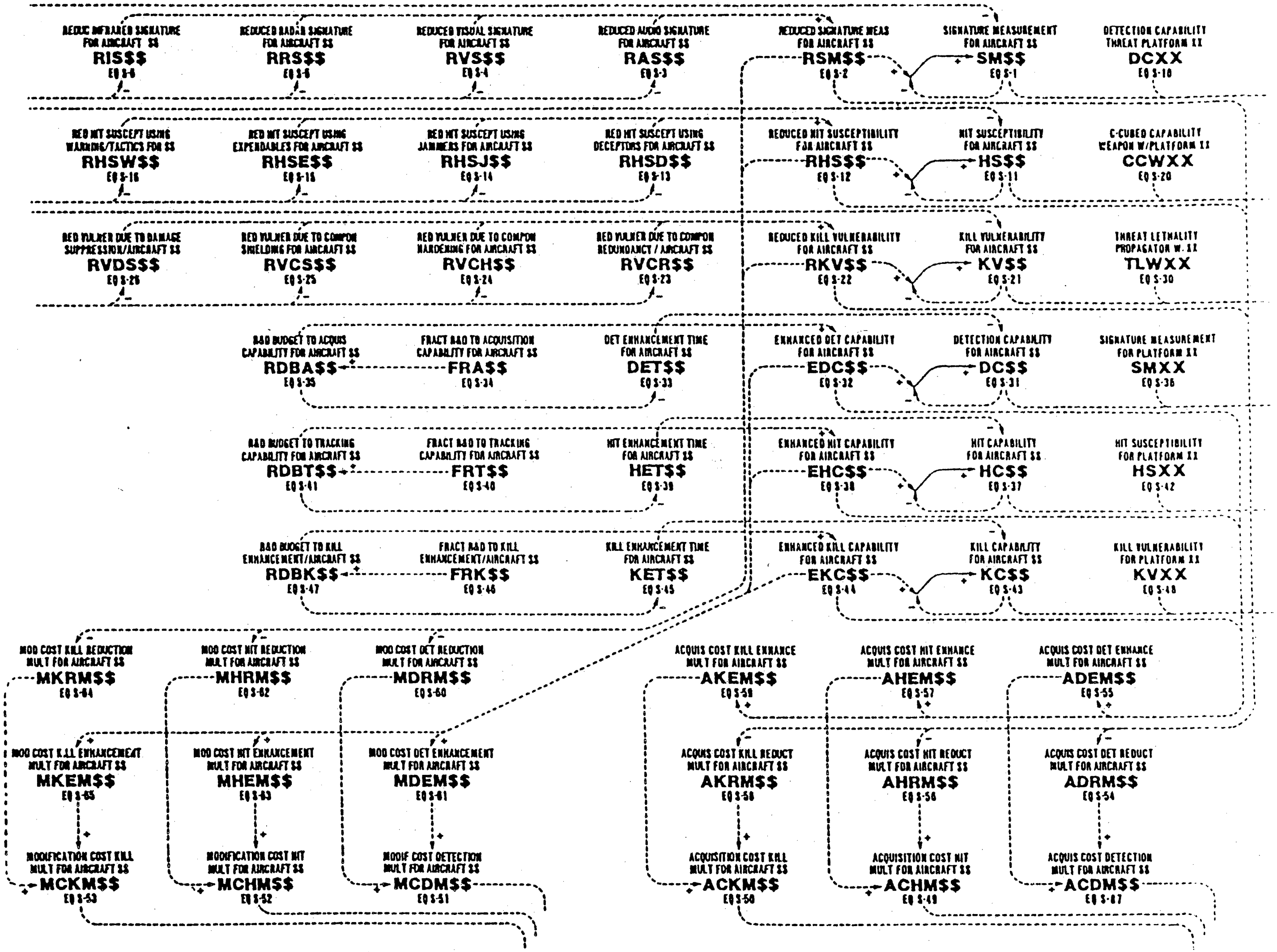


Fig. 4.17 SURVIVABILITY SUBMODEL - 1

and the shielding or cooling of heat sources serve these needs. The reduction of these signatures in the model depends on the size of the "R&D Budget to Detection Denial."

Reduction in the probability of a hit, given detection, can be accomplished by reducing the probability of acquisition and/or tracking [87]. Acquisition is the confirmation of enemy aircraft flying a bearing that will bring it within weapons' range. After detection and acquisition, which may take place in less than a minute, the aircraft must be tracked, visually or by fire-control radar, and fired upon. These components of the "hit" process can be frustrated by using deceptors, jammers, expendables, and warning/tactics (see Fig. 4.17). Deceptors fool the radar by sending false signals or manipulating the signal to make tracking difficult. While the purpose of deceptors is to degrade tracking capabilities, jammers serve to cause much shorter detection ranges by burying the actual signal in the noise on the radar presentation. Expendables, which take the form of chaff, decoys, or flares, create a signal larger than that of the aircraft causing a fire control system or a missile guidance system to track it instead of the aircraft. Warning and tactics refers to the capability of alerting an aircraft's crew of a threat in time for something to be done to avert it. Hit susceptibility reduction realized by these four approaches depends on the amount of R&D funds devoted to these efforts [77].

The basic vulnerability reduction concepts incorporated into the model (see Fig. 4.17) are component redundancy, component hardening, component shielding, and damage suppression. Component redundancy provides back-up capability in the event of failure or damage of the primary capability. Hardening refers to: "vulnerability reduction effects by interposing less essential components between critical components and the damage mechanisms, by reducing or eliminating the criticality of components through redesign or reallocation of functions, or by the use of materials having improved characteristics" [22]. Component shielding refers to the incorporation of armor, here. The fourth approach, damage suppression, can be achieved by using damage tolerant materials that deform but not shatter, that leak but do not rupture, or that suppress fires and explosions. These activities are supported in the model by the "R&D Budget to Kill Vulnerability Reduction."

The ability of combat aircraft to protect themselves is referred to in the literature as "self-defense systems" [22]. The term is used to describe any system which tends to enhance survivability by providing a real-time method of destroying the threat propagator before initiation of the damage process. Examples of active self-defense systems are: (1) a bomber defense missile (BDM) for damage to, or destruction of, airborne interceptors; and (2) a short-range attack missile (SRAM) for damage to, or destruction of, surface-based threats. This activity is not the same as tactics, electronic countermeasures (ECM), electronic counter-countermeasures (ECCM), etc. which is covered in the model under warning/tactics, a subset of susceptibility reduction. To model self-defense systems a detection- hit-kill breakdown was used which describes the aircraft's capability to destroy hostile weapons through the same process that the threat confronts the aircraft [77].

Survivability enhancement, like quality assurance goals applied to all real-world systems, must be pursued objectively -- not single-mindlessly. The benefits and the penalties associated with alternative survivability enhancement techniques of aircraft and subsystems must be examined and quantified. When performed at the micro level on individual aircraft, survivability enhancement trade-off analysis integrates penalties such as increased weight, reduced payload, reduced performance, increased cost, etc. with benefits measured in terms of increased probability of survival, reduced force requirements, reduced attrition, etc. This model, in its present form, strives to measure penalties and benefits in terms of the basic input, dollars, and the basic output, national security. Weight, payload, performance, etc. are viewed as tactical refinements to be considered only within a strategic framework. Within this chain of causality between input and output are the concepts of availability and acquisiton/modification cost multipliers depicted in Fig. 4.18.

The difference between availability and readiness is vague. We interpret readiness as being subjective but capable of description in arbitrary terms such as indicated above. Availability is a relatively precise concept -- a dimensionless, quantifiable parameter, a probability. In Fig. 4.18 the availability of combat aircraft is seen as a function of supply and demand -- the supply or capacity of maintenance/repair facilities and the demand (arrival rates) requiring these services based on aircraft reliability. Maintenance functions in the DOD normally are performed at three levels or echelons (with names peculiar to the Service -- Army, Navy and Air Force): the organizational (or servicing) level, the intermediate level (staffed predominantly by military personnel), and the depot level (staffed largely by civilians). The first two are integral to the combat units they support; the third level is normally a part of a major logistics agency in one of the military departments [88].

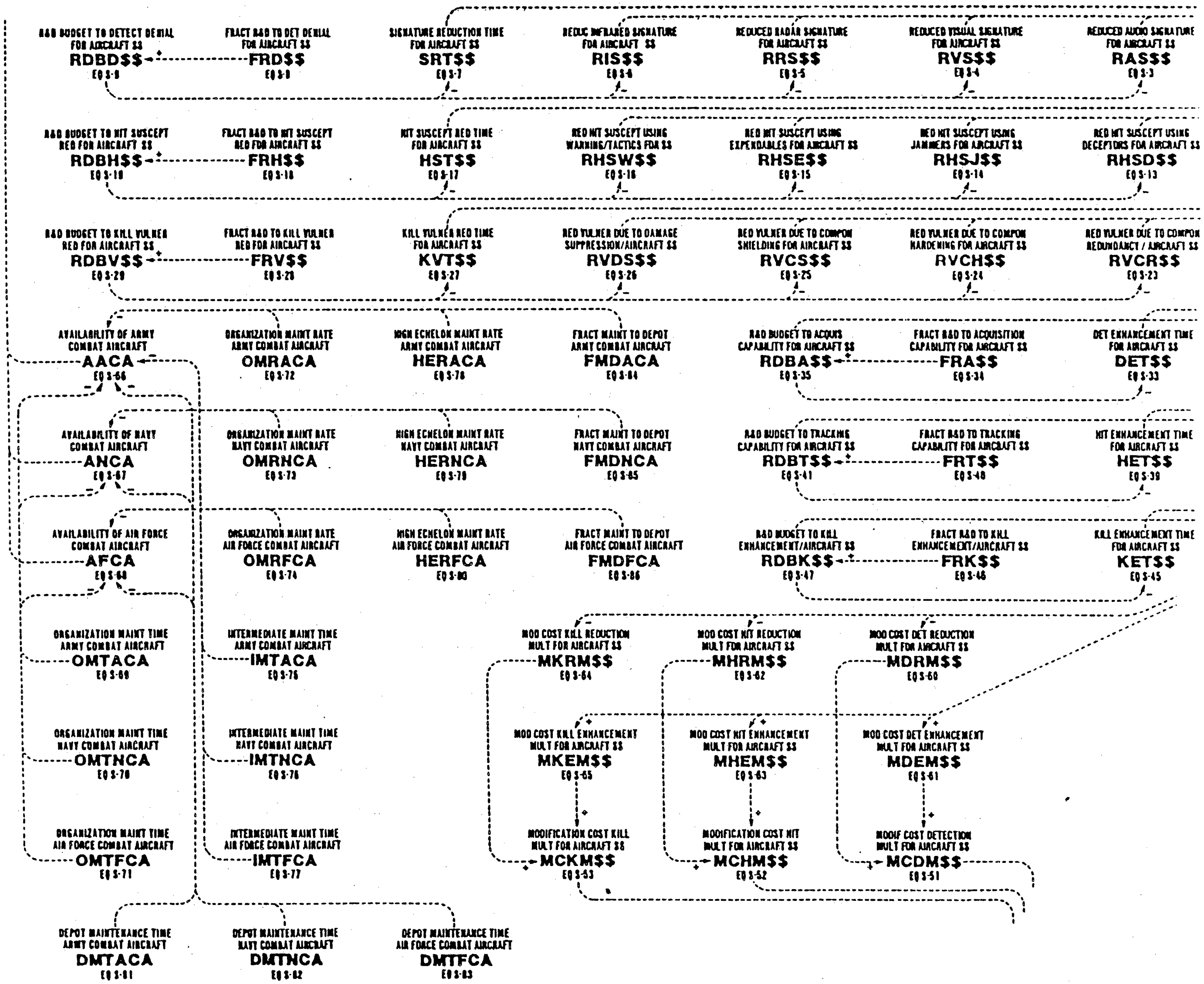


Fig. 4.18 SURVIVABILITY SUBMODEL - 2

There are six basic acquisition cost and six basic modification cost "multipliers" in the model that account for survivability enhancement cost-input tradeoffs between quality measured in survivability terms and quantity without these enhancements. They are the elements of the matrix comprised of the detection-hit-kill vector and the reduction-enhancement vector in each case.

4.8 SURVIVABILITY SUBMODEL SUBSYSTEMS

The complementary course of action for fulfilling the objectives of this research is the "bottom-up" approach. The idea here is to disaggregate the Survivability Submodel into elements that identify the susceptibility/vulnerability reduction of subsystem x to weapon effect y using survivability enhancement method z. Subsystems include structures, personnel stations, fuel systems, propulsion installations, power train systems, rotor blade systems, flight control systems, fluid power systems, environment control systems, armament systems, electrical power systems, avionic systems, launch/recovery systems, oxygen, and armor. Weapon effects include both primary -- ballistic impact or penetration of nonexplosive projectiles, ballistic impact or penetration of fragments for externally-detonated missile warheads, external blast effects, internal blast effects, and high energy laser effects, and secondary -- internal fires and explosives, hydraulic ram effects, liberation of corrosive materials, liberation of high temperature gases, and liberation of toxic gases. Survivability enhancement methods include redundancy, separation, isolation, damage tolerance using materials, damage tolerance using construction method, damage resistance using materials, damage resistance using construction methods, delayed failure, leakage suppression and/or control, fire and/or explosion suppression, fail safe response, localization, shielding masking/geometry/armor, and laser protective techniques [77].

The end results of the "bottom-up" approach are the usual forms of a system dynamics model, the methodology used in this research. They are causal diagrams and DYNAMO equations describing the causal chains between decision parameters (survivability enhancement methods) and impact variables (subsystem response to weapon effects).

The Survivability Submodel Subsystems incorporated in the JTCG/AS Model are shown in Fig. 4.19; they are Engine Susceptibility, Airframe Susceptibility, Engine Vulnerability, Power Train, Rotor Blades, Flight Control, Fluid Power, Environmental Control, Oxygen, Armament, Electrical Power, Avionics, Launch and Recovery, Armor, Structures, Personnel Stations, Propulsion, and Fuel Systems.

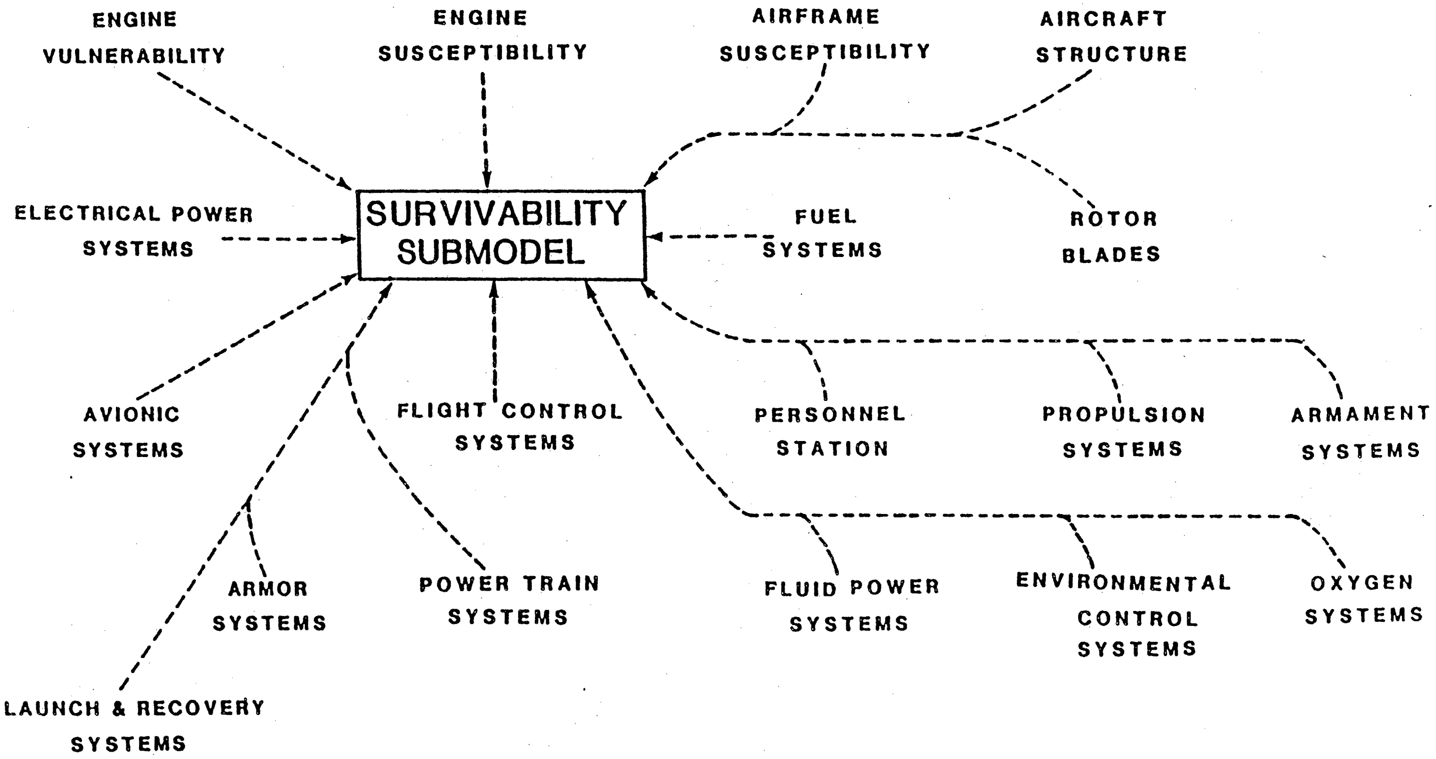


Fig. 4.19 SURVIVABILITY SUBMODEL SUBSYSTEMS (ORGANIZATION OF BOTTOM-UP APPROACH)

Chapter V

THEORY OF SURVIVABILITY-ATTRITION CONCEPTS

5.1 INTRODUCTION

The measure of success of the aircraft survivability professional community will be measured in part, by the confidence that exists in the state-of-the-art capability to accomplish the following:

- Quantify combat survivability in terms of the probability of kill given a hit by system and component.
- Once quantified, identify specific technological approaches to reducing defined vulnerability and susceptibility issues.
- Develop and integrate this technology to achieve the required level of weapon system survivability.
- Ensure through a consistent, orderly and logical evolutionary process the assessment capability required to meet the faster paced development of new threat technology and employment.

Critical to the understanding of the survivability phenomenon, in general, the Computer Simulation Management Model developed in this research, in particular, is an appreciation of the mathematics of aircraft combat survivability.

5.2 PROBABILITY OF SURVIVAL

Survivability has been receiving increased emphasis because of concern over limited aircraft production due to rising costs and the potential for high aircraft loss rates against lethal threat missile system. "Survivability" here is interpreted more precisely than it is in common usage. It is the capability of a weapon system, such as an aircraft, to continue to carry out its designated mission in a combat environment. It is a function of both "susceptibility," the combination of factors that determine the probability of hit by a given "threat," and "vulnerability," the extent of degradation of a system after having been subjected to combat. A "threat," as used here, is a man-made element employed by the enemy to reduce the ability of an aircraft to perform its mission. While there is general agreement in the meaning of these terms, there is no unaminity in their mathematical treatment.

A popular rendition of the probability of survival, P_S, is given in the following equation [89]:

$$P_{S} = 1 - (P_D \times P_{H/D}) \times P_{K/H} \qquad (5.1)$$

where P_D = probability of being detected

$P_{H/D}$ = probability of being hit, if detected

$P_{K/H}$ = probability of being "killed," if hit.

Retaining again to semantics, "kill" of course is a generic term. In the military there are several categories of kill based on criteria that define the degree to which the aircraft suffers performance degradation. In this discussion we mean "attrition kill" -- the rendering of damage to the aircraft to the extent it is either incapable or uneconomical to repair.

Basically, the probability of survival is simply the probability of not being killed. That is

$$P_S = 1 - P_K \tag{5.2}$$

The probability of being killed has been interpreted in various ways by different analysts. Ball [27] defines it as the product of susceptibility (P_H in his terms) and vulnerability, $P_{K/H}$,

$$P_K = P_H \times P_{K/H} \tag{5.3}$$

where susceptibility is determined by such factors as threat activity; aircraft detention, identification and tracking; and missile launch and gun firing, propagator flyout, and warhead impact or detonation. These actions, in this context, are measured by P_A (the probability the threat is active), P_D (the probability that the aircraft is detected), and P_T (the probability that a threat propagator is launched or fired, guided and either hits the aircraft or detonates sufficiently close to the aircraft to cause a hit by a damage mechanism) --

$$P_H = P_A \times P_T \times P_D \tag{5.4}$$

In the newly published military handbook [28] the probability of being killed is expressed as

$$P_K = P_D \times P_C \times P_H \times P_L \times P_{K/H} \tag{5.5}$$

where P_D is the probability of being detected; P_C is the conversion probability, i.e., the probability that the encounter will lead to a position where the threat weapon can be launched/fired; P_L is the probability of weapon launch; and P_H is the probability of the weapon (or its released fragments) hitting the target.

5.3 DERIVATION OF SURVIVABILITY EQUATIONS [77]

In truth, probability of survival is a summary measure and, depending on the particular application, may be computed for various aspects of a mission or a complete mission. Two popular parameters are the probability of survival per sortie, P_{SM}, and the probability of survival per encounter, P_{S/E_i}. The probability that an aircraft will survive a single operational flight or sortie during which it may have multiple engagements with the various weapons of a zone defense is given in [22][28] by

$$P_{SM} = \underset{i}{\pi} \exp - \frac{N_i x D x 2 R_{eff_i} x (1 - P_{S/E_i})}{A_i} \qquad (5.6)$$

where

P_{SM} = probability of mission survival over i^{th} engagements with the zone defense weapons mixture

A_i = the area in which the weapon systems or firing units are expected to be randomly distributed

N_i = the number of i^{th} type weapon systems in area A

R_{eff_i} = the effective range of the i^{th} type weapon system

D = the distance the aircraft flies through area A without significantly changing altitude or airspeed

P_{S/E_i} = the probability of the aircraft surviving a single encounter with the i^{th} type of weapon system.

All of the above parameters with the exception of P_{S/E_i} are environmental oriented. The probability of survival per encounter is consistently representative in the literature [22][28] as

$$P_{S/E_i} = (P_{LOS})(P_D)(P_L)(P_G)(P_{DET})[\overset{n}{\pi}(1-P_{SSK})] \qquad (5.7)$$

where

P_{LOS} = probability of line-of-sight to the target

P_D = probability of detection, given line-of sight

P_L = probability of launch or firing, given detection

P_G = probability of succesful guidance, given launch or firing

P_{DET} = probability of warhead detonation (fuzed warheads), given successful guidance

n = number of shots fired during a pass

P_{SSK} = single-shot kill probability

A number of essential functions must be performed in sequence by any type of antiaircraft system to be effective. First, a radar or visual line-of-sight to the target must exist. Next, the target aircraft must be detected, recognized, and identified as an enemy. Projectile or missile launch can then occur given that the target is within its range and angular-rate limitations. Successful guidance to the target is a function of the defense system type, the launched projectile or missile associated with the defense system (i.e., free flight projectile, radar or IR guided, etc.), and the kinetic aspects of the target. Referring to equation 5.7, the five terms preceding the bracketed term represent the threat system effectiveness, TSE. Since it is the product of five probabilities, it is itself a probability, P_{TSE}. Rewriting equation 5.7,

$$P_{S/E_i} = P_{TSE} \times [\overset{n}{\pi}(1-P_{SSK})] \qquad (5.8)$$

The problem is that equations 5.7 and 5.8 are incorrect. While it can be argued that these are close approximations, they are misleading nevertheless. Looking at equations 5.7 and 5.8, one would conclude that an increase (decrease) in the threat system effectiveness causes an increase (decrease) in survivability -- which of course is illogical.

It is instructive to derive the correct form for P_{S/E_i}. To begin with

$$P_{S/E_i} = 1 - P_{TSE} \times P_{K/TSE} \qquad (5.9)$$

where $P_{K/TSE}$ is the probability of being killed for a certain threat system effectiveness. Using the binomial distribution with parameters n (the number of shots fired) and P_{SSK} (the single shot kill probability).

$$P_{K/TSE}(x) = \sum_{x=1}^{n} \frac{n!}{x!(n-x)!} (P_{SSK})^{x} (1-P_{SSK})^{n-x} \qquad (5.10)$$

This is one minus the probability of not being killed in n shots,

$$P_{K/TSE}(x) = 1 - P_{K/TSE}(0) = 1 - (1-P_{SSK})^{n} \qquad (5.11)$$

Substituting (5.11) in (5.9) gives

$$P_{S/E} = 1 - P_{TSE} + P_{TSE} \times [\prod^{n} (1-P_{SSK})] \qquad (5.12)$$

Only if P_{TSE} equals one is equation 5.8 (and therefore equation 5.9) correct.

Repeating the derivation under the assumption of a Poisson distribution, equation 5.10 becomes

$$P_{K/TSE}(x) = \sum_{x=1}^{\infty} e^{-m} m^{x}/x! \qquad (5.13)$$

where $m = n \times P_{SSK}$. Instead of (5.11), one now obtains

$$P_{K/TSE}(x) = 1 - P_{K/TSE}(0) = 1 - e^{-n\,P_{SSK}} \qquad (5.14)$$

Substituting (5.14) in (5.9) gives

$$P_{S/E_i} = 1 - P_{TSE} + P_{TSE} \times e^{-n\,P_{SSK}} \qquad (5.15)$$

Equation 5.15 is an approximation of equation 5.12 just as the Poisson is an approximation of the binomial distribution. That is

$$\prod^{n}(1-P_{SSK}) = (1-P_{SSK})^{n} = [(1-P_{SSK})^{1/PSSK}]^{-n\,P_{SSK}} = e^{-n\,P_{SSK}} \qquad (5.16)$$

In order to get the popular forms of equations 5.1 to 5.4 which are

P(survival)=1- P(detection) x P(hit/detection) x P(kill/hit)

we can take equation 5.15, expand the last term into an exponential series, neglecting higher order terms --

$$P_{S/E_i} = 1 - P_{TSE} \times n\,P_{SSK} \qquad (5.17)$$

where from (5.3) we have for P_{SSK}

$$P_{SSK} = P_{SSH} \times P_{K/H} \qquad (5.18)$$

and

$$P_{S/E_i} = 1 - (P_{TSE})(nP_{SSH})(P_{K/H}) \qquad (5.19)$$

Substitution of (5.19) into (5.6) gives the expression for mission survivability

$$P_{SM} = \pi_{i} \exp[-(ZDF)(P_{TSE})(nP_{SSH})(P_{K/H})] \qquad (5.20)$$

where $ZDF = N_i D \times 2R_{eff_i}/A_i$ and can be thought of as the "zone defense factor" as implied by the parameter definitions given in equation 5.6.

The degree of sophistication employed in an analysis of defense system effectiveness depends on the intended use of the results and the confidence level placed on the inputs. Realistic results require the inclusion of many parameters, some of which such as aircraft vulnerability areas, blast and fragmentation envelopes, weapon system accuracy, etc., are illusive. Consider the last term of (5.19): the probability of a random hit killing the aircraft is equal to the ratio of its vulnerable area A_V to its presented area A_P [91]. Substituting in (5.19) gives

$$P_{S/E_i} = 1 - P_{TSE} \times n \times P_{SSH} \times A_V/A_P \qquad (5.21)$$

Now consider P_{SSH} in equation 5.19, the probability of hitting an aircraft in a single firing from a threat. This single shot probability determination can be approached in many ways including the following. Using the concept of CEP (the circular error probability of a group of n shots defining a circle within which half will hit) the probability of the aircraft being hit

$$P(x) = \frac{m^x}{x!} e^{-m} = \frac{m^x}{x!} (1 - m + \frac{m^2}{2!} - \ldots.) \qquad (5.22)$$

where

$$m = \frac{A_P}{\pi(CEP)^2} x \frac{1}{2} \qquad (5.23)$$

Neglecting higher order terms in the exponential expansion,

$$P_{SSH} = \frac{A_P}{2\pi(CEP)^2} \qquad (5.24)$$

and after substituting in (5.19)

$$P_{S/E_i} = 1 - P_{TSE} \frac{n\ A_V}{2\pi(CEP)^2} \qquad (5.25)$$

5.4 COMBAT ATTRITION MODELS

For large numbers of repeated sorties per aircraft, such as is common in tactical nonnuclear strike operations, successful continuation of operations is sensitive to the level of combat attrition experienced per sortie. This aspect of warfare, victory through enemy force attrition, has long fascinated analysts and practitioners. Among the most famous of the individual approaches and techniques that have been developed is the Lanchester Equations introduced in Chapter II.

Mathematical representation of military operations have long fascinated analysts and practitioners. In 1916 the English mathematician Frederick W. Lanchaster represented the attrition rates of two opposing forces in the form of two differential equations, functions of the size and combat effectiveness of each side [30]. Lanchester's model was an intellectual breakthrough in the analysis of warfare insofar as it provided a deep insight into the possibilities inherent in simple models of combat. Interestingly enough, Lanchester's representation of the problem as a dynamic system is precisely the approach used in the system dynamics methodology employed here. The difference is that Lanchester chose to represent the system as a second order because it was the highest order for which he could obtain a solution. Of course, in applying mathematics to human affairs, including warfare, the ability to solve models must not be confused with the ability to formulate the correct or appropriate model. In system dynamics, differential equations are converted to difference equations and there is virtually no limit on the number that can be employed to represent the known and complex details of a system [90].

5.4.1 Time Invariant Approach

Aircraft attrition is dependent on many factors including the susceptibility of the aircraft to detection and hit; the vulnerability of the aircraft once it is hit; the type, number, and placement of enemy defenses; and the tactics and countermeasures as its disposal. When an aircraft penetrates a specified threat scenario, its survival probability P_S can be estimated from the aforementioned considerations. Then the probability that the aircraft gets killed P_K, or its attrition, is $1 - P_S$.

We begin our mathematical treatment of the subject by developing the expression for the cumulative number of sorties flown CS by an aircraft with survivability probability P_s after n scheduled sorties, which is given by the following geometric series:

$$CS = 1 + P_S + P_S^2 + P_S^3 + \ldots\ldots + P_S^{n-1} \qquad (5.26)$$

Multiplying both sides by P_S gives

$$P_S \times CS = P_S + P_S^2 + P_S^3 + \ldots + P_S^{n-1} + P_S^n \qquad (5.27)$$

Substracting (5.27) from (5.26), and solving for CS, one obtains

$$CS = (1-P_S^n)/(1-P_S) \qquad (5.28)$$

Taking the limit as n approaches infinity, the expected number of sorties scheduled by an aircraft in its lifetime is

$$E(n) = 1/(1-P_S) \qquad (5.29)$$

Frequently, measures of effectiveness are expressed in term of "exchange ratios." An example of an exchange ratio is the number of targets destroyed per aircraft lost TDPL, expressed as

$$TDPL = E(n) \times TDPS \qquad (5.30)$$

where TDPS is the number of targets destroyed per sortie.

The analysis developed in this section forms the theoretical basis for two additional measure of effectiveness's used in comparing two competing systems. They are cost for equal effectiveness and effectiveness obtained for equal cost as well as indifference or breakeven curves. A trivial example of each will follow:

a. Equal Effectiveness

If we desire to determine the force size of aircraft with two different, say ECM (Electronic Counter Measures) configurations, which gives equal effectiveness we merely equate the total sorties flown and returning by a force of N aircraft as per equation 5.29.

$$\frac{N_{(Base)}\, P_{S(Base)}}{P_{K(Base)}} = \frac{N_{(MOD)}\, P_{S(MOD)}}{P_{K(MOD)}} \qquad (5.31)$$

where the subscript BASE and MOD identify the baseline and new ECM configuration respectively. Equation 5.31 is merely the number of sorties for the new ECM configuration that yields the same effectiveness as the old configuration. Then the number of aircraft required, for the MOD configuration, that give the same effectiveness as the baseline configuration is merely

$$N_{(MOD)} = \frac{N_{(BASE)} P_{S(BASE)} P_{K(MOD)}}{P_{K(BASE)} \quad P_{S(MOD)}} \tag{5.32}$$

b. Equal Cost

The equal cost MOE determines the number of sorties that can be flown for an equal total life cycle cost (C_T). Life cycle cost for the baseline configuration is determined and is used as the equal cost level for the analysis. An iterative process (i.e., trial and error) is used to determine the number of aircraft that can be operated for each competing ECM configuration for the given cost level (C_T). The results should converge rapidly to the solution. In order to determine the unit cost (C_U) for a given ECM configuration, the 10 or 15 year operating cost plus the ECM procurement and operating cost for each competing unit equipment is obtained. The number of aircraft, $N_{(MOD)}$ which can be modified and operated for a given total cost (C_T) is given by:

$$N_{(MOD)} = C_T/C_U \tag{5.33}$$

c. Indifference Curves

An extremely simplified analysis that attempts to illustrate the indifference or breakeven curve between attrition (P_K) cost (C) and target destroyed potential (T_D) for the modified aircraft (MOD) and baseline aircraft (BASE) are the following:

	MOD	BASE
Targets killed/sortie	$T_{D(MOD)}$	$T_{D(BASE)}$
Targets killed/ac. loss	$T_{D(MOD)}/P_{K(MOD)}$	$T_{D(BASE)}/P_{K(BASE)}$
Targets killed/cost	$T_{D(M)}/P_{K(M)}C_{(M)}$	$T_{D(B)}/P_{K(B)}C_{(B)}$

Equating the final relationships we obtain:

$$\frac{P_{K(MOD)}}{P_{K(BASE)}} = \frac{T_{D(MOD)}\quad C_{BASE}}{T_{D(BASE)}\quad C_{MOD}} \tag{5.34}$$

One can readily solve Eq. 5.34 for the indifference or breakeven curve shown in Fig. 5.1. For example, suppose the attrition of the modified aircraft was reduced from 2%, for the baseline, to 1.6% (i.e., $P_{K(MOD)}/P_{K(BASE)}=0.8$). The foregoing simple analysis would suggest that if both aircraft had the same target kill potential, then in order to breakeven we could afford to pay 1.25 more for the modified aircraft than the baseline. However, the target kill potential of the modified aircraft may be reduced. This can happen, for example, the target kill potential ratio

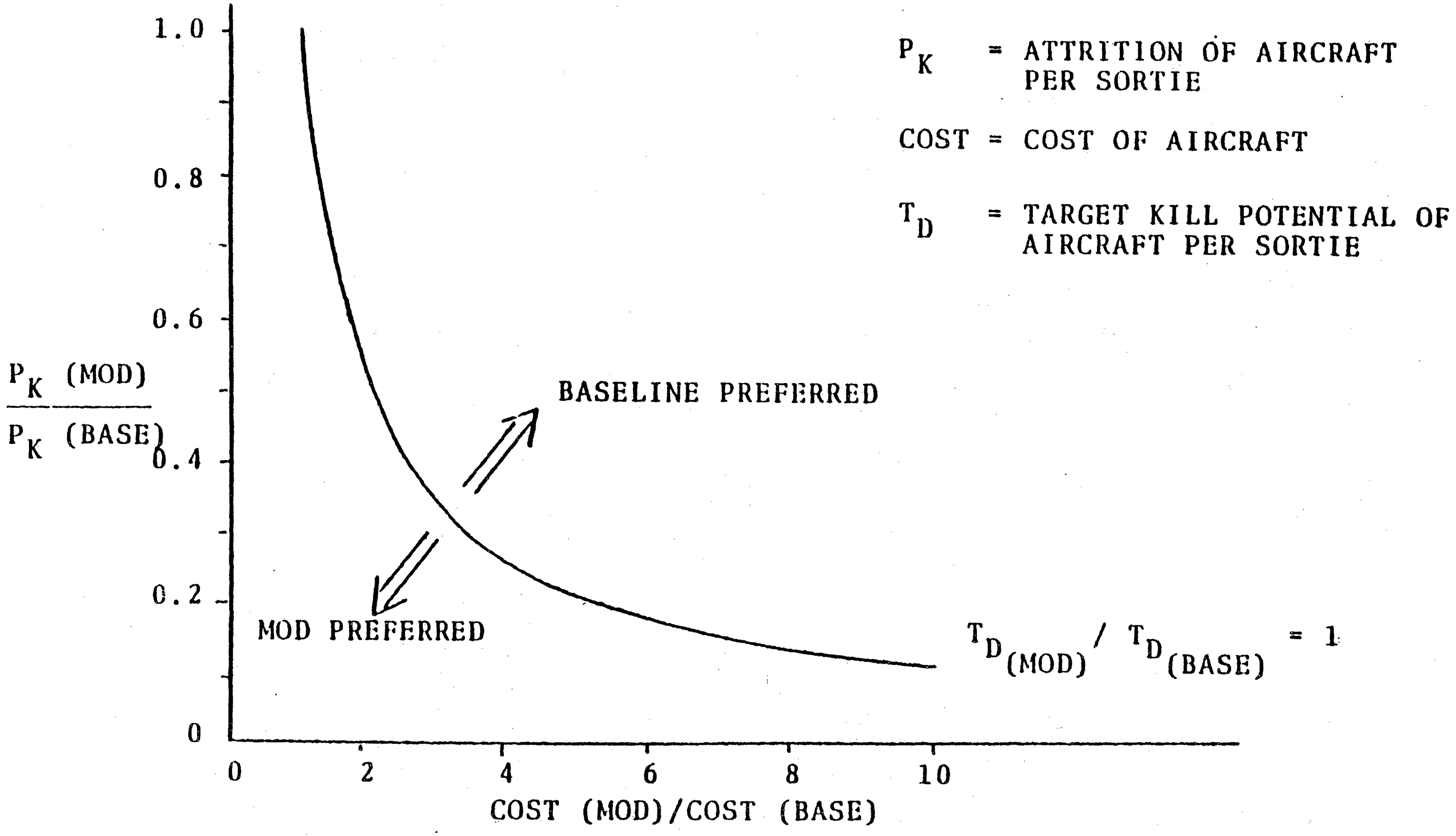


Fig. 5.1 COST EFFECTIVENESS INDIFFERENCE CURVE

$T_{D(MOD)}/T_{D(BASE)}$ is reduced to 0.75 then Eq. 5.34 (1.25 x 0.75 = 0.938) suggests that the baseline aircraft is in reality still preferred - even with its higher attrition values. Of course, this assumes that the cost of the crew member that is lost cannot be quantified.

In the preceding analysis several MOE's involving exchange ratios were used. The use of exchange ratios can often lead to misleading results. Because in formulating exchange ratios one devides numbers and the impact of the magnitude of the numbers is lost. For example, a large aircraft may have a high target kill potential and higher attrition than a small aircraft having a low kill potential. Due to the magnitude of the numbers involved the small aircraft may show a higher exchange ratio but may not be preferred in a situation where striking the targets early in the conflict may be of paramount importance. Thus, although the MOE presented in this section are useful indicators of aircraft combat effectiveness they give no indication of how fast an aircraft can inflict damage to the enemy targets. Nevertheless these relations are at times useful, especially in comparing similar systems, such as modified programs where the aircraft sortie rate is not likely to change and thus a time independent effectiveness comparison may be appropriate.

5.4.2 Time Dependent Considerations

There are two important shortcomings of this time invariant approach for determining attrition measures of effectiveness. First, knowing how fast a given number of targets can be destroyed is as important as knowing the ultimate number destroyed. Secondly, attrition and the threat responsible for this attrition are not constant, but change over time. Companile [92] overcomes the first shortcoming by bringing time into the picture as follows:

$$n = SR \times t \qquad (5.35)$$

where SR is the sortie rate. The sortie rate, a complex function involving maintenance, repair time, reliability, crew ratio, etc., is assumed to be constant. Using (5.35) the cumulative sorties flown by an aircraft with survivability P_S and sortie rate SR in t days is

$$CS = (1 - P_S^{SRxt})/(1-P_S) \qquad (5.36)$$

The cumulative sorties flown by a force of N aircraft, CS_N, is obtained by multiplying (5.36) by N:

$$CS_N = N\,(1-P_S^{SRxt})/(1-P_S) \qquad (5.37)$$

The cumulative targets destroyed by a force of N aircraft, TN, is obtained by multiplying equation 5.37 by the target kill potential TDPS:

$$T_N = (TDPS)(N)(1-P_S^{SRxt})/(1-P_S) \qquad (5.38)$$

Other parameters that can be obtained from the above relations are the function of force remaining FFR and the fraction of force lost FFL which are defined as follows:

$$FFR = P_S^{SRxt} \tag{5.39}$$

$$FFL = 1 - P_S^{SRxt} \tag{5.40}$$

5.4.3 Continuous Model Formulation

Let us begin by expressing the fraction of force remaining FFR in Eq. 5.39 in alternate forms:

$$FFR = P_S^n = \left[(1-P_K)^{-1/P_K} \right]^{-nP_K} \tag{5.41}$$

As n approaches infinity, the base of natural logarithm is defined so that with substitution for n and P_K we obtain

$$FFR = e^{-nP_K} = e^{-(1-P_S)(SR)(t)} \tag{5.42}$$

Recognizing that

$$FFR = \$\$_t/\$\$_o \tag{5.43}$$

where $\$\$_t$ is the number of aircraft at time t and $\$\$_o$ is the initial value for this variable, we see that Eq. (5.42) is really the solution to the differential equation,

$$\frac{d\$\$_t}{dt} = (1-P_S)(SR)(\$\$_t) \tag{5.44}$$

Expressed as an integral equation, (5.44) becomes

$$\$\$_t = \$\$_{t-1} - \sum_{t-1}^{t} (1-P_S)(SR)dt \tag{5.45}$$

$$\$\$.K = \$\$.J - (DT)(AR\$\$.JK) \tag{5.46}$$

where AR$$, the attrition rate is given by

$$AR\$\$.KL = (1-S\$\$)(SR\$\$)(\$\$.K) \qquad (5.47)$$

The advantages of a system dynamics formulation of the aircraft combat attrition phenomenon over the discrete-event representation of the preceding sections is that it permits the incorporation of much more realism. For example, attrition due to both surface threat and air threat platforms can be considered simultaneously. This is important because it recognizes that the threat, and therefore attrition inflicted by the threat, will change from sortie to sortie in a real situation. Indeed, many aircraft are designed specifically for counterair missions so as to reduce enemy air-launched threat propagators (e.g., enemy combat aircraft with air to surface and air to air missiles) [90].

5.5 FIRST ORDER FEEDBACK ATTRITION MODEL

$$\frac{d\$\$}{dt} = A - M\,\$\$ \qquad (5.48)$$

$$\frac{dXX}{dt} = P - N\,XX \qquad (5.49)$$

Where A, P are the procurement rate and M, N are the combat effectiveness. Differentiating equation (5.48) will give

$$\frac{d^2\$\$}{dt^2} = -M\,(A - M\,\$\$)$$

$$= -AM + M^2\$\$ = M^2\,(\$\$ - A/M)$$

This can be written as:

$$\frac{d^2(\$\$-A/M)}{dt^2} - M^2\ (\$\$-A/M) = 0 \qquad (5.50)$$

The general solution of this differential equation is:

$$\$\$_t - A/M = C_1\ e^{\omega t} + C_2\ e^{-\omega t} \qquad (5.51)$$

$$\frac{d(\$\$_t - A/M)}{dt} = C_1\ \omega\ e^{\omega t} - C_2\ \omega\ e^{-\omega t} \qquad (5.52)$$

$$\frac{d^2(\$\$_t - A/M)}{dt^2} = C_1\ \omega^2\ e^{\omega t} + C_2\ \omega^2\ e^{-\omega t} \qquad (5.53)$$

Substituting (5.51) and (5.53) into (5.50) gives:

$$\omega^2\ (C_1\ e^{\omega t} + C_2\ e^{-\omega t}) - M^2\ (C_1\ e^{\omega t} + C_2\ e^{-\omega t}) = 0$$

$$(C_1\ e^{\omega t} + C_2\ e^{-\omega t})(\omega^2 - M^2) = 0 \qquad \rightarrow \omega = M$$

At time equals zero (t=0), $C_1 + C_2 = \$\$_o - A/M$

and $C_1 - C_2 = A/M - \$\$_o$

these will lead to: $C_1 = 0$

$C_2 = \$\$_o - A/M$

The solution can be written as :

$$\$\$_t = A/M + (\$\$_0 - A/M)\ e^{-Mt}$$

with the same procedure, we can obtain:

$$XX_t = P/N + (XX_0 - P/N)\ e^{-Nt}$$

5.6 SECOND ORDER FEEDBACK ATTRITION MODEL

$$\frac{d\$\$}{dt} = A - B\ XX \qquad (5.54)$$

$$\frac{dXX}{dt} = P - C\ \$\$ \qquad (5.55)$$

Where A,P are the procurement rate and B, C are the combat effectiveness. If equation (5.55) is differentiated, we obtain

$$\frac{d^2\$\$}{dt^2} = -\ B\ \frac{dXX}{dt} = -\ B\ (P - C\ \$\$)$$

$$= BC\ (\$\$ - P/C)$$

This can be written as:

$$\frac{d^2(\$\$-P/C)}{dt^2} - BC\ (\$\$-P/C) = 0 \qquad (5.56)$$

The general solution of this differential equation is:

$$\$\$_t - P/C = C_1\ e^{\omega t} + C_2\ e^{-\omega t} \qquad (5.57)$$

$$\frac{d(\$\$_t - P/C)}{dt} = C_1\ \omega\ e^{\omega t} - C_2\ \omega\ e^{-\omega t} \qquad (5.58)$$

$$\frac{d^2(\$\$_t - P/C)}{dt^2} = C_1\ \omega^2\ e^{\omega t} + C_2\ \omega^2\ e^{-\omega t} \qquad (5.59)$$

Substituting (5.57) and (5.59) into (5.56) gives:

$$\omega^2\ (C_1\ e^{\omega t} + C_2\ e^{-\omega t}) - BC\ (C_1\ e^{\omega t} + C_2\ e^{-\omega t}) = 0$$

$$(C_1\ e^{\omega t} + C_2\ e^{-\omega t})(\omega^2 - BC) = 0$$

and this leads to $\omega = \sqrt{BC}$

At time equals to zero, we find,

$$C_1 + C_2 = \$\$_o - P/C$$

$$C_1\ \omega - C_2\ \omega = A - B\ XX_o$$

or $C_1 + C_2 = \$\$_o - P/C$

and $C_1 - C_2 = (A - B\ XX_o)/\sqrt{BC}$

Using this values we find:

$$C_1 = [\$\$_o - P/C + (A - B\ XX_o)/\sqrt{BC}\ ]/2 \qquad (5.60)$$

$$C_2 = [\$\$_o - P/C - (A - B\ XX_o)/\sqrt{BC}\ ]/2 \qquad (5.61)$$

Substituting (5.60) and (5.61) into equation (5.57) gives

$$\$\$_t - P/C = [(\$\$_o - P/C)/2][e^{\omega t} + e^{-\omega t}] + [(A - BXX_o)/2\sqrt{BC}][e^{\omega t} - e^{-\omega t}]$$

$$= [\$\$_o - P/C][(e^{\omega t} + e^{-\omega t})/2] + [(A - BXX_o)/\sqrt{BC}][(e^{\omega t} - e^{-\omega t})/2]$$

$$= (\$\$_o - P/C)\ \cosh\ \omega t - (XX_o - A/B)\sqrt{BC}\ \sinh\ \omega t$$

Since $\omega = \sqrt{BC}$, this equation can be written as

$$\$\$_t - P/C = (\$\$_o - P/C)\ \cosh\ \sqrt{BC}\ t - (XX_o - A/B)\sqrt{B/C}\ \sinh\ \sqrt{BC}\ t$$

$$\$\$_t = P/C + (\$\$_o - P/C)\ \cosh\ \sqrt{BC}\ t - (XX_o - A/B)\sqrt{B/C}\ \sinh\ \sqrt{BC}\ t$$

with the same procedure, the equation for XX_t can be obtained as follows:

$$XX_t = A/B + (XX_o - A/B)\ \cosh\ \sqrt{BC}\ t - (\$\$_o - P/C)\sqrt{C/B}\ \sinh\ \sqrt{BC}\ t$$

In the following sections, different cases of attrition model with different types of combat effectiveness will be presented.

5.7 ANALYTICAL TREATMENT OF CASE 1

$$\frac{d\$\$}{dt} = - M\ (XX + \$\$) \tag{5.62}$$

$$\frac{dXX}{dt} = - N\ (\$\$ + XX) \tag{5.63}$$

Solving the system for (XX+$\$\$$) gives

$$N \int_{\$\$_o}^{\$\$} d\$\$ = M \int_{XX_o}^{XX} dXX \tag{5.64}$$

with the solution

$$N\ (\$\$ - \$\$_o) = M\ (XX - XX_o) \qquad \text{or}$$

$$XX = (N/M)(\$\$ - \$\$_o) + XX_o \tag{5.65}$$

Substituting (5.65) into (5.62) gives

$$d\$\$/dt = - M\ [(N/M)(\$\$-\$\$_o) + XX_o + \$\$] \quad \text{or}$$

$$d\$\$/dt = - (M+N)\$\$ + N\$\$_o - MXX_o \tag{5.66}$$

Separation of variables gives:

$$\frac{d\$\$}{-(M+N)\$\$ + N\$\$_o - MXX_o} = dt \tag{5.67}$$

Integrating the left-hand-side of equation 5.67 from $\$\$_o$ to $\$\$_t$ and the right-hand-side from zero to t, we have

$$\int_{\$\$_o}^{\$\$_t} \frac{d\$\$}{-(M+N)\$\$ + N\$\$_o - MXX_o} = \int_o^t dt$$

$$\int_{\$\$_o}^{\$\$_t} \frac{d\$\$}{-\$\$+[N/(M+N)]\$\$_o-[M/(M+N)]XX_o} = \int_o^t (M+N)\ dt$$

This will give the following results:

$$- \ln [-\$\$ + (N\$\$_o - MXX_o)/(M+N)] \Big|_{\$\$_o}^{\$\$_t} = (M+N)t$$

$$\ln \frac{[-\$\$_t + (N\$\$_o - MXX_o)/(M+N)]}{[-\$\$_o + (N\$\$_o - MXX_o)/(M+N)]} = - (M+N)t$$

$$\frac{-\$\$_t + (N\$\$_o - MXX_o)/(M+N)}{-\$\$_o + (N\$\$_o - MXX_o)/(M+N)} = e^{-(M+N)t}$$

$$-\$\$_t + (N\$\$_o - MXX_o)/(M+N) = [-\$\$_o + (N\$\$_o - MXX_o)/(M+N)]e^{-(M+N)t}$$

$$\$\$_t = [\$\$_o + (MXX_o - N\$\$_o)/(M+N)]e^{-(M+N)t} - (MXX_o - N\$\$_o)/(M+N)$$

With the same procedure, it will give:

$$XX_t = [XX_o + (N\$\$_o - MXX_o)/(M+N)]e^{-(M+N)t} - (N\$\$_o - MXX_o)/(M+N)$$

5.8 ANALYTICAL TREATMENT OF CASE 2

$$\frac{d\$\$}{dt} = - B\ XX - R\ \$\$$$

$$\frac{dXX}{dt} = - C\ \$\$ - R\ XX \qquad (5.68)$$

The general solution of the system (5.68) may be written as:

$$\$\$_t = a_1\ P_1\ e^{\lambda_1 t} + a_2\ P_2\ e^{\lambda_2 t}$$

$$XX_t = a_1\ Q_1\ e^{\lambda_1 t} + a_2\ Q_2\ e^{\lambda_2 t} \qquad (5.69)$$

Let us assume that $\$\$ = Pe^{\lambda t}$

$$XX = Qe^{\lambda t} \qquad (5.70)$$

Substituting (5.70) into (5.68) we obtain

$$\begin{aligned} P\lambda e^{\lambda t} &= - BQe^{\lambda t} - RPe^{\lambda t} \\ Q\lambda e^{\lambda t} &= - CPe^{\lambda t} - RQe^{\lambda t} \end{aligned} \qquad (5.71)$$

and this leads at once to the algebraic system

$$\begin{aligned} (\lambda+R)P + \quad B\,Q &= 0 \\ C\,P + (\lambda+R)Q &= 0 \end{aligned} \qquad (5.72)$$

We seek the non-trivial solutions of the system. A necessary and sufficient condition that the system have a non-trivial solution is that the determinant

$$\begin{vmatrix} \lambda + R & B \\ C & \lambda + R \end{vmatrix} = 0 \qquad (5.73)$$

Expanding this determinant we are led at once to the quadratic equation

$$\lambda^2 + 2\,\lambda R + R^2 - BC = 0 \qquad (5.74)$$

Solving this, we find the roots $\lambda_1 = - R + \sqrt{BC}$ and
$\lambda_2 = - R - \sqrt{BC}$

Setting $\lambda = \lambda_1 = - R + \sqrt{BC}$ in equation (5.72), we obtain

$$\begin{aligned} \sqrt{BC}\ P + \quad B\ Q &= 0 \\ C\ P + \sqrt{BC}\ Q &= 0 \end{aligned}$$

A simple non-trivial solution of this system is obviously

$P = -B$ and $Q = \sqrt{BC}$.

With these values of P, Q, and λ we find:

$$\begin{aligned} \$\$ &= - B\ e^{(-R+\sqrt{BC})t} \\ XX &= \sqrt{BC}\ e^{(-R+\sqrt{BC})t} \end{aligned} \qquad (5.75)$$

Now, setting $\lambda = \lambda_2 = - R - \sqrt{BC}$ in equation (5.72), we find

$$-\sqrt{BC}\ P + B\ Q = 0$$
$$C\ P - \sqrt{BC}\ Q = 0$$

A simple non-trivial solution of this system is

$$P = B \quad \text{and} \quad Q = \sqrt{BC}$$

Using these values of P, Q and λ we find

$$\begin{aligned} \$\$ &= B\ e^{(-R-\sqrt{BC})t} \\ XX &= \sqrt{BC} e^{(-R-\sqrt{BC})t} \end{aligned} \qquad (5.76)$$

Therefore, the general solution of the system may be written as follows:

$$\begin{aligned} \$\$_t &= - a_1\ B\ e^{(-R+\sqrt{BC})t} + a_2\ B\ e^{(-R-\sqrt{BC})t} \\ XX_t &= a_1\sqrt{BC}\ e^{(-R+\sqrt{BC})t} + a_2\sqrt{BC}\ e^{(-R-\sqrt{BC})t} \end{aligned} \qquad (5.77)$$

where a_1 and a_2 are arbitrary constants.

By setting the time equals to zero (t=0), we find

$$\$\$_o = - a_1\ B + a_2\ B$$
$$XX_o = a_1\ \sqrt{BC} + a_2\ \sqrt{BC}$$

These equations will give the value of:

$$a_1 = - (\$\$_o\sqrt{BC} - XX_oB)\ /\ 2\ B\ \sqrt{BC} \qquad \text{and}$$
$$a_2 = (\$\$_o\sqrt{BC} + XX_oB)\ /\ 2\ B\ \sqrt{BC}$$

Substituting these values into (5.77), the system may be written as:

$$\$\$_t = [(\$\$_o\sqrt{BC}-XX_oB)e^{(-R+\sqrt{BC})t}+(\$\$_o\sqrt{BC}+XX_oB)e^{(-R-\sqrt{BC})t}]/2\sqrt{BC}$$

$$XX_t = [(-\$\$_o\sqrt{BC}+XX_oB)e^{(-R+\sqrt{BC})t}+(\$\$_o\sqrt{BC}+XX_oB)e^{(-R-\sqrt{BC})t}]/2B$$

This can be written as:

$$\$\$_t=e^{-RT}\ \frac{\$\$_oe^{\sqrt{BC}t}+\$\$_oe^{-\sqrt{BC}t}}{2} - \frac{XX_oBe^{\sqrt{BC}t}-XX_oBe^{-\sqrt{BC}t}}{2\sqrt{BC}}$$

$$XX_t=e^{-RT}\ \frac{XX_oe^{\sqrt{BC}t}+XX_oe^{-\sqrt{BC}t}}{2} - \frac{\$\$_o\sqrt{C/B}e^{\sqrt{BC}t}-\$\$_o\sqrt{C/B}e^{-\sqrt{BC}t}}{2}$$

or

$$\$\$_t = e^{-Rt}\ [\$\$_o \cosh \sqrt{BC}\ t - XX_o \sqrt{B/C} \sinh \sqrt{BC}\ t] \qquad (5.78)$$

$$XX_t = e^{-Rt}\ [XX_o \cosh \sqrt{BC}\ t - \$\$_o \sqrt{C/B} \sinh \sqrt{BC}\ t] \qquad (5.79)$$

Using the transformation of Laplace, system 5.68 can be written as

$$s\ \$\$(s) - \$\$_o = - B\ XX(s) - R\ \$\$(s) \qquad (5.80)$$

$$s\ XX(s) - XX_o = - C\ \$\$(s) - R\ XX(s) \qquad (5.81)$$

Solving (5.81) for XX(s),

$$XX(s) = \frac{XX_o}{s+R} - \frac{C}{s+R}\ \$\$(s) \qquad (5.82)$$

Substituting (5.82) in (5.80),

$$s\ \$\$(s) - \$\$_o = -B\left[\frac{XX_o}{s+R} - \frac{C}{s+R}\$\$(s)\right] - R\ \$\$(s) \qquad (5.83)$$

Collecting $\$\$(s)$ terms on the left hand side,

$$\$\$(s)\left[\ s+R - \frac{BC}{s+R}\ \right] = \$\$_o - \frac{B}{s+R}XX_o$$

$$\$\$(s) = \frac{\$\$_o\ (s+R)}{(s+R)^2 - BC} - \frac{B\ XX_o}{(s+R)^2 - BC} \qquad (5.84)$$

Referring to the Laplace transforms, it is better to express (5.84) as:

$$\$\$(s) = \frac{\$\$_o\ (s+R)}{(s+R)^2 - (\sqrt{BC})^2} - \frac{B\ XX_o}{(s+R)^2 - (\sqrt{BC})^2} \qquad (5.85)$$

Equation 5.85 is the transform of the solution. Taking the inverse,

$$\$\$(t) = \$\$_o\ e^{-Rt}\cosh\sqrt{BC}t - XX_o\ \sqrt{B/C}\ e^{-Rt}\ \sinh\sqrt{BC}t \qquad (5.86)$$

This equation is the solution of $\$\$$.

Using the same procedure to find XX(t). The transform is found to be:

$$XX(s) = \frac{XX_o(s+R) - C\ \$\$_o}{(s+R)^2 - BC}$$

$$XX(s) = \frac{XX_o\ (s+R)}{(s+R)^2 - (\sqrt{BC})^2} - \frac{C\ \$\$_o}{(s+R)^2 - (\sqrt{BC})^2} \qquad (5.87)$$

Taking the inverse, the solution to XX is found as

$$XX(t) = XX_o\ e^{-Rt} \cosh\sqrt{BC}t - \$\$_o\ \sqrt{C/B}\ e^{-Rt} \sinh\sqrt{BC}t \qquad (5.88)$$

The solutions for XX and $$ using the Laplace transforms are the same as equations 5.78 and 5.79.

5.9 ANALYTICAL TREATMENT OF CASE 3

$$\begin{aligned} \frac{d\$\$}{dt} &= - B\ XX - R_1\ \$\$ \\ \frac{dXX}{dt} &= - C\ \$\$ - R_2\ XX \end{aligned} \qquad (5.89)$$

The general solution of the system (5.89) may be written as:

$$\begin{aligned} \$\$_t &= a_1\ P_1\ e^{\lambda_1 t} + a_2\ P_2\ e^{\lambda_2 t} \\ XX_t &= a_1\ Q_1\ e^{\lambda_1 t} + a_2\ Q_2\ e^{\lambda_2 t} \end{aligned} \qquad (5.90)$$

Let us assume that

$$\begin{aligned} \$\$ &= Pe^{\lambda t} \\ XX &= Qe^{\lambda t} \end{aligned} \qquad (5.91)$$

Substituting (5.91) into (5.89) we obtain

$$\begin{aligned} P\lambda e^{\lambda t} &= - BQe^{\lambda t} - R_1 Pe^{\lambda t} \\ Q\lambda e^{\lambda t} &= - CPe^{\lambda t} - R_2 Qe^{\lambda t} \end{aligned} \qquad (5.92)$$

These equations lead at once to the system:

$$\begin{aligned} (\lambda+R_1)P + \quad B\ Q &= 0 \\ C\ P + (\lambda+R_2)Q &= 0 \end{aligned} \qquad (5.93)$$

in the unknowns P and Q.

We seek the non-trivial solutions of the system. A necessary and sufficient condition that the system have a non-trivial solution is that the determinant

$$\begin{vmatrix} \lambda + R_1 & B \\ C & \lambda + R_2 \end{vmatrix} = 0 \qquad (5.94)$$

Expanding this determinant we are led at once to the quadratic equation

$$\lambda^2 + (R_1+R_2)\lambda + R_1R_2 - BC = 0 \qquad (5.95)$$

Solving this, we find the roots

$$\lambda_1 = \frac{-(R_1+R_2) + \sqrt{(R_1-R_2)^2 + 4BC}}{2} \qquad (5.96)$$

$$\lambda_2 = \frac{-(R_1+R_2) - \sqrt{(R_1-R_2)^2 + 4BC}}{2} \qquad (5.97)$$

Setting $\lambda = \lambda_1$ in equation (5.93), we obtain

$$(\lambda_1+R_1)\, P + B\, Q = 0$$
$$C\, P + (\lambda_1+R_2)\, Q = 0$$

A simple non-trivial solution of this system is

$P = -B$ and $Q = \lambda_1+R_1$

Now, setting $\lambda = \lambda_2$ in equation (5.93), we obtain

$$(\lambda_2+R_1)\, P + B\, Q = 0$$
$$C\, P + (\lambda_2+R_2)\, Q = 0$$

A simple non-trivial solution of this system is

$P = -B$ and $Q = \lambda_2+R_1$

Using these values of P, Q and λ, the general solution may be written as follows:

$$\$\$_t = - a_1\ B\ e^{\lambda_1 t} - a_2\ B\ e^{\lambda_2 t}$$

$$XX_t = a_1(\lambda_1+R_1)e^{\lambda_1 t} + a_2(\lambda_2+R_1)e^{\lambda_2 t} \qquad (5.98)$$

where a_1 and a_2 are arbitrary constants.

By setting the time equals to zero (t=0), we find

$$\$\$_o = - a_1\ B - a_2\ B = -B(a_1+a_2)$$

$$XX_o = a_1(\lambda_1+R_1) + a_2(\lambda_2+R_1)$$

These equations will give the value of:

$$a_1 = \frac{XX_o + [\$\$_o/B]\ (R_1+\lambda_2)}{\lambda_1 - \lambda_2} \text{ and}$$

$$a_2 = \frac{XX_o + [\$\$_o/B]\ (R_1+\lambda_1)}{- \lambda_1 + \lambda_2}$$

Substituting these values into (5.98), the system may be written as:

$$\$\$_t = \frac{[XX_o+(\$\$_o/B)(R_1+\lambda_2)][-Be^{\lambda_1 t}]+[XX_o+(\$\$_o/B)(R_1+\lambda_1)][Be^{\lambda_2 t}]}{\lambda 1 - \lambda 2}$$

$$XX_t = \frac{[XX_o+(\$\$_o/B)(R_1+\lambda_2)][(\lambda_1+R_1)e^{\lambda_1 t}]}{\lambda_1 - \lambda_2} - \frac{[XX_o+(\$\$_o/B)(R_1+\lambda_1)][(\lambda_2+R_1)e^{\lambda_2 t}]}{\lambda_1 - \lambda_2}$$

It can be written as

$$\$\$_t = \frac{BXX_o(e^{\lambda_2 t}-e^{\lambda_1 t}) + \$\$_o[(R_1+\lambda_1)(e^{\lambda_2 t})+(R_1+\lambda_2)(-e^{\lambda_1 t})]}{\lambda_1 - \lambda_2}$$

$$XX_t = \frac{-[(\$\$_o/B)(R_1+\lambda_1)(R_1+\lambda_2)][e^{\lambda_2 t}-e^{\lambda_1 t}]}{\lambda_1 - \lambda_2} + \frac{XX_o[(\lambda_1+R_1)e^{\lambda_1 t}-(R_1+\lambda_2)e^{\lambda_2 t}]}{\lambda_1 - \lambda_2}$$

where

$$\lambda_1 = \frac{-(R_1+R_2) + \sqrt{(R_1-R_2)^2 + 4BC}}{2}$$

$$\lambda_2 = \frac{-(R_1+R_2) - \sqrt{(R_1-R_2)^2 + 4BC}}{2}$$

5.10 GAME THEORY FORMULATION OF THE PROBLEM

A specific set of mathematical models, essentially based on the early work of John von Neumann and Oskar Morgenstern, has evolved over the last thirty-five years and is known as game theory or game-theory models. The theory and its models treat competitive or cooperative situations involving two or more players whose interests are pursued through a variety of strategies and whose gains and losses can often be calculated in terms of outcome or payoff matrixes [93].

The game theory formulation can be applied also to determine the optimal allocation of aircraft into different type of mission sorties. In this section the mission are divided into two types, those are, sortie against another combat aircraft and sortie against land targets. The payoff is developed to determine the winner after the first strike which will probably the winner at the end of the war.

$$ represents the number of U.S. combat aircraft and XX represents the number of U.S.S.R. combat aircraft. The attrition rates of the U.S. aircraft are B vs airborne threats and R1 vs surface threats, and the attrition rates of the U.S.S.R. aircraft are C and R2 respectively. The proportion of missions to airborne and surface operations for U.S. aircraft are a and b and for U.S.S.R. aircraft they are p and q, respectively [94].

Each side utilizes the allowable attrition rates (AAXXA,AAXXS,AA$$A, AA$$S) which limit the sortie rates. AA$$A is the allowable attrition of $$ aircraft vs airborne threats and AA$$S is the allowable attrition of $$ aircraft vs surface threats, and the same thing for the XX aircraft. The attrition rate B is the minimum of AA$$A and (SRXXM)(AXX)(1-MS$$A)(p) while C is the minimum of AAXXA and (SR$$M)(A$$)(1-MSXXA)(a). R1 is the minimum of AA$$S and (SR$$M)(A$$)(1-MS$$S)(b) while R2 is the minimum of AAXXS and (SRXXM)(AXX)(1-MSXXS)(q). SR$$M and SRXXM are the sortie rate maximum of $$ and XX aircraft, A$$ and AXX are the availability of $$ and XX, MS$$A and MS$$S are the mission survivability of $$ vs airborne threats and surface threats, MSXXA and MSXXS are the mission survivability of XX vs airborne threats and surface threats, respectively. It should be noted that AA$$A ⩽ (SRXXM)(AXX)(1-MS$$A), AAXXA ⩽ (SR$$M)(A$$)(1-MSXXA), AA$$S ⩽ (SRXXM)(A$$)(1-MS$$S) and AAXXS ⩽ (SRXXM)(AXX)(1-MSXXS).

The number of U.S. aircraft lost per day is (XX)B + ($$)R1 and the number of U.S.S.R. aircraft lost per day is ($$)C + (XX)R2. The payoff value is formulated as [94]:

Payoff = [($$)C+(XX)R2]/k - [(XX)B+($$)R1] +
[(SR$$S)($$)(TDPS$$)/m - (SRXXS)(XX)(TDPSXX)]/z

where: k = XX/$$

m = number of U.S.S.R. tank / number of U.S. tank

z = cost of aircraft / cost of tank

TDPS$$ = target destroyed per sortie of $$

TDPSXX = target destroyrd per sortie of XX

The following example is provided to illustrate the concept.

1. SR$$M = SRXXM = 2 ; A$$ = AXX = 0.5

   MS$$A = .99 , MS$$S = .98 ; MSXXA = .96 , MSXXS = .98

   TDPS$$ = 1 , TDPSXX = .25 ; $$ = 500 , XX = 1000

   AA$$A = .007 , AAXXA = .03 ; AA$$S = AAXXS = .015

   k = 2 , m = 2 , z = 20

$a = b = p = q = 0.5$

$$\text{Payoff} = [(500).02+(1000).01]/2-[(1000).005+(500).01] + [(250/2)-125]/20 = 0$$

2. If all conditions are the same as above except $a=p=1$ and $b=q=0$. Then payoff $= [(500).03]/2 - [(1000).007] = 0.5$

Using different numbers of a,b,p and q, the following payoff matrix can be obtained. The payoff matrix represents the gains on the U.S. side.

The payoff matrix is found to be:

	p	1	0.75	0.5	0.2	0
a	b \ q	0	0.25	0.5	0.8	1
1	0	.5	-0.125	1.25	3.0	2.5
0.75	0.25	1.125	0.5	1.875	4.25	6.25
0.5	0.5	-0.75	-1.375	0	3.375	4.375
0.2	0.8	-3.125	-3.75	-2.375	0	2.0
0	1	-5.125	-5.75	-4.375	-2.0	0

It is evident that the allocation of $a=0.75$ and $b=0.25$ dominate all the other U.S. strategies. Therefore the U.S. will use this strategy, while the U.S.S.R. should use $p=0.75$ and $q=0.25$ in order to minimize their losts [94].

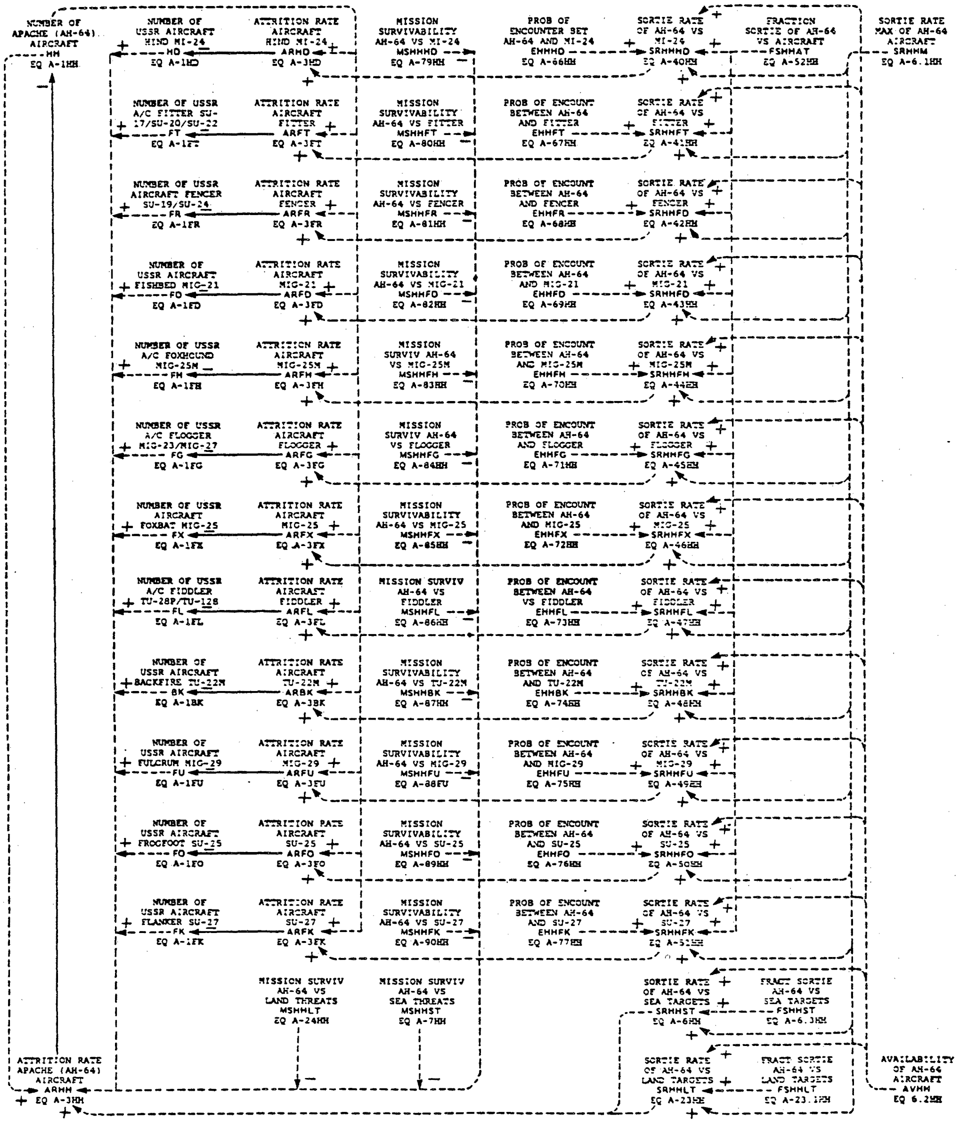
Chapter VI

DESCRIPTION OF THE ATTRITION MODELS

6.1 ORGANIZATION OF THE ATTRITION SUBMODEL

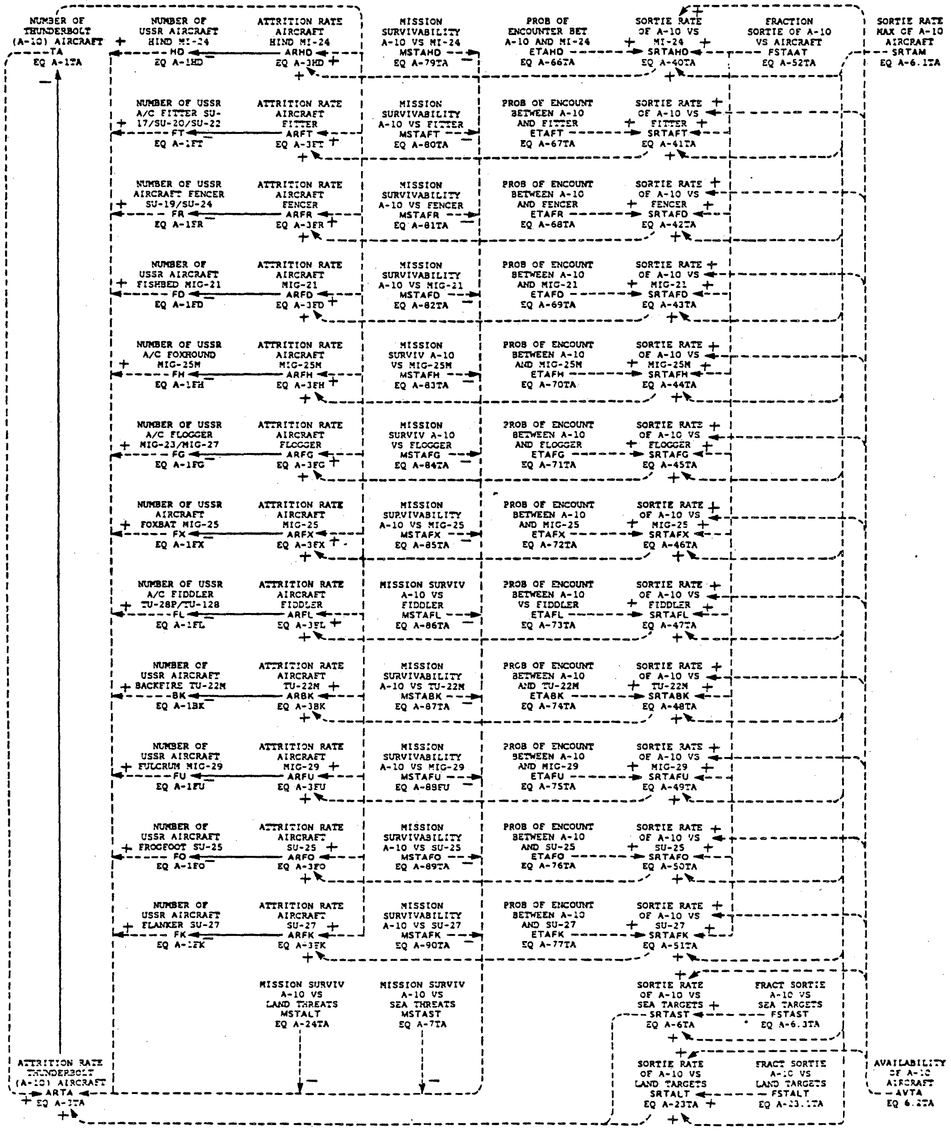
The attrition submodel is used to describe and to quantify the survivability of combat aircraft in encounters with hostile forces. Military Standards and Military Handbooks identify numerous descriptors and summary measures used to define the results of engagements between aircraft and various threats [22,28]. In general, these measures address the probability of survival per shot from a given weapon, probability of survival per encounter with a given weapon, and probability of survival per sortie or mission during which an aircraft may have multiple engagements with the various weapons of a zone defense. Aircraft probability of survival is a summary measure that an aircraft will survive a defined level of damage or kill category -- attrition, forced landing, mission abort, and mission available. In the model the kill category used is attrition kill, which covers those aircraft with combat damage so extensive that it is neither reasonable nor economical to repair.

In Figs 6.1 - 6.12, combat attrition for twelve key U.S. aircraft is modeled. The number of aircraft is reduced by



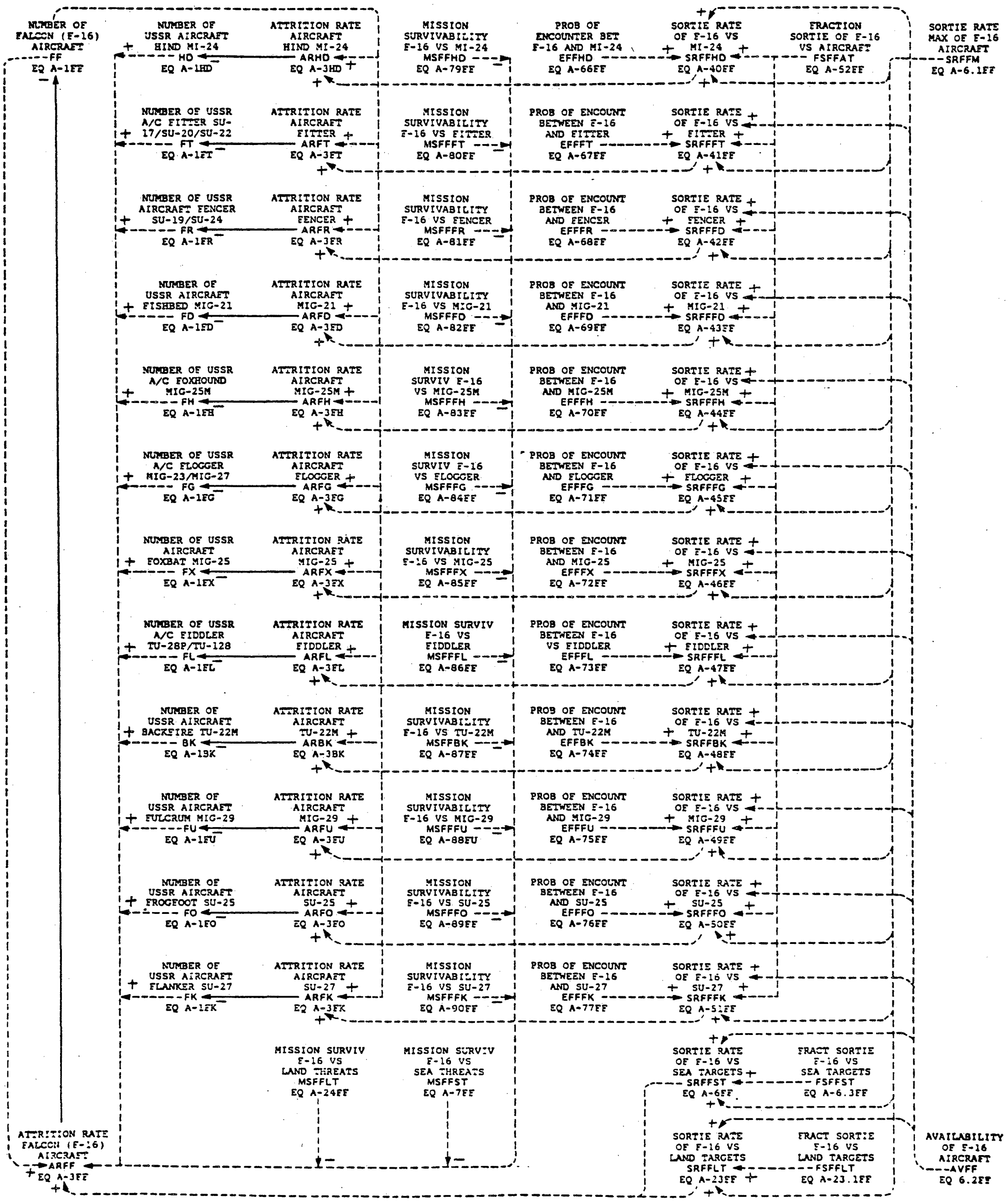
ATTRITION SUBMODEL FOR APACHE ATTACK AIRCRAFT

Fig. 6.1



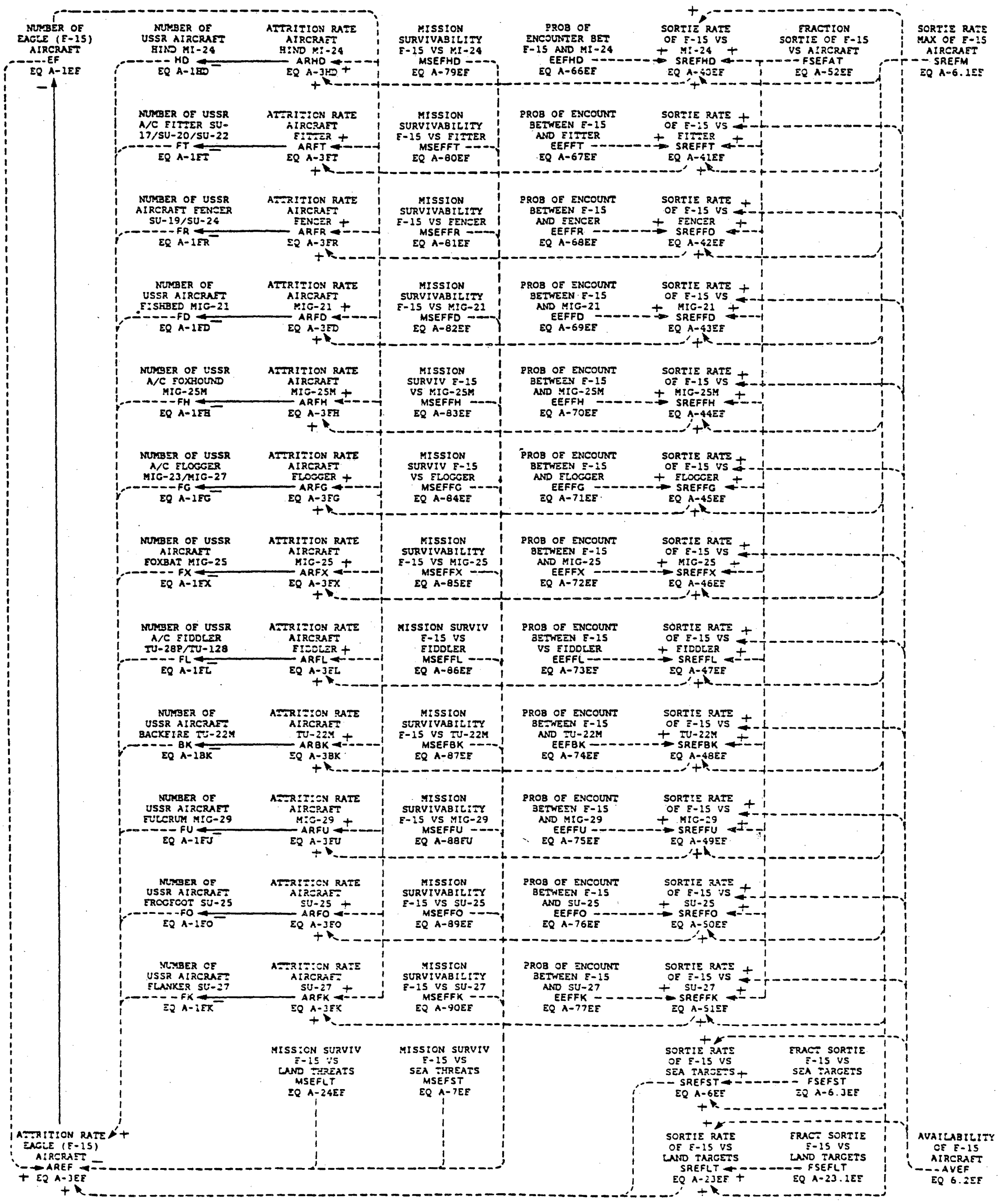
ATTRITION SUBMODEL FOR THUNDERBOLT ATTACK AIRCRAFT

Fig. 6.2



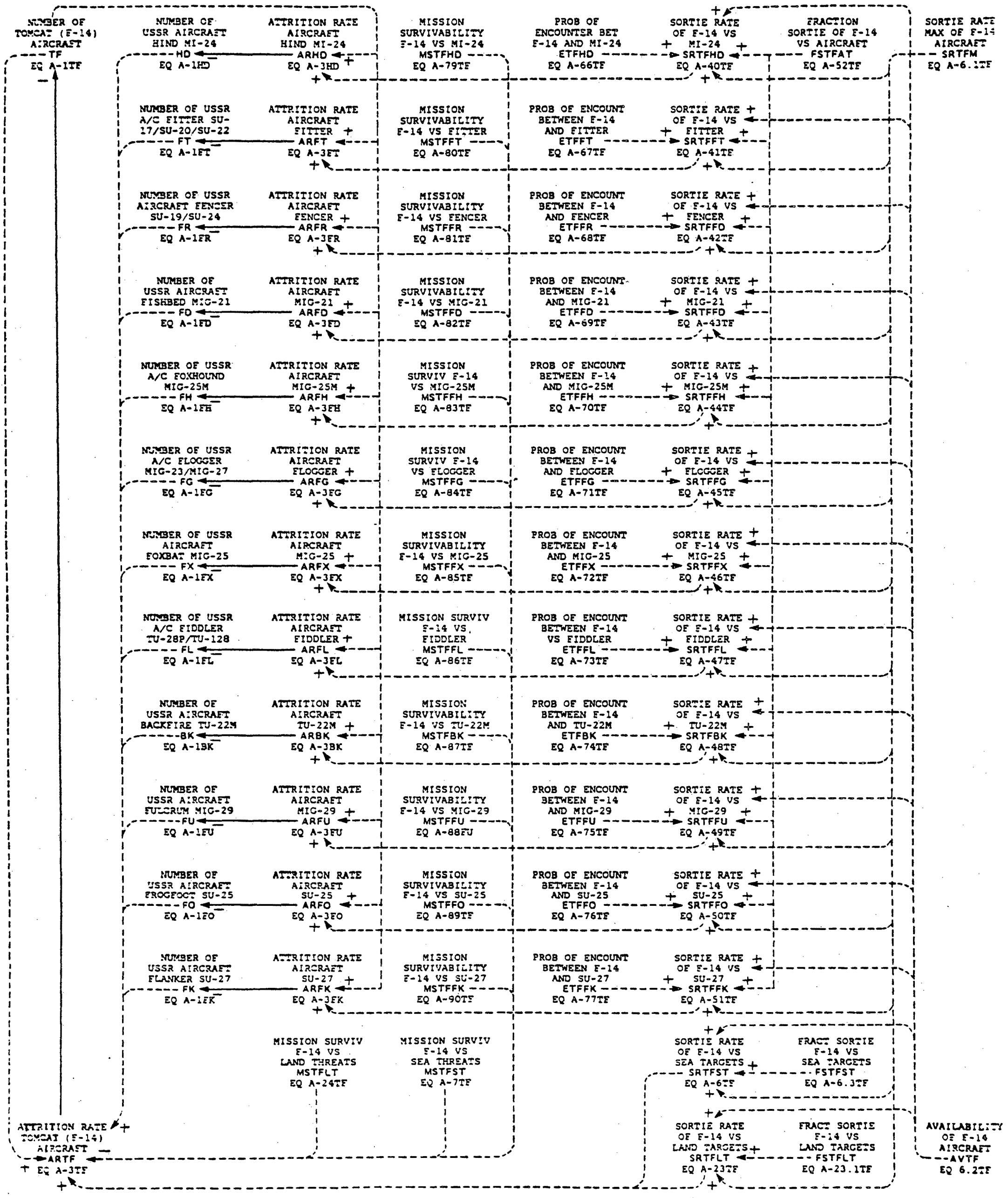
ATTRITION SUBMODEL FOR FALCON FIGHTER AIRCRAFT

Fig. 6.3



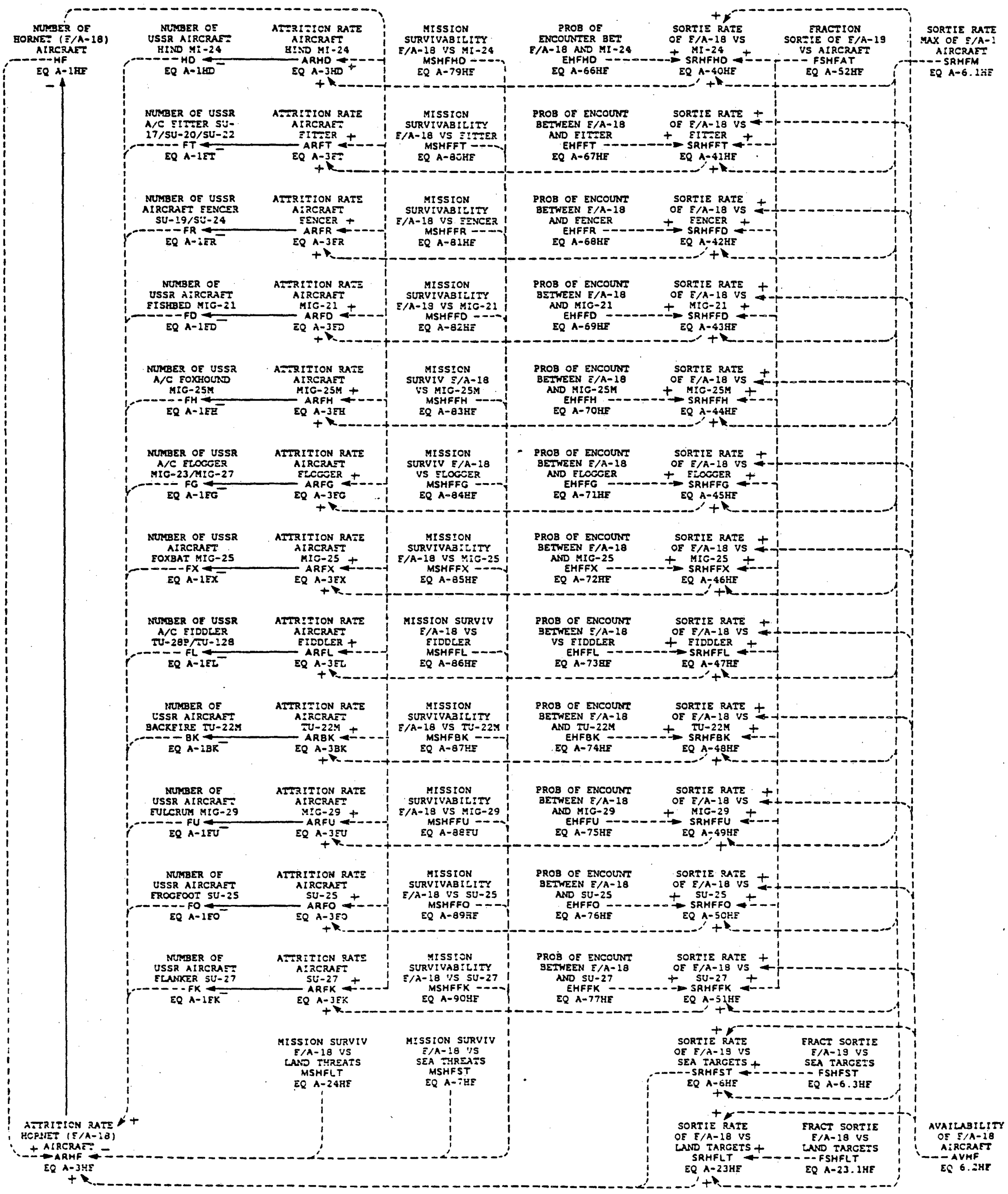
ATTRITION SUBMODEL FOR EAGLE FIGHTER AIRCRAFT

Fig. 6.4



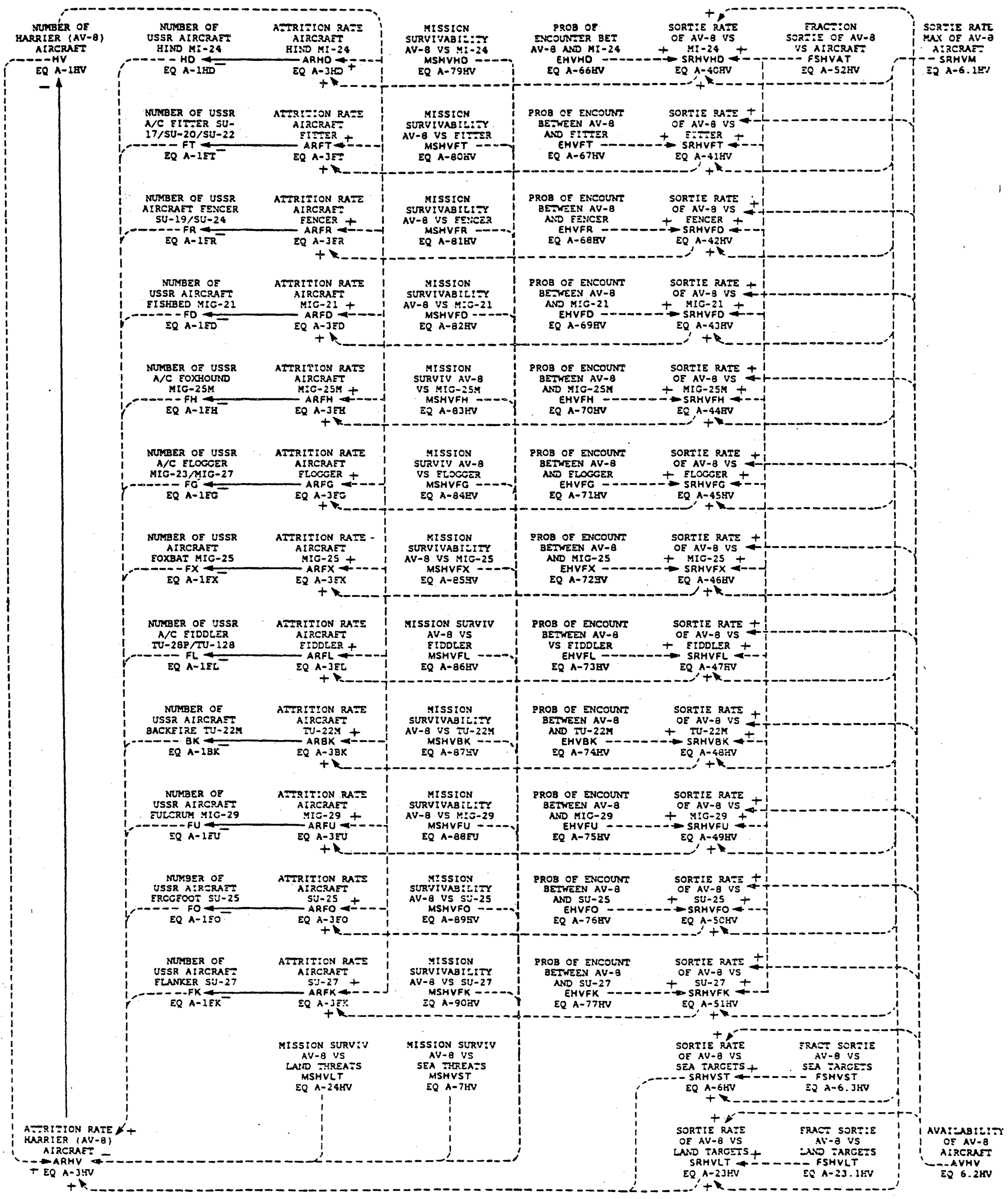
ATTRITION SUBMODEL FOR TOMCAT FIGHTER AIRCRAFT

Fig. 6.5



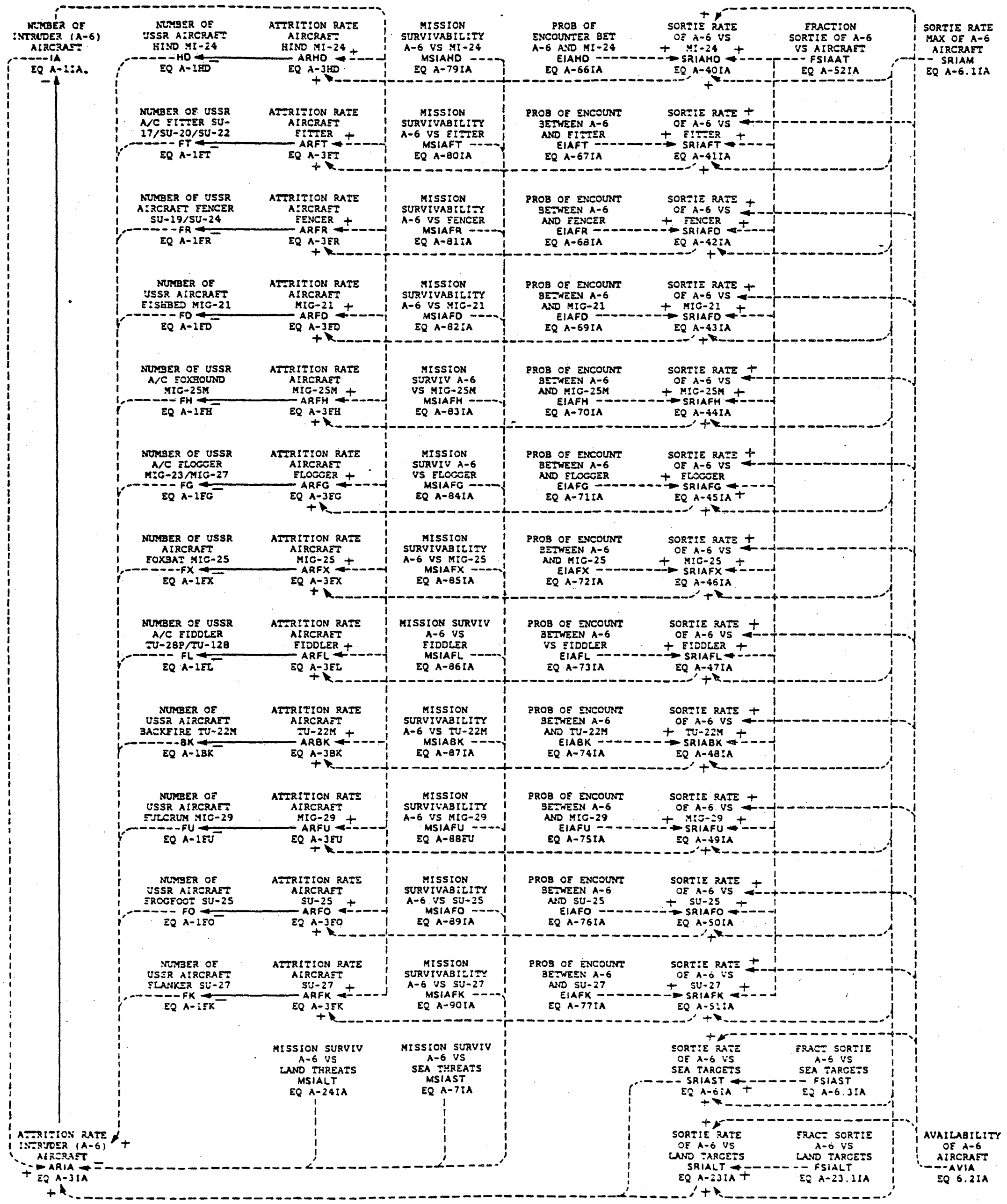
ATTRITION SUBMODEL FOR HORNET FIGHTER AIRCRAFT

Fig. 6.6



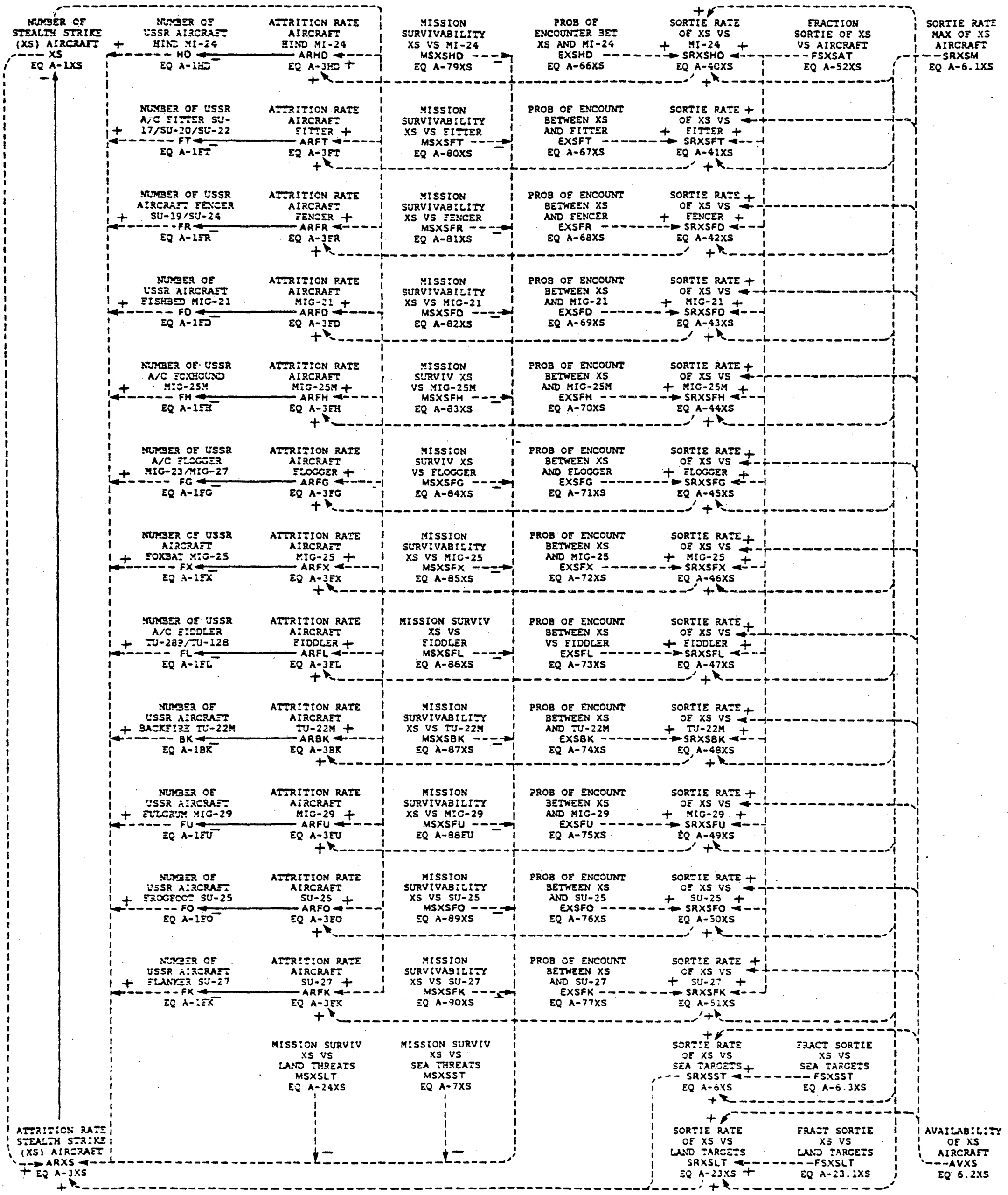
ATTRITION SUBMODEL FOR HARRIER ATTACK AIRCRAFT

Fig. 6.7



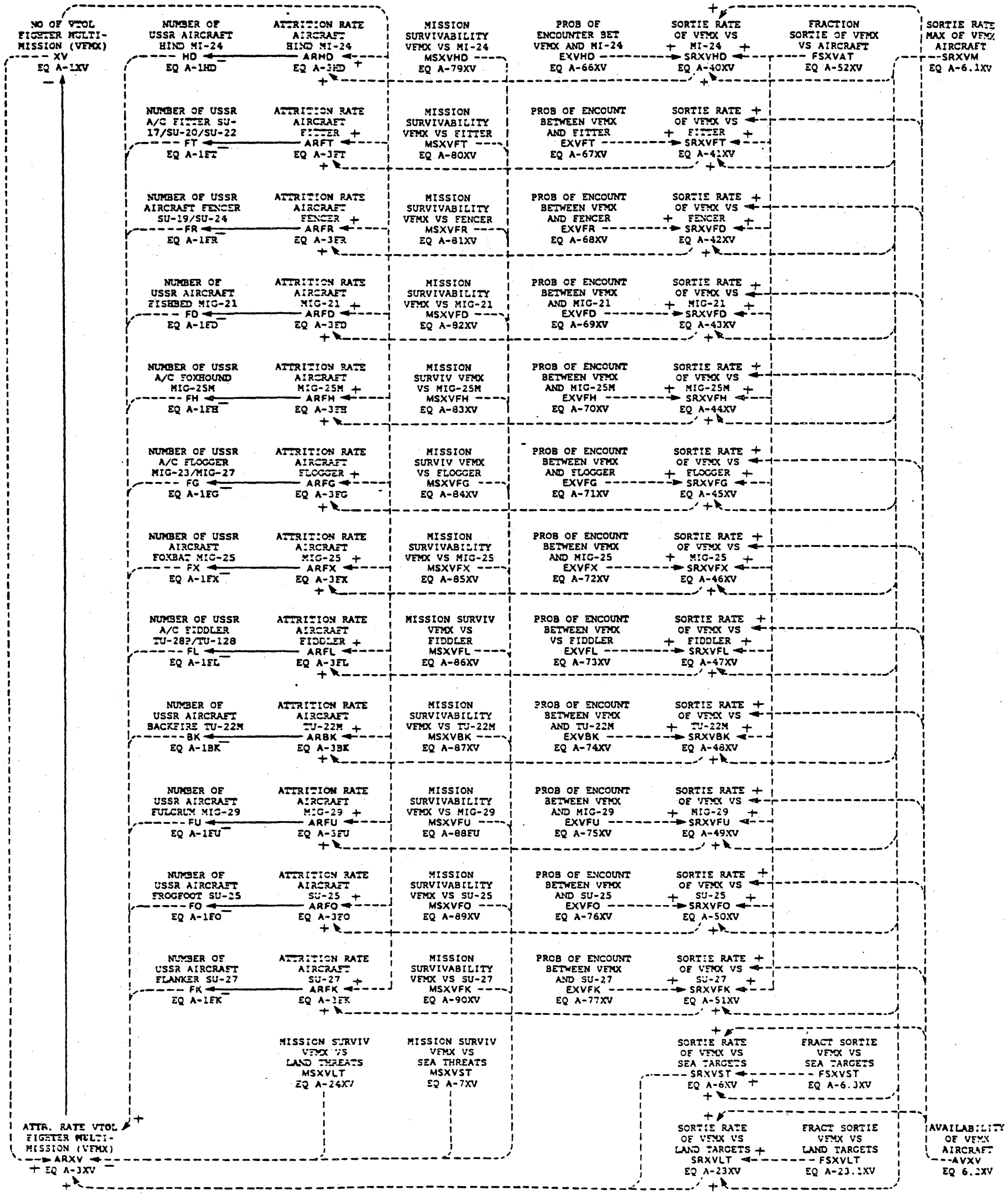
ATTRITION SUBMODEL FOR INTRUDER ATTACK AIRCRAFT

Fig. 6.8



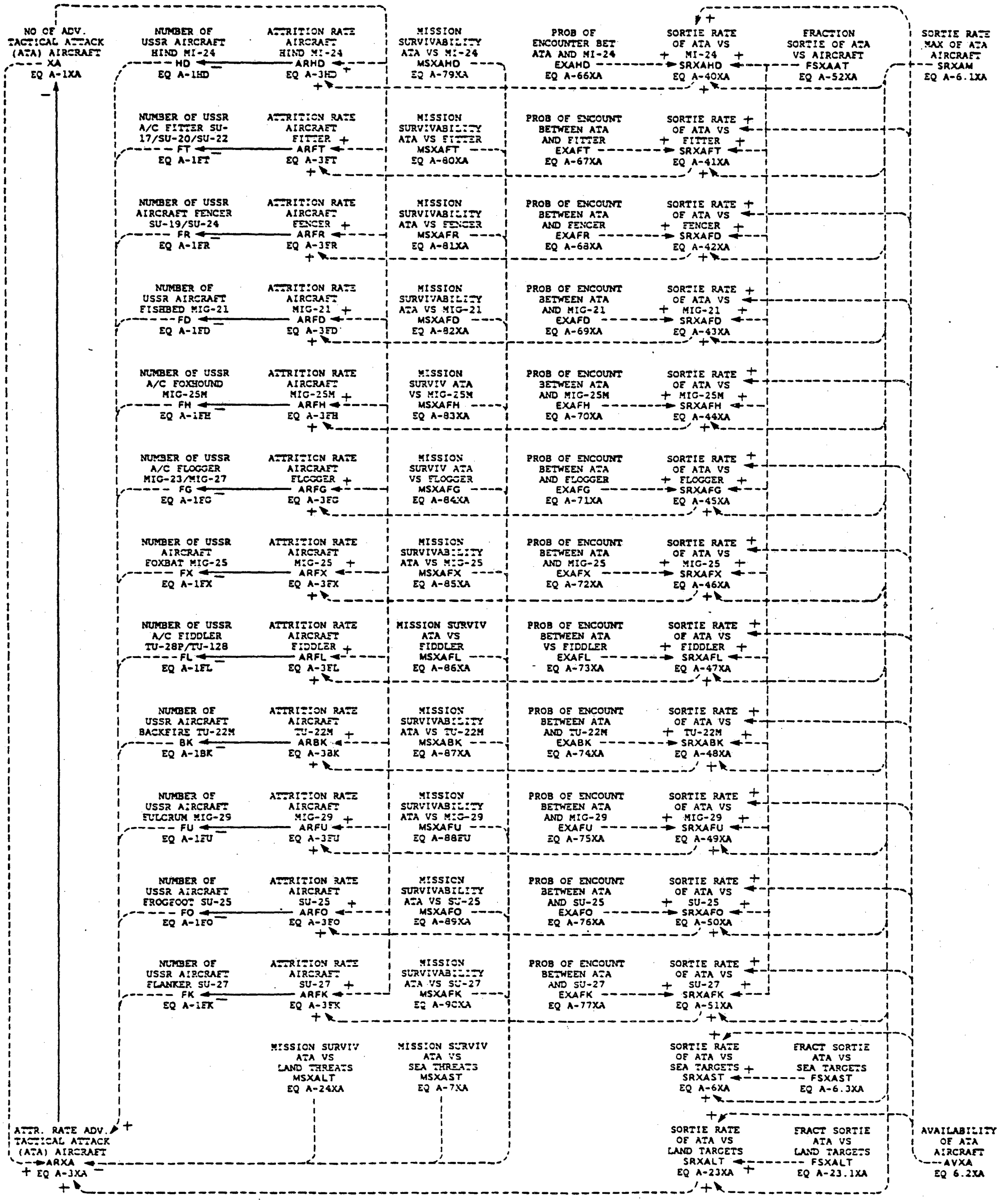
ATTRITION SUBMODEL FOR STEALTH STRIKE AIRCRAFT

Fig. 6.9



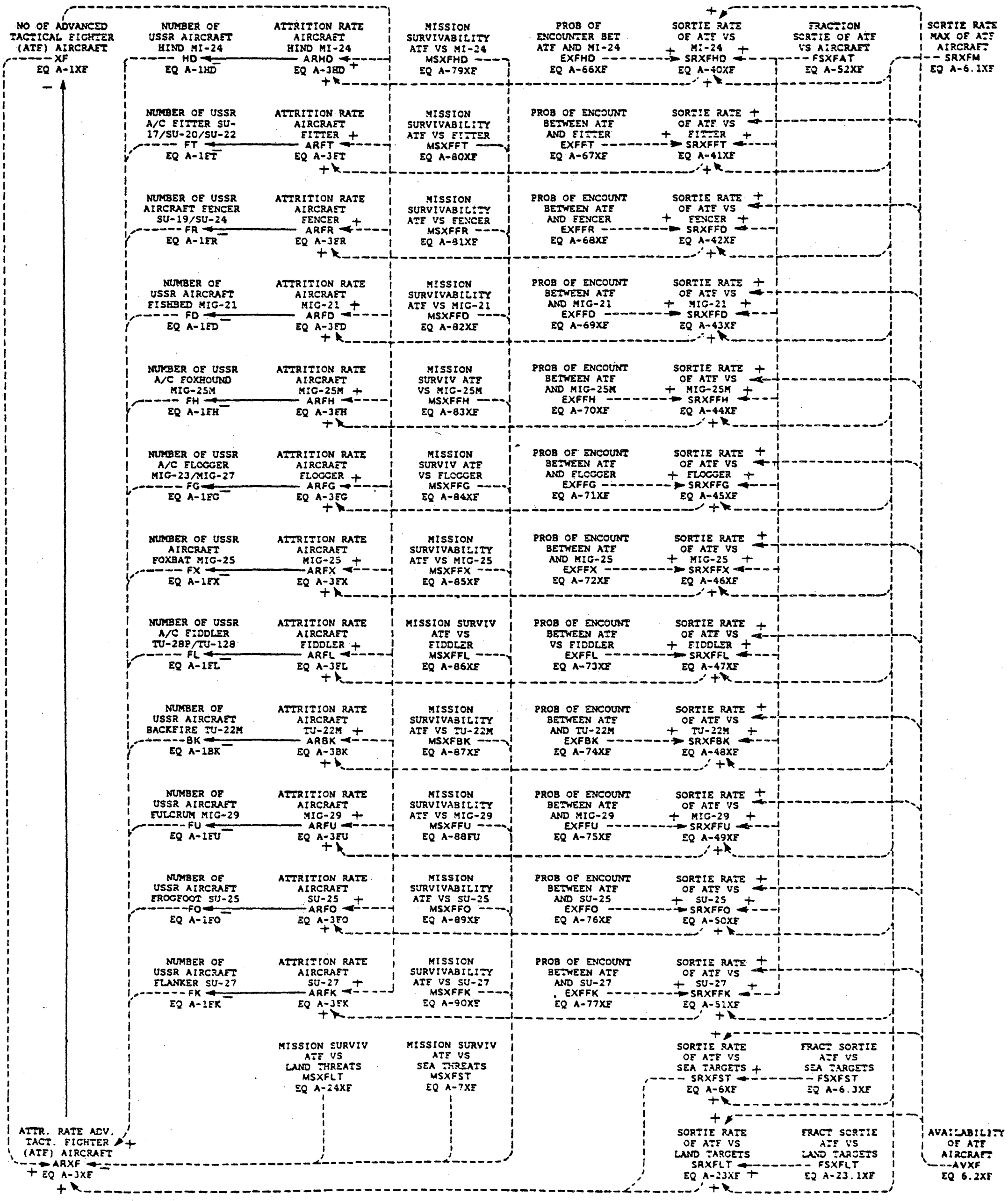
ATTRITION SUBMODEL FOR VTOL FIGHTER MULTIMISSION AIRCRAFT

Fig. 6.10



ATTRITION SUBMODEL FOR ADVANCED TACTICAL ATTACK AIRCRAFT

Fig. 6.11



ATTRITION SUBMODEL FOR ADVANCED TACTICAL FIGHTER AIRCRAFT

Fig. 6.12

the attrition rate (aircraft/day). The attrition rate is the product of the sortie rate (sorties per day), the number of aircraft available (aircraft), and mission survivability (probability).

In this model, the sorties are divided into three types, sortie versus sea targets, land targets and airborne targets (enemy aircraft). The sortie rate varies directly with the availability of the aircraft (probability), fraction sortie versus a certain target (fraction), sortie rate maximum (sorties/day) and the probability of encounter (probability) between aircraft or between aircraft and land or sea threats.

The attrition submodel treats the Soviet aircraft in an identical manner except that the causal diagrams were arranged based on the U.S. aircraft. Twelve key types of Soviet aircraft are also included in the attrition submodel.

6.2 U.S. AIRCRAFT AND THEIR MISSIONS

In this model, twelve types of aircraft are selected based on the assumption that these types of aircraft are still in operation when the war starts.

The Apache AH-64 represents the Army aircraft. The Airforce aircraft are represented by Thunderbolt A-10, Falcon F-16, Eagle F-15, Stealth Strike Aircraft and

Advanced Tactical Fighter (ATF). The Navy is represented by Tomcat F-14, Hornet F-18, Harrier AV-8, Intruder A-6, VTOL Fighter Multimission (VFMX) and Advanced Tactical Attack Aircraft (ATA).

Basically, tactical airpower can be divided into two groups: aircraft that attack ground or sea targets (attack aircraft and bombers) and those that engage other aircraft (fighters). The goal of their missions is to win the war, and each aircraft can carry its own mission, to attack the targets, to attack other airplanes or to defense the national territory.

In Table 6.1 is shown some specific aircraft with their characteristics.

6.3 U.S.S.R. AIRCRAFT AND THEIR MISSIONS

With the same basic assumption of selecting the twelve types of U.S. aircraft, twelve types of U.S.S.R. aircraft are selected to counter the strength of U.S. airpower.

The Tupolev Tu-22M or Tu-26 (Backfire) is the bomber aircraft, Mil Mi-24 (Hind) is a helicopter. The attack aircraft are: Sukhoi Su-17, Su-20, and Su-22 (Fitter), Sukhoi Su-24 (Fencer), and Sukhoi Su-25 (Frogfoot). The fighters are: MiG-21 (Fishbed), MiG-23/MiG-27 (Flogger), MiG-25 (Foxbat), Tupolev Tu-28P/Tu-128 (Fiddler), MiG-25M (Foxhound), MiG-29 (Fulcrum) and Sukhoi Su-27 (Flanker).

TABLE 6.1 U.S. AIRCRAFT

		Fairchild A-10	Grumman F-14	General Dynamics F-16	Northrop/ McDD F-18	McDonnell Douglas F-15
Year introduced		1977	1970	1980	1982	1977
Main role		Close air support	Interception	Air superiority	Interception Air superiority	Interception Air superiority
Secondary role		-	Interdiction	Interdiction	Interdiction	Interdiction
Number built or planned		825	597	1800	1900	941
Crew		1	2	1	1	1
DIMENSIONS						
Length Overall	m	16.26	18.89	14.52	17.07	19.43
Span (max/min)	m	17.53	19.45/11.65	10.01	11.43	13.05
Height	m	4.47	4.88	5.01	4.66	5.63
Wing Area	m^2	47.01	52.49	27.87	37.16	56.50
WEIGHTS						
Empty weight	kg	10866	17830	6607	9336	12700
Crew	kg	100	200	100	100	100
Ammunition for guns	kg	670	170	200	200	330
Internal fuel	kg	4830	7459	3162	4540	5050
T/O Weight (full int. fuel and no ext. stores)	kg	16340	24950	9780	14200	17350
Max. payload with full int fuel	kg	4330	7591	5220	5800	7200
Max. payload	kg	7258	7700	6894	5900	7600
Max. take off weight	kg	20650	33724	14968	22710	25401
ENGINE(S) - no. and type		2xTF34-GE-100	2XTF30-P412-A	1xF100-PW-100	2xF404-GE-400	2XF100-PW-100
Bypass ratio		6.2:1	?	0.72:1	0.32:1	0.72:1
Compression ratio		22:1	?	24:1	25:1	24:1
No. of shafts		2	2	2	2	2
Max. take off thrust (without AB)	kg	2 x 4075	2 x 6100	1 x 6530	2 x ?	2 x 6530
Max. take off thrust (with AB)	kg	-	2 x 9480	1 x 11340	2 x 7270	2 x 11340
Specific fuel consumption at T/O with/without AB		?	?	0.68/2.55	?	0.68/2.5
SPECIFIC DATA						
Wing loading						
at combat weight	kg/m^2	405	385	325	327	283
at max TOW	kg/m^2	455	422	578	520	432
Thrust/weight ratio						
at combat wt		0.45	0.76	35	1.15	1.475
at max TOW		0.40	0.69	76	0.73	0.925
Maintainability		7	25	10	12	12
NAV/ATTACK SYSTEM						
Main sensors						
Nose radar		-	pulse doppler	pulse doppler	monopulse	pulse doppler
Navigation radar		-	-	-	-	-
Inertial system		-	.	.	-	.
Passive radar detector (RHAWS)		.	.	.	.	.
Computer						
Central digital computer		-	.	-	.	.
Air data computer		.	.	.	.	.
Navigating computer		.	-	.	.	?
Bombing computer		-	-	.	.	.
Flight control computer		-	.	.	.	.
Displays						
-HUD		.	.	.	.	.
-Radar scope		-	.	.	.	.
-Map projection display		-	-	?	.	tact. situation
Typical mission armament						
Gun(s)		1x30mm GAU-8A	1x20mm M61A1	1x20mm M61A1	1x20mm M61A1	1x20mm M61A1
Rounds carried		1350	680	500	500	950
Air to air missiles		-	4xAIM-7 Sparrow or AIM-54 Phoenix under fuselage, 2xAIM-9 Sidewinder or 1xAIM-9 and 1XAIM-7 or AIM-54 under each wing	2 IR 1xAIM-9J/L S-winder at each wing tip (can include 4 more AIM-9 or AIM-7)	2 radar, 2 IR AIM-9 Sidewinder or AIM-7 Sparrow	4 radar, 4 IR 4xAIM-7F and 4xAIM-9 under guidance of APG-63 radar
Weapon stations for A/G armament		11	6	5	5	5
FLIGHT PERFORMANCE						
Take off run	m	345-1170	370-	300-850	300-800	270-550
Take off speed	km/h	?	220	210	240	230
Landing run	h	330-650	460-	500-760	500-750	700-1300
Max. Mach no at SL/11000m		0.7	1.2/2.4	1.2/2.0	1.2/>1.8	1.2/2.5
Ceiling	m	?	>17000	18288	>15000	19203
Max. rate of climb at SL	m/sec	?	840	?	?	2032
RADII OF ACTION						
Combat air patrol	km	-	?	up to 1900	up to 1900	up to 1800
Mach 2 intercept	km	-	?	250	?	250
Ground attack lo-lo-lo	km	?	?	350-1000	350-1000	300-900
hi-lo-hi	km	1000-1200	?	700-1350	700-1350	600-1100
Max. ferry range	km	4380	?	4800	3700	4800

Their mission can be divided also into two groups: aircraft that attack ground or sea targets (attack aircraft and bombers) and those that attack another aircraft (fighters). The fighters can be involved in the counterair and defense, while the attack aircraft mostly in the close air support operation.

In Table 6.2, the characteristics of six types of U.S.S.R aircraft are shown.

6.4 U.S. THREAT SYSTEMS

The threats to aircraft have been defined as those elements of a man-made environment designed to reduce the ability of an aircraft to perform mission-related functions by inflicting damaging effects, forcing undesirable maneuvers, or degrading system effectiveness. The hostile environment can be made up of numerous threat elements, each having a distinct set of characteristics and capabilities [27].

6.4.1 Land-Based Systems

The land-based threat systems can be divided into two categories, those are small arms and anti-aircraft artillery (AAA), and surface-to-air missiles (SAM). AAA denotes that category of guns that fire projectiles greater than 20mm

TABLE 6.2 U.S.S.R. AIRCRAFT

		FISHBED J MiG-21	FLOGGER B MiG-23	HIND-B Mi-24	BACKFIRE-B Tu-26	FOXBAT A/B MiG-25	FIDDLER B Tu-28
Year introduced		1956	1971	1973	1974	1970	1962
Primary operational role(s)		Air superiority in the combat zone Air intercept	Air superiority in the combat zone Air intercept	Armed troop transport helicopter	Rear zone interdiction	Air superiority in the combat zone Air intercept	Air superiority in the combat zone Air intercept
Secondary role		Counter air Battlefiled interdiction	Battlefield interdiction Counter air	Ground strike-support	Battlefield interdiction	Counter air Battlefiled interdiction	Battlefield interdiction Counter air
Number built or planned		10000	2000	550	420	825	597
Crew		1	1	2	4	1	2
TECHNICAL DATA							
Length(without pitot tube/overall)	m	14.65/15.8	16.8	16.8	38/40.2	22.3	26
Wingspan (max/min)	m	7.15	14.3/8.7	17.0	34.5/26.2	14.0	20
Height	m	4.5	3.96	4.25	9.1	5.6	7
Wing area	m^2	23	36		166	56.2	80
Weight empty	kg	5500	10700	6500	50000	20000	25000
Warload (normal/max)	kg	3600/4900	4300/6300	2400/3400	-/47000	-/13700	18000/19000
Takeoff weight (normal/max)	kg	9100/10400	15000/17000	8400/11500	-/110000	-/37500	-/45000
External loads	kg	1850	4000	2000	10000 in bomb bay	2000	2000
Engine(s)		1 Tumansky R 13-300	1 Tumansky R-29B	2 TV 2-117 shaft turbines of max	2 Kuznetsou NK-144 mod	2 Tumansky R-31	2 AL-21F-1
Total max. thrust (without/with afterburner)	kg	3900/6200	8000/12000	-	30000/40000	15200/22000	13600/19000
Thrust/weight ratio (normal/max)	-	0.68/.0.6	0.8/0.7	-	-/0.35	-/0.6	-/0.47
Wing loading (normal/max)	kg/m^2	395/455	525/595	-	-/540	-/660	-/445
Maintainability		15	25		50	40	40
PERFORMANCE							
Radius of action (hi-lo-hi/lo-lo-lo)	km	900/150	1300/250-400	-/250	5800/2600	-	-
Intercept radius (normal/min time)	km	250/120	450/200	-	-	1100/450	2000/800
Time to climb to 11000m.	min	8	8	-	-	2.5 or 8	8
Service ceiling	m	18000	18000	4500	-	18000	18000
Max. speed at 11000m	Mach	2.1	2.3	-	1.8-2.0	2.8	1.8
Max. speed at SL	Mach	1.06	1.1	0.2	1.1	1.2	-
Combat cruise speed at SL	Mach	0.9	0.85	0.18	0.85	-	-
Takeoff/landing distance to/from 15m	m	800/550	600/600	-	2600/1000	2100	1500/800
Max. endurance	h	2.5	2.5	2.5	12	3.4	3.3
AVIONICS							
Radar and Fire Control							
Radar		Jay Bird air intercept radar		-	Fan Tail tail-mounted fire control radar	air-intercept radar Jay-Bird variant	air intercept radar Big Nose
IFF		SRO-2	SRO-2M	SRO-2M	SRO-2	SRO-2	SRO-2M
Radar Homing and Warning System (RHAWS)		Sirena 3	Sirena 3(360°)	-	Sirena	Sirena 3 (360°)	Sirena
Navigation System							
Radio compass		ARK-10	ARK-10 or -15	ARK-15	2x ARK-11	ARK-10	ARK-10
Radio altimeter		RV-UM	RV-4S	RV-5	RV-UM and RV-17M	RV-UM	RV-UM
Beacon receiver		MRP-56	MRP-56P	MRP-56P	MRP-56P	MRP-56P	MRP-56P
ATC/SIF		SOD 57M	SOD 57M	SOD-57N	SOD-57N	SOD 57M	SOD 57M
Doppler Radar Nav. computer		-	-	-	NJ-50BN	-	-
Short range nav. system		-	RSBN-2S	RSBN-2S	RSBN-25 and long range nav system	RSBN-2S	RSBN-2S(SD-1)
Autopilot		-	-	-		-	-
ILS		-	SP-50	-	SP-50	-	SP-50
Communications							
HF-system		-	-	Mikron	RSB-70 and RPS	-	Helium and US-8
VHF system		RSIU-5	RSIU-5	Landysh-5	2xRSIU-5	RSIU-5	RSIU-5
VHF with data link		ARL-S	ARL-S	-	-	ARL-S	Lasur
UHF system		-	R-831	SPU-7	SPU-10	-	SPU-2
ARMAMENT							
Cannon(s)		1 23mm twin MG pack with 200 rds under fus.	1 23mm twin MG pack under fuselage	MG 12.7mm	1x23 mm radar-controlled tail-mounted cannon	-	-
External stores stations		5(4 fus.,1 wing)	5(1 fus.,4 wing)	9(1 fus.,8 wing)		4 (wing)	4 (wing)
Bombs		2x500 kg and 2x250 kg or	4 x 500 kg or	4x250 kg and 4x16 or 4X32	9000 kg nuclear bombs or 15x500 kg bombs in bomb bay	2x500 kg and 2x250 kg	4 x 500 kg or
Rockets		4 x 16 57 mm or 4 x 240 mm or	4 x 16 57 mm or	or 4x210/ 240/280 mm rockets			
Guide missiles		2xAA-2IR-Atoll 2xAA-2 Radar-Atoll	2xAA-2IR-Atoll and 2xAA-2Radar -Atoll	4 anti-tank missiles Sagger or Swatter	2 new air-ground missiles with 800 km range	4xAA-6 or 2xIR and 2x semi active radar missiles	4xAA-5Ash

in sizes. AAA is generally standardized to calibers 23mm, 30mm, 37mm, 57mm, 85mm, and 100mm. Like small arms, AAA may have either single- or multiple-barrel configurations [27]

The land-based platform is used to launch and guide surface-to-air missiles (SAM) to an intercept point. SAM launch and guidance equipment varies in size from a single hand-held launch tube to a semi-permanent complex containing numerous trailers, vans, and launch sites. The system may employ both optical and radar target tracking in conjunction with special missile tracking and guidance computers. In many cases, the systems employ electronic counter-countermeasure schemes to enhance their effectiveness.

Missiles can be divided into three major types of homing systems; active, semi-active and passive. If the aircraft is tracked by electronic radiation equipment in the missile, the system is referred to as active. An example is a system that uses a radar transmitter located on the missile to illuminate the aircraft, and then uses the radar reflections from the aircraft for guidance. A major advantage of active homing is the fact that the missile can be launched and forgotten by the operational unit. No further tracking is required. The disadvantages of active homing are the additional weight and expense for each missile and the fact that the radiation from the missile can reveal its presence.

If the aircraft is illuminated by a tracking beam from some source not on the missile, and if the reflections from the aircraft in the direction of the missile are used by the missile for guidance, the system is referred to as a semi-active homing system [27]. Examples of U.S. semi active homing systems are Hawk, Bloodhound and Aspide. Passive homing systems use electromagnetic emissions or natural reflections from the aircraft itself for guidance. Chaparral, Redeye and Stinger are the land-based SAM passive homing systems.

6.4.2 Sea-Based Systems

The U.S. sea-based missiles tend to be smaller than the Soviet missiles of similar size and capabilities. Missiles size is a particularly important considerations for ships, which are space and weight critical, since it affects magazine capacity. The average capacity of a U.S. SAM magazine is 40 missiles, compared with an estimated 22 for Soviet warships [95].

Some of the important Sea-Based SAM's are:

1. Standard ER RIM67A which has a range of 110 km.
2. Standard MR RIM66A which has a range of 32 km.
3. Tartar RIM24B which has a range of 20 km.
4. Sea Sparrow RIM7H which has a range of 5 km.

6.4.3 Airborne Systems

The variety of aircraft-mounted weaponry available to the U.S. is considered far in advance of that used by the U.S.S.R. The standard U.S. aircraft cannon is the 20mm GE M61 Gatling gun. Capable of firing at rates up to 6,600 rounds/minute, this weapon has led to the development of a range of Gatling guns from 5.56mm calibre up to 30mm which have armed U.S. fixed-wing aircraft and helicopters.

Some of the important AAM's are:

1. Hughes AIM-54 Phoenix

   No other missile can match the impressive range of this type which can cope with targets more than 124 miles away from the launch aircraft. Hughes is developing the improved AIM-54 C Phoenix which will have a digital autopilot and signal processor, plus a new proximity fuse and solid-state transmitter/receiver [95].

2. AIM-9 Sidewinder

   This AAM is an IR guidance with a range of 5 to 10 miles.

3. AIM-7 Sparrow; it can reach the range up to 50 miles.
4. Sky Flash, the range is up to 25 miles.

6.5 U.S.S.R. THREAT SYSTEMS

In most instances, it is not difficult to determine the identity of the enemy. On 27 November 1920, the Soviet Premier, Nikolai Lenin, stated one of the basic tenets of the Soviet Communist Doctrine:

> As long as Capitalism and Socialism remain side by side, we cannot live peacefully - the one or the other will be the victor in the end.

History to date has yielded no direct confrontation between the U.S. and the Soviet Union. Experience, however, has shown that the Soviet Union is the major arms supplier for the many other communist and third world countries where minor conflicts periodically erupt. Consequently, the Soviet systems are the ones usually confronted when an armed conflict results, and for that reason only the Soviet threat system will be addressed here [27].

6.5.1 Land-Based Systems

Since the middle of the 1960's, the Soviets have developed and deployed a large number of mobile and semi-mobile surface-to-air missiles and air defense guns for air defense of their field units. This mix of guns and missiles provides a mobile umbrella which accompanies each echelon of the Soviet armies, including forward deployed battalions. These air defense units are assigned to a major branch of the Soviet Ground Forces.

a. Small Arms and AAA

Standard weapon calibers defined as small arms and available in Communist Block Countries are 7.62mm, 7.92mm, 12.7mm, and 14.5mm. These weapons are normally only effective against slow and low-flying aircraft within 600 meters and are usually employed in the barrage fire mode.

Anticraft artillery have sizes that range from 14.5 mm up to and including 130 mm. Weapons through 57 mm are usually mobile. The larger systems are located in fixed installations.

One of the most important Soviet mobile air defense weapons is called Shilka. This system is a self-contained package of mobile firepower with its own target acquisition and fire control equipment. It can fire on the move at speeds up to 25 kilometers per hour [27].

b. Surface-to-Air Missile Systems

The Soviet land-based surface-to-air missile systems are the SA-1 through the SA-13 (See Table 6.3). Marshal Batitskii, lauding their high firepower and precision, claims they man "varied types of surface-to-air rocket systems that are capable of destroying every means of enemy attack at the whole spectrum of their altitudes and speeds of flight, and at long distances from the objectives

TABLE 6.3

Surface-to-Air Missiles

ABM-1B (NATO 'Galosh')

The Soviet Union deactivated half of the 64 operational launchers of its 'Galosh' ABM (anti-ballistic missile) defence system, which were deployed around Moscow during 1980. A single nuclear warhead is fitted. Missile range is said to be over 200 miles.

SA-1 (NATO 'Guild')

Dimensions: length 39 ft 0 in, body diameter 2 ft 3.5 in.
Performance: range 31 miles.

SA-2 (NATO 'Guideline')

This missile is a standard anti-aircraft weapon in about 20 countries and has been operational since 1959.

Power Plant: liquid-propellant sustainer, burning nitric acid and hydrocarbon propellants, solid-propellant booster
Guidance: automatic radio command with radar tracking of target. Some late versions employ terminal homing.
Warhead: normally high-explosive weight 288 lb.
Dimensions: length 34 ft 9 in, body diameter 1 ft 8 in, wing span 5 ft 7 in.
Launching weight: 5,070 lb
Performance: max speed Mach 3.5, slant range 28 miles effective ceiling 82,000 ft.

SA-3 (NATO 'Goa')

It is the most widely-used surface-to-air missile in the Soviet Navy, fired from a roll-stabilised twin-round launcher.

Power Plant: two-stage solid propellant
Guidance: radio command with radar terminal homing
Warhead: high-explosive, weight 132 lb.
Dimensions: length 22 ft 0 in ,body diameter 1 ft 6 in, wing span 4 ft 0 in.
Performance: max speed Mach 2, slant range 21.75 miles effective ceiling 49,200 ft.

SA-4 (NATO 'Ganef')

The SA-4 is a standard Soviet weapon for defence of combat areas. It is reported to be operational also with the East German and Czech forces.

Power Plant: ramjet sustainer, four wrap-around solid-propellant boosters.
Guidance: radio command, with semi-active radar terminal homing
Warhead: high-explosive
Dimensions: length 26 ft 10.5 in, body diameter 2 ft 8 in, wing span 7 ft 6 in.
Launching weight: 3.975 lb
Performance: slant range 43 miles, effective ceiling 80,000 ft.

SA-5 (NATO 'Gammon')

It is described by DoD as providing long range, high altitude defence for Soviet targets, and about 1,200 are deployed at more than 100 silos.

Power Plant: Two stage solid propellant, possibly with terminal propulsion for warhead
Guidance: semi-active radar homing
Dimensions: length 54 ft 0 in, body diameter 2 ft 10 in, wing span 12 ft 0 in.
Launching weight: 44,090 lb
Performance: max speed above Mach 3.5, slant range 185 miles, effective ceiling 95,000 ft.

SA-6 (NATO 'Gainful')

Its unique integral all-solid rocket/ramjet propulsion system was a decade in advance of comparable Western technology, and the US-supplied ECM equipment which enabled Israeli aircraft to survive attack by other missiles proved ineffective against the SA-6.

Power Plant: solid-propellant booster. After burnout its empty casing becomes a ramjet combustion chamber for ram air mixed with the exhaust from a solid-propellant gas generator.
Guidance: radio command, semi-active radar terminal homing.
Warhead: high-explosive, weight 176 lb
Dimensions: length 20 ft 4 in, body diameter 1 ft 1.2 in.
Launching weight: 1,212 lb.
Performance: max speed Mach 2.8, range 18.5 miles, effective ceiling 59,000 ft.

SA-7 (NATO 'Grail')

Designed for use by infantry, the SA-7 is also carried by vehicles, including ships, in batteries of four, six and eight, for both offensive and defensive employment with radar aiming. Some are deployed on helicopters for anti-helicopter combat use.

Power Plant: solid-propellant booster/sustainer
Guidance: infra-red homing with filter to screen out decoy flares.
Warhead: high-explosive, weight 5.5 lb
Dimensions: length 4 ft 3 in, body diameter 2.75 in.
Launching weight: 20 lb
Performance: max speed Mach 1.5, slant range 2.15 miles, effective ceiling 5,000 ft.

SA-8 (NATO 'Gecko')

This short range, all-weather system is unique among Soviet tactical air defense weapons in that all components needed to conduct a target engagement are on a single vehicle. Missile configuration is conventional. Surveillance radar with an estimated range of 18 miles.

Power Plant: probably dual-thrust solid propellant
Guidance: command guidance by proportional navigation, semi-active radar terminal homing.
Warhead: high-explosive, about 90-110 lb weight
Dimensions: length 10 ft 6 in, body diameter 8.25 in.
Launching weight: 440 lb
Performance:range 1.8-7.5 miles, effective ceiling 32,800 ft

SA-9 (NATO 'Gaskin')

Dimensions: length 8 ft 9 in, body diameter 4.5 in
Launching weight: 66 lb
Performance: range 4.35 miles, effective ceiling 10,400 ft

SA-10

If press reports are to be believed, this weapon threatens the viability of US cruise missiles. A range of up to 60 miles in the 1,000-16,500 ft height band is suggested with active radar terminal homing. Reported dimensions are a length of 23 ft and body diameter of 17.7 in.

SA-11

This new weapon system comprises a four-rail launch vehicle for Mach 3 radar-guided missiles with a reported ability to deal with targets at altitude between 100 and 46,000 ft, at ranges up to 17 miles. SA-11s are said to be deployed already alongside SA-6s, and may represent an improved version of the latter.

SA-13

SA-13 is the replacement for the SA-9, providing improved capability in rough terrain and increased storage for re-load missiles. Range is about 5 miles at altitude between 165 ft and 32,000 ft.

New Infantry SAM

To overcome the limitations of shoulder-fired, infra-red homing missiles like the SA-7, the Soviet Union has been developing improved infantry SAMs for some years. One type of which deployment is about to start, uses a laser beam for beam-riding guidance.

SA-N-1 (NATO 'Goa')

Ship-launched variant of SA-3, carried on roll-stabilised twin launchers by 43 ships of Soviet Navy.

SA-N-2 (NATO 'Guideline')

Ship-launched version of SA-2. On cruiser Dzerzhinski only.

SA-N-3 (NATO 'Goblet')

The twin-round surface-to-air missile launchers fitted to many of the latest Soviet naval vessels, including the carrier cruisers Kiev and Minsk, helicopter cruisers Moskva and Leningrad, and Kara and Kresta II cruisers, carry a new and more effective missile than the SA-N-1 (Goa). This is said to have an anti-ship capability and to carry a 132 lb high-explosive warhead. The original version has a range of 18.6 miles and effective ceiling of 32,000 ft. A later version has a range of 34 miles.

Dimension: length 19 ft 8 in
Weight: 1,200 lb

SA-N-4

This naval close-range surface-to-air weapon system are similar to those used in the land-based mobile SA-8 system.

SA-N-5

A variety of small Soviet ships have this simple air defense system.

SA-N-6

This new missile is housed in 12 vertical launch tubes under the foredeck of the new Soviet battle cruiser Kirov. It is assumed to deal with the same multiple threats as the US Navy's Aegis defence system. Best estimates suggest a length of about 23 ft effective ceiling of at least 100,000 ft and range of 37 miles at Mach 6, carrying a 200 lb warhead.

SA-N-7

Two single-rail launchers for this new missile are fitted in each ship of the new Sovremennyy class of guided missile destroyers. The SA-N-7 itself is thought to be a naval equivalent of the landbased SA-11 defended, regardless of weather conditions or the time of day or night." Together with the interceptors, he boasts they provide "an insurmountable air defense for the country's most important targets" [96].

It is estimated that there are at least 12,000 missiles on 10,000 launchers (some multiple) at some 1,000 fixed positions throughout the U.S.S.R. The Soviet has concentrated on modernizing rather than expanding this network.

6.5.2 Sea-Based Systems

Too often in the past the Soviet Navy has been written off as a purely defensive force, reminiscent of its 1950's and early 1960's capabilities. This conclusion is no longer valid, for in recent years the Soviet Navy has been transformed into a wide-ranging ocean power specifically tailored to challange the U.S. Navy's dominance as a tactical and strategic force on the high seas [27].

The air defense systems on board operational Soviet surface ships consists of AAA ranging in size from 23 mm to 76 mm and of seven surface-to-air missile systems (Table 6.3), the SA-N-1 through 7.

6.5.3 Airborne Systems

Although recent Soviet fighters sometimes carry aerial cannon, air-to-air missiles continue to be the main armament of the interceptor inventory. Given recent trends in modern aerial combat, the importance of such missiles should grow rather than decline. At present heavier emphasis is being placed by all air forces on the initial use of long-range air-to-air weapons during the opening stage of an air battle. Soviet systems in service that could be used in this role are the AA-5, the AA-6, and AA-7. All are available in both radar and infrared guidance versions. The type of air-to-air missiles that the Soviet have recently are listed in Table 6.4.

6.6 AIR-TO-AIR INTERACTIONS

In this model, the air-to-air interactions are based on the Lanchester equations, those are $dx/dt = -by$ and $dy/dt = -cx$. The attrition rate depends on the strength of the enemy power. The stronger the enemy, the higher the attrition rate and vice versa. In this model, there are interactions between twelve U.S. aircraft and twelve U.S.S.R. aircraft. The attrition rates depend on the sortie rate of the enemy aircraft, the number of enemy aircraft and the mission survival of the aircraft versus enemy aircraft. The

TABLE 6.4

Airborne and Tactical Defence Missiles

AS-2 (NATO 'Kipper')

First seen 22 years ago, a 2,200 lb high explosive warhead is fitted.
Dimensions: span 16 ft 0 in, length 31 ft 0 in.
Weight: 9,260 lb
Performance: max speed Mach 1.2, range 130 miles.

AS-5 (NATO 'Kelt')

Guidance is said to be by autopilot on a preprogrammed flight path, with radar terminal homing.
Dimensions: span 14 ft 1.25 in, length 28 ft 2 in.
Weight: 7,715 lb
Performance: max speed Mach 0.9 at low altitude, Mach 1.2 at 30,000 ft.

AS-7 (NATO 'Kerry')

Carried by the Su-17 'Fitter' and Yak-36 'Forger', this tactical air-to-surface missile is said to have a single-stage solid-propellant rocket motor, radio command guidance system, and 220 lb high-explosive warhead.
Dimension: length 11 ft 6 in.
Weight: 2,640 lb
Performance: max speed Mach 0.6, max range 7 miles.

AS-X-9

A reported anti-radiation missile with a range of 50-56 miles to arm the Su-24 ('Fencer').

New air-to-surface weapons

Several new Soviet air-to-surface weapons have been reported in recent years, some of which are already operational. The designation AS-8 appears to have been misapplied to the AT-6 (NATO 'Spiral') described below, but AS-10, AS-11 and AS-12 are believed to include a Mach 0.8 laser-guided solid-propellant missile, about 9 ft. 10 in. long, with a range of 6 miles, and the weapon shown under the wing gloves of an Su-17 in an accompanying illustration. Longer-range cruise missiles are almost certainly under development, not least as armament for the new 'Blackjack' strategic bomber.

AT-2 (NATO 'Swatter')

This standard Soviet anti-tank weapon formed the original missile armament of the Mi-24 (Hind A and D) helicopter gunship and is carried by the 'Hip-E' version of the Mi-8.
Dimensions: span 2 ft 2 in, length 3 ft 9.75 in.
Weight: 65 lb
Performance: cruising speed 335 mph, range 1,640-11,500 ft.

AT-3 (NATO 'Sagger')

Dimensions: span 1 ft 6 in, length 2 ft 10.25 in
Weight: 25 lb
Performance: speed 270 mph, range 1,650-9,650 ft.

AT-6 (NATO 'Spiral')

Unlike previous Soviet helicopter launched anti-tank missiles, Spiral does not appear to have a surface-launched application. It equips the Hind-E version of the Mi-24, and is said to have a range of 4.3 to 6.2 miles.

AA-2 (NATO 'Atoll')

Designated K-13A in the USSR. Atoll is the Soviet counterpart to the American Sidewinder 1A (AIM-9B) to which it is almost identical in size, configuration, and infra red guidance.
Dimensions: length 9 ft 2 in, body diameter 4.72 in.
Weight: 154 lb
Performance: cruising speed Mach 2.5 range 3 to 4 miles.

AA-2-2 (NATO 'Advanced Atoll')

The radar version is known as Advanced Atoll. Length is increased to at least 9 ft 10 in.

AA-3 (NATO 'Anab')

This solid-propellant air-to-air missile is estimated as being in the thousands.
Dimensions: length 13 ft 5 in (IR) or 13 ft 1 in (SAR), body diameter 11 in, wing span 4 ft 3 in.
Performance: range over 10 miles.

AA-5 (NATO 'Ash')

Several thousand of these larger air-to-air missiles have been produced as armament for the Tu-28P interceptors of Voyska PVO.
Dimensions: length 17 ft 4.5 in (IR) or 17 ft 0 in (SAR), body diameter 12 in, wing span 4 ft 3 in.

AA-6 (NATO 'Acrid')

This is the air-to-air missile that was identified during 1975 as one of the weapons caried by the Foxbat-A interceptor version of the MiG-25.
Dimensions: length 20 ft 7.5 in (radar version) 19 ft 0 in (IR version).
Weight: 1,650 lb
Performance: cruising speed Mach 2.2, range at least 23 mi.

AA-7 (NATO 'Apex')

This long-range air-to-air missile is one of the two types carried as standard armament by interceptor versions of the MiG-23 and is reported to be an alternative weapon for the MiG-25. 'Apex' has a solid-propellant rocket motor, and is likely to exist in both infra-red and radar homing versions. Warhead weight is 88 lb.
Dimensions: length 15 ft 1.25 in, body diameter 8.75 in. wing span 3 ft 5.5 in.
Weight: 705 lb
Performance: range 20 miles.

AA-8 (NATO 'Aphid')

Second type of missile carried by the MiG-23 and also by late-model MiG-21s. 'Aphid' is a highly-maneuverable close-range solid-propellant weapon with infra-red homing guidance, and 13.2 lb warhead.
Dimensions: length 7 ft 2.5 in ,body diameter 4.75 in, wing span 1 ft 3.75 in.
Weight: 121 lb
Performance: range under 1,650 ft min, 3-4.3 miles max.

AA-X-9

The missile known in the West as AA-X-9 is reported to have achieved successes against simulated cruise missiles, after look-down snap-down launch from a MiG-25M interceptor

Anti-Helicopter 'Grail'

In addition to AT-3 anti-tank missiles. Gazelle helicopter license-built by SOKO for the Yugoslav Air Force carry SA-7 'Grail' tube-launched IR homing missiles for use against other helicopters.

probability of encounter between aircraft are based on the type of mission that the aircraft carry. For example, the aircraft which interdict into enemy territory will be encountered by defense aircraft which basically are fighters.

The measure of effectiveness of the air-to-air interactions is the number of aircraft lost, or the number of aircraft killed per number of aircraft lost.

6.7 SURFACE-AIR INTERACTIONS

The surface-air interactions are based on the Lanchester linear law, $dx/dt = -bx$ and $dy/dt = -cy$. The attrition rate of the aircraft depends on the number of aircraft sent on this mission, the sortie rate, and the mission survivability of the aircraft against the enemy surface threat. Once the aircraft attack the land targets there is an interaction between aircraft and the land threat or in other words, the probability of encounter between aircraft and land is 1. Attack aircraft usually are responsible for missions to attack the land targets.

The measure of effectiveness of the surface-air interactions is the target destroyed per aircraft lost.

6.8 CONCEPT OF MANAGED ATTRITION

Managed attrition is a concept to reduce rate or to limit the attrition rate over time for a force.

Managed attrition can only be applied in the case of surface-air interactions, because the surface threat cannot kill the aircraft unless the aircraft try to attack surface targets. The more aircraft sent to battle, the more aircraft killed. By using the concept of managed attrition, the number of aircraft sent to attack surface targets are limited. By using the concept of managed attrition, the number of aircraft sent to attack surface targets are limited. By managing attrition, we can reduce the number of aircraft killed but it will not assure that we can win the war. If we limit the number of aircraft which are sent, in the same time we limit the targets that will be destroyed by the aircraft.

In the case of air-to-air interactions, managed attrition is not an appropriate consideration since the attrition rate of one side depends on the enemy strength; and one side cannot ask the enemy to limit their power.

Managed attrition affects the sortie rate of the aircraft; the lower the managed attrition, the lower the sortie and at the same time it will lower the target destroyed.

It can be concluded that the concept of managed attrition is a concept to save the combat aircraft but it is not a concept to win the war, and therefore may be shortsighted and suboptimum.

6.9 WRITING EQUATIONS

6.9.1 Number of Aircraft Initially

In this model, the simulation time starts from the year 1980 until 2000 for peace time build-up and from day 0 until the end of the war. Therefore, the initial number of aircraft are concerned with the year 1980 aircraft data, and the following year aircraft data are used to determine the procurement rate.

In the Military Balance 1980-1981 and 1981-1982 [97,98], some of the Soviets aircraft in operation are shown as follows:

	1980-1981	1981-1982
Hind Mi-24	750	950
Foxbat MiG-25	500	490
Flogger MiG-23/MiG-27	1900	2550
Backfire Tu-22M/Tu-26	130	135

These numbers are almost the same as written in the "Soviet Armed Forces Review Annual 6" [99], but they are somewhat different with the data in "How to Make War" [100]. It was stated there; since the figure was projected in late 1981, there might be some small errors due to increased accident/losses or production changes. Those numbers are used as a comparison to the others.

It is known [43], that the procurement rate of Hind Mi-24 is 15/month or 180/year. In the year 2000, therefore, the total number of Mi-24 will be 750+(20x180) = 4350.

For MiG-25, the number of aircraft is decreasing which is probably because of the production of the new version Foxhound MiG-25M. Eventhough, MiG-25 is assumed to be produced 10/year. This number is assumed to be minimum procurement rate.

Flogger MiG-23/MiG-27 is increased by 600 from 1980 to 1981, but it does not mean that this will happen until the year 2000. Due to the fact that there are another new fighters such as MiG-29 and Su-25 [43], the procurement rate of MiG-23/MiG-27 is also affected. Therefore, it is assumed that the procurement rate of this aircraft is 100/year.

Backfire Tu-22M/Tu-26 is projected to be 200 in the year 1985 [95], the procurement is therefore about 15/year.

Some of the Soviet's aircraft are not known; by using the data of their capability and the number of aircraft planned, the number of aircraft and the procurement can be asserted.

The number of U.S. aircraft are reflected from the other submodel, such us Economic-Budget and Procurement Submodel.

6.9.2 Mission Survivability versus Land and Sea Threats

It is shown in Table 6.5 that Thunderbolt A-10 has the highest strike capability with the rating of 18 among the other aircraft and 3 types of Soviet's fighter aircraft rank the lowest capability with the rating of 1.

It is assumed that the highest probability of survival of aircraft versus threats is 0.99 and the lowest is 0.95. Therefore the mission survivability can be formulated as:

$$[(X-1)/(18-1)][.99-.95]+.95$$

where X is the strike capability of aircraft.

To clarify this formula, some examples are presented below.

1. Eagle F-15, the mission survivability is:

   $$[(10-1)/17][.04] + .95 = .971$$

2. Falcon F-16, the mission survivability is:

   $$[(6-1)/17][.04] + .95 = .962$$

3. Flogger MiG-23/MiG-27, the mission survivability is:

   $$[(3-1)/17][.04] + .95 = .955$$

TABLE 6.5 CAPABILITY RATING

AIRCRAFT		INTERCEPT	STRIKE
Eagle	F-15	12	10
Falcon	F-16	10	6
Thunderbolt	A-10	5	18
Harrier	AV-8	4	6
Tomcat	F-14	8	10
Intruder	A-6	4	10
Hornet	F-18	9	12
Fishbed	MiG-21	5	2
Flogger	MiG-23/MiG-27	8	3
Fitter	Su-17/Su-20/Su-22	4	4
Fencer	Su-19/Su-24	5	9
Backfire	Tu-22M/Tu-26	4	10
Foxbat	MiG-25	5	1
Foxhound	MiG-25M	7	1
Fiddler	Tu-28P/Tu-128	4	1
Fulcrum	MiG-29	5	7
Frogfoot	Su-25	6	5
Flanker	Su-27	0	11

Source: How To Make War
[100]

6.9.3 Mission Survivability versus Airborne Threats

First of all, it is assumed that all the aircraft have the probability of survival between 0.95 and 0.99. To determine the mission survivability of one aircraft against another, the capability rating of intercept data are used (See Table 6.5).

The mission survivability of X versus Y is formulated as:

$$[(X-Y)/Y]*.02 + .97$$

Some examples of the U.S. and Soviet aircraft mission survivability are as follows:

1. Mission Survivability of F-15 vs. MiG-23/MiG-27 is
   $$[(12-8)/8] * .02 + .97 = .98$$
2. Mission Survivability of MiG-23/MiG-27 vs. F-15 is
   $$[(8-12)/12] * .02 + .97 = .963$$
3. Mission Survivability of F-15 vs. MiG-21 is
   $$[(12-5)/5] * .02 + .97 = .998$$

According to the previous assumption, the mission survivability is 0.99. Therefore .99 is used instead of .998.

According to another reference [43], the Fulcrum MiG-29 is a single -seat air superiority fighter in the class of the F/A-18 Hornet and the Flanker Su-27 is believed to be in the same category as the F-15 Eagle. For this reason, it is better to assume that the intercept capability of MiG-29 and Su-27 are 7 and 9 respectively.

6.9.4 Mission Survivability of U.S. Baseline Aircraft

To determine the value of mission survivability of U.S. aircraft in the year 1980, the figures of intercept and strike capabilities from Table 6.5 is utilized.

It is considered that the U.S. combat aircraft have a higher quality compared with the U.S.S.R. combat aircraft. Therefore, it makes sense if the baseline U.S. aircraft have the probability of survival between .99 and .97. F-15 is obvious to have the highest probability of survival and AV-8 has the lowest.

To calculate these values, the following formula can be used:

$$\text{Mission Survivability} = [(R-10)/12]*.02 + .97$$

where R is the rate capability (intercept+strike)

Some examples are given below:

1. F-16, MSFF = $[(16-10)/12] * .02 + .97 = .98$
2. F-18, MSHF = $[(21-10)/12] * .02 + .97 = .988$

6.9.5 DYNAMO Equations

The following DYNAMO equations are based on the previous discussion. The number of aircraft initially, the mission survivability versus land and sea threats and the mission survivability versus airborne threats will be shown below. In these equations, the Flogger MiG-23/MiG-27 represents the

Soviet's aircraft and Eagle F-15 represents the U.S. aircraft.

```
L    FG.K=FG.J+(DT)(PRFG.JK-ARFG.JK)                     (A-1)
N    FG=FGN                                              (A-1.1)
C    FGN=1900                                            (A-1.2)
NOTE  FG - Number of MiG-23/MiG-27 aircraft
R    PRFG.KL=CLIP(0.6,200,TIME.K,WAR)                    (A-2)
NOTE  PRFG - Procurement Rate of FG (aircraft/day or year)
R    ARFG.KL=FG.K*SRFGST.K*(1-MSFGST)+FG.K*SRFGLT.K*
X      (1-MSFGLT)+EF.K*SREFFG.K*(1-MSFGEF)               (A-3)
NOTE  ARFG - Attrition Rate FG (aircraft/day)
C    MSFGST=.955                                         (A-6.4)
NOTE  MSFGST - Mission Surviv. FG vs sea threats (prob)
C    MSFGLT=.955                                        (A-23.3)
NOTE  MSFGLT - Mission Surviv. FG vs land threats (prob)
C    MSFGEF=.963                                          (A-83)
NOTE  MSFGEF - Mission Surviv. FG vs F-15 (prob)
A    SRFGST.K=FSFGST*MIN(AAFGST/(1-MSFGST),SRFGM*AVFG) (A-6)
C    SRFGM=4                                             (A-6.1)
C    AVFG=.5                                             (A-6.2)
C    FSFGST=.2                                           (A-6.3)
C    AAFGST=.10                                          (A-6.4)
NOTE  SRFGST - Sortie Rate FG vs Sea Targets (fract/day)
NOTE  SRFGM - Sortie Rate FG maximum (fract/day)
NOTE  AVFG - Availability of FG (prob)
```

```
NOTE  FSFGST - Fraction Sortie of FG vs Sea Targets (fract)
NOTE  AAFGST - Allowable attrition FG vs Sea Threats (fract)
A    SRFGLT.K=FSFGLT*MIN(AAFGLT/(1-MSFGLT),SRFGM*AVFG) (A-23)
C    FSFGLT=.4                                      (A-23.1)
C    AAFGLT=.10                                     (A-23.2)
NOTE  SRFGLT - Sortie Rate FG vs Land Targets (fract/day)
NOTE  FSFGLT - Fraction Sortie of FG vs Sea Targets (fract)
A    SREFFG.K=FSEFAT*EEFFG.K*MIN(AAFGAT/(1-MSFGEF),
X      SREFM*AVEF)                                  (A-44)
C    FSEFAT=.7                                      (A-52)
C    AAFGAT=.07                                   (A-45.1)
C    SREFM=4                                       (A-6.1)
C    AVEF=.5                                       (A-6.2)
NOTE  SREFFG - Sortie Rate F-15 vs FG (fract/day)
NOTE  FSEFAT - Fraction Sortie of EF vs FG (fract)
NOTE  AAFGAT - Allowable Attr of FG vs Airborne Threats (fr)
NOTE  SREFM - Sortie Rate F-15 maximum (fract/day)
NOTE  EEFFG - Prob. of Encounter Between EF and FG (prob)
```

6.10 SURVIVABILITY TRADE-OFF

The measures of mission effectiveness are varied that any system can be evaluated with respect to its mission objectives. Some of the measures used as a survivability trade-off are "cumulative targets destroyed per aircraft lost" and "kills per aircraft lost."

Cumulative targets destroyed per aircraft lost is used to measure the effectiveness of attack and bomber aircraft, since their operations are primarily destroying the enemy's land targets. Cumulative targets can be calculated by accumulating the targets destroyed by aircraft and targets destroyed is calculated by multiplying the number of aircraft, the sortie rate and the target destroyed per sortie. The DYNAMO equations are given below:

A TDB$$.K=$$.K*SR$$LT.K*TDPS$$ (A-214)

L CTDB$$.K=CTDB$$.J+(DT)(TDB$$.J) (A-215)

N CTDB$$=0 (A-215.1)

NOTE TDB$$ - Targets Destroyed by $$ Aircraft

NOTE TDPS$$ - Targets Destroyed per Sortie $$

NOTE CTDB$$ - Cumulative Targets Destroyed by $$

A TDP$$L.K=CTDB$$.K/CL$$.K (A-217)

NOTE TDP$$L - Cumulative Targets Destroyed per A/C Lost

NOTE CL$$ - Cumulative Lost $$

The higher the TDP$$L means that the mission is more effective, either destroys more targets or more aircraft survived.

Kills per aircraft lost are basically used to measure the effectiveness of fighter aircraft which kill enemy's aircraft in their missions. The DYNAMO equations are shown below.

A KPXXL.K=CL$$.K/CLXX.K (A-218)

```
A    KP$$L.K=CLXX.K/CL$$.K                           (A-218)
L    CLXX.K=CLXX.J+(DT)(ARXX.JK)                     (A-4)
L    CL$$.K=CL$$.J+(DT)(AR$$.JK)                     (A-4)
NOTE  KPXXL - $$ Killed per XX Lost
NOTE  KP$$L - XX Killed per $$ Lost
NOTE  CLXX - Cumulative Lost of XX
NOTE  CL$$ - Cumulative Lost of $$
NOTE  ARXX - Attrition Rate of XX
NOTE  AR$$ - Attrition Rate of $$
```

The higher the KP$$L, the better the fighter aircraft in their mission.

It is suggested to consider more than one kind of measure of effectiveness in order to reduce the possibility of misunderstanding in interpreting the result of this simulation.

Another measure of effectiveness is the combat value of each side. This measure of effectiveness is based on the equilibrium condition where the two side forces are equal. The combat value can be expressed as follows:

```
A    $$CV.K=($$.K*FS$$AT-(PRXX.JK*FSXXAT*EXX$$.K)/
X      (SR$$XX.K*(1-MSXX$$)))*SQRT(SR$$XX.K*(1-MSXX$$))
X      +$$.K*SQRT(SR$$LT.K*(1-MS$$LT))*TDPS$$  (A-222)
NOTE  $$CV - Combat Value of $$
NOTE  FS$$AT - Fraction Sortie of $$ vs Aircraft
NOTE  PRXX - Procurement Rate of XX
```

```
NOTE  FSXXAT - Fraction Sortie of XX vs Aircraft

NOTE  EXX$$ - Probability of Encounter Bet. XX and $$

NOTE  SR$$XX - Sortie Rate of $$ vs XX

NOTE  MSXX$$ - Mission Survivability of XX vs $$

NOTE  SR$$LT - Sortie Rate of $$ vs Land Targets

NOTE  MS$$LT - Mission Surviv of $$ vs Land Threats

NOTE  TDPS$$ - Target Destroyed per Sortie $$
```

Chapter VII

RESULTS, CONCLUSIONS AND DISCUSSION

7.1 COMBAT AIRCRAFT EFFECTIVENES RELATIONSHIPS

When two sides have the same effectiveness, an equilibrium condition is reached, neither side will win nor lose, the war will last until infinity. Fig. 7.1 shows the relationship between parameters to gain an understanding of the mission effectiveness of each side. The graph is used only for the equilibrium condition. If the attrition per sortie for both sides are equal, the fraction of aircraft lost will be the same at any time.

The example which is shown on the graph is based on the following model:

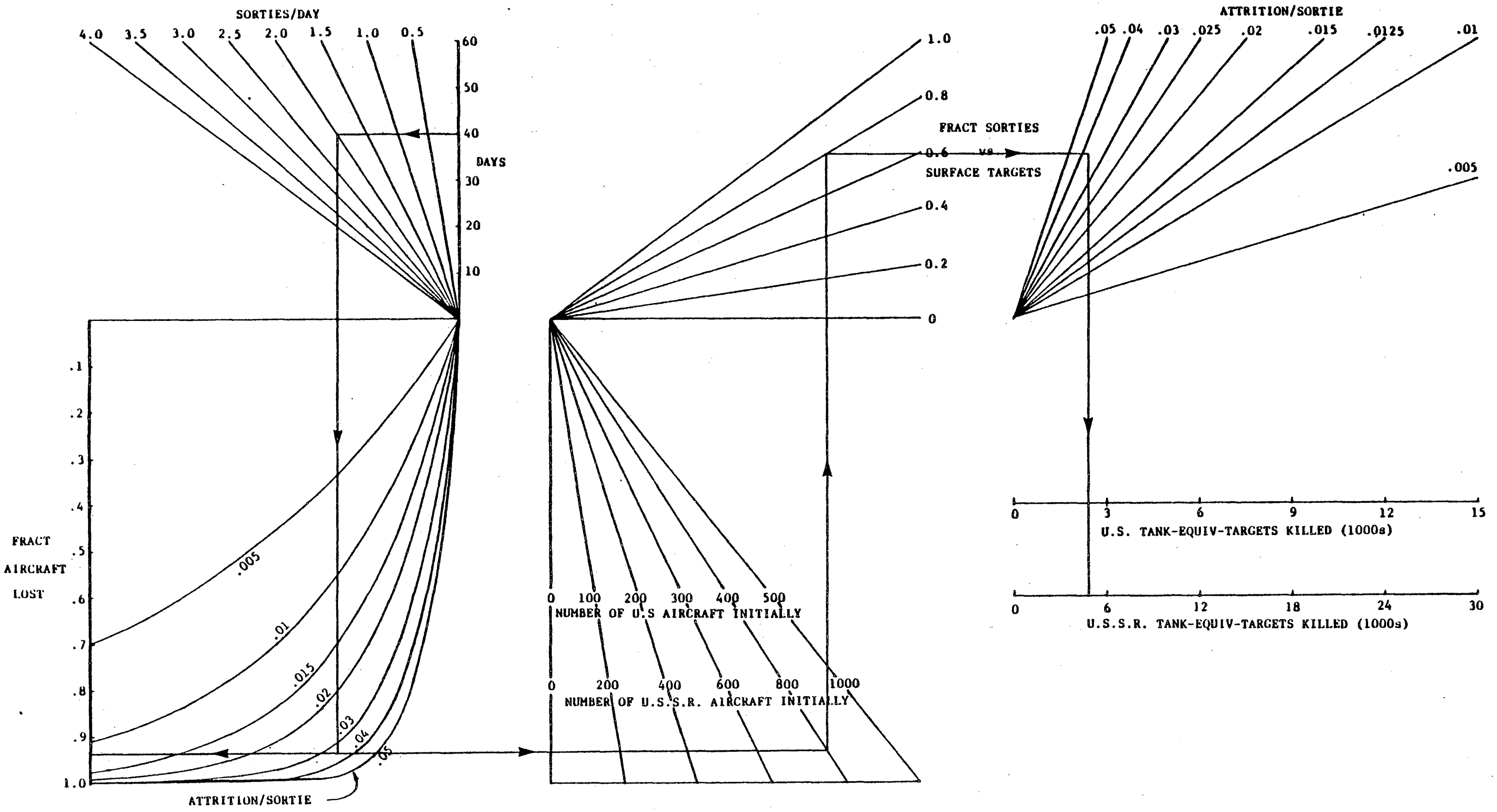
d$$t/dt = -.006 XXt - .024 $$t

dXXt/dt = -.008 $$t - .032 XXt

where XX denotes the number of USSR and $$ denotes the number of US aircraft.

The number of USSR aircraft initially is twice the U.S. number and it is also assumed that the USSR tank equivalent targets killed initially is twice the U.S. number.

The graph shows only the relationship between parameters and the sensitivity of the parameters themselves. It does not give information for the case in which one side



COMBAT AIRCRAFT EFFECTIVENESS RELATIONSHIPS

Fig. 7.1

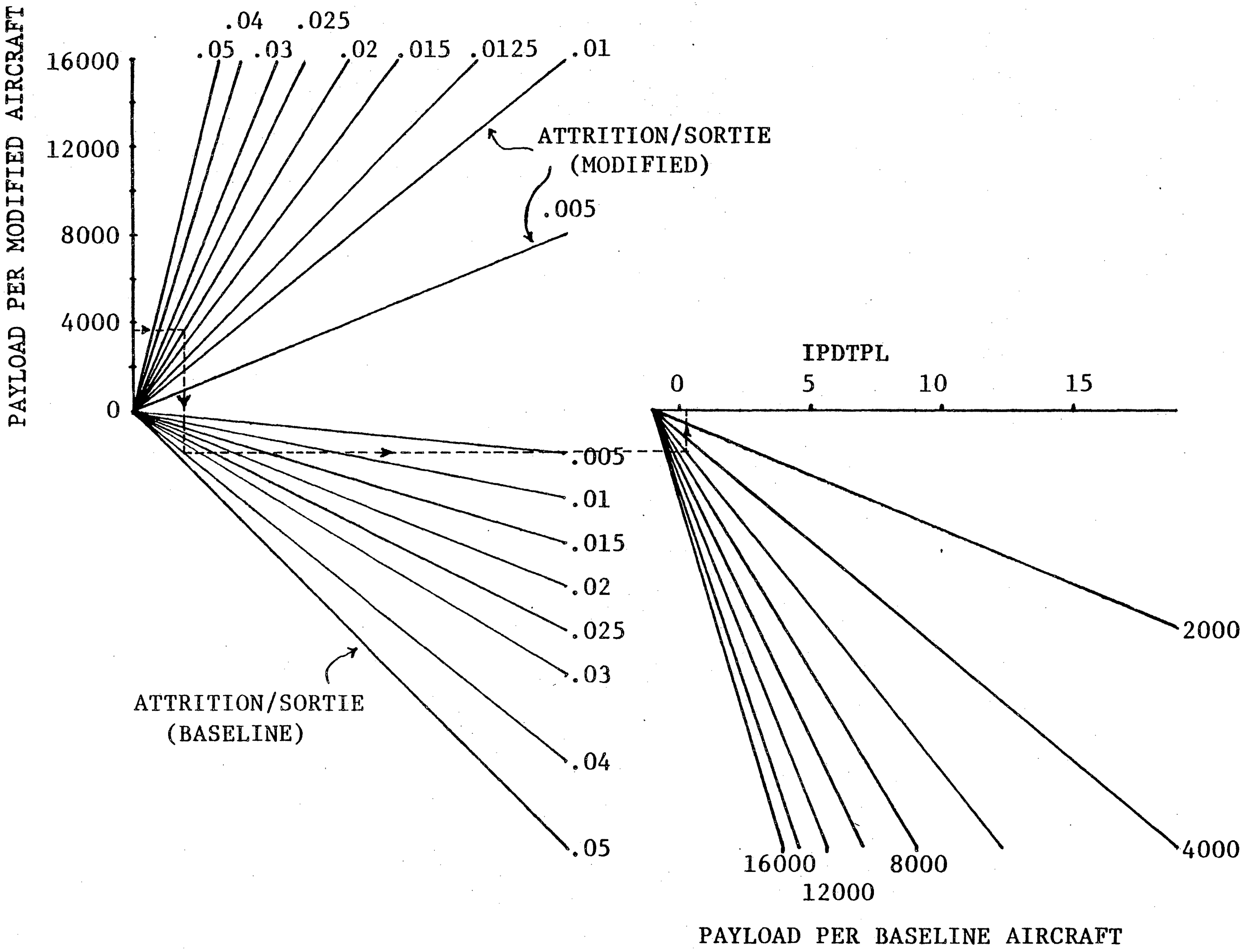
increases its capability so to move the system out of equilibrium. What it does is to provide the reader with a feel for the quality-quantity aspects of the U.S. - Soviet match-up.

7.2 SURVIVABILITY-ATTRITION RELATIONSHIPS

The purpose of the attrition submodel in this research is to feed back to the survivability submodel so that we are able to know whether a proposed modification will be more effective or less effective with respect to the unmodified or baseline aircraft. This information is necessary for guiding a rational peacetime buildup.

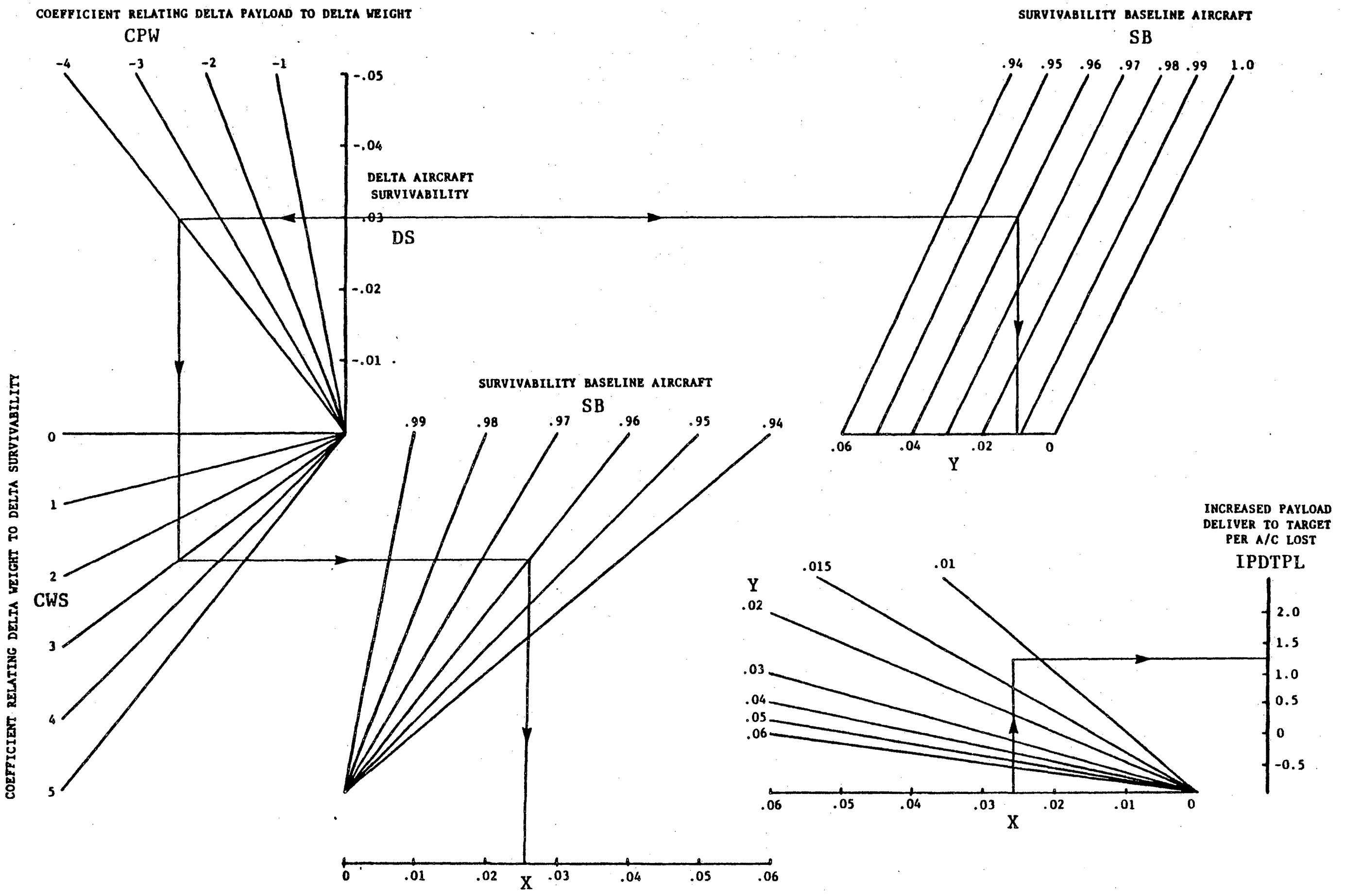
Two measures of effectiveness for evaluating attack aircraft and fighter aircraft are IPDTPL and DPLCC. IPDTPL is increased payload delivered to target per aircraft lost and DPLCC is decreased program life cycle cost.

Fig. 7.2 shows the relationship between payload and attrition per sortie for modified and baseline aircraft. In the example of Fig. 7.2 the IPDTPL is greater than 0 which means that the modified aircraft is more effective than the baseline aircraft. Fig. 7.3 shows the relationship between the coefficients relating the deltas and the survivability of baseline aircraft. "Delta's" are defined as the difference between baseline's and modified's over the



INCREASED PAYLOAD AS A MEASURE OF EFFECTIVENESS FOR SURVIVABILITY TRADEOFF ANALYSIS
(ATTACK AIRCRAFT)

Fig. 7.2



INCREASED PAYLOAD AS A MEASURE OF EFFECTIVENESS FOR SURVIVABILITY TRADEOFF ANALYSIS
(ATTACK AIRCRAFT)

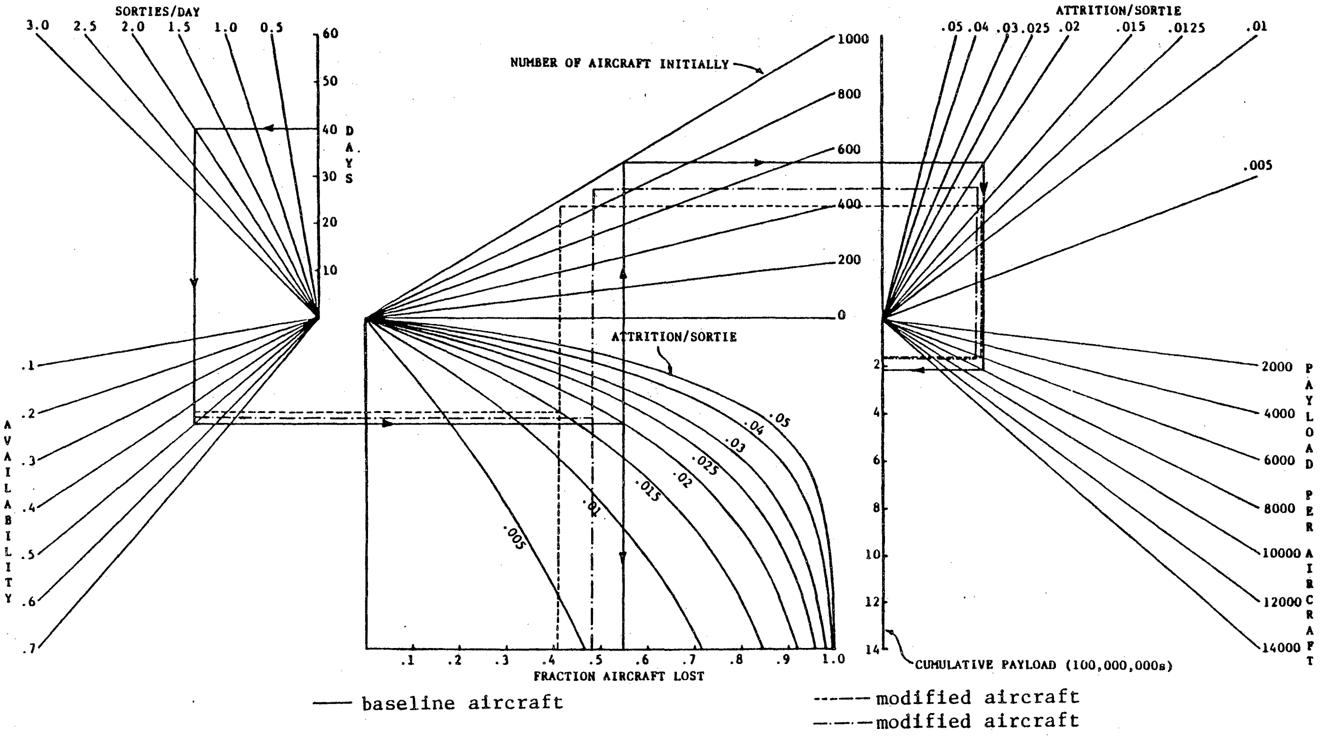
Fig. 7.3

baseline's. For example, delta aircraft survivability (DS) is (SB-SM)/SB, where SB is the survivability of baseline aircraft and SM is the survivability of modified aircraft. Figs. 7.2 and 7.3 apply to attack aircraft.

Figs. 7.4 and 7.5 show the relation between parameters which determine the fraction aircraft lost and the cumulative payload as measures of effectiveness. The examples in Figs. 7.4 and 7.5 show that one modification improves the baseline aircraft while the other modification makes the aircraft less effective and therefore should not be performed.

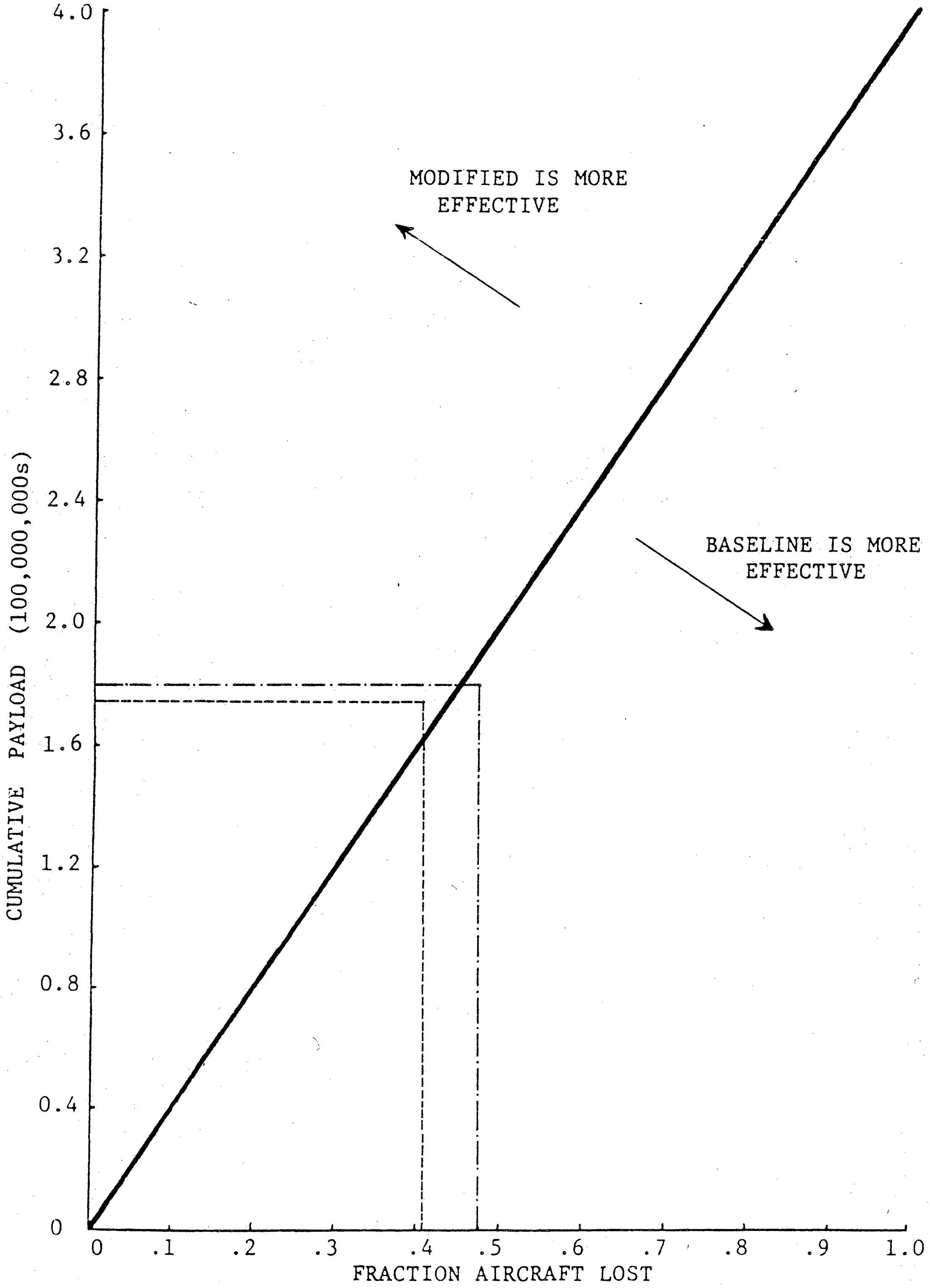
Due to the complexity of the relations between parameters for the fighter aircraft, it is impossible to provide a graph as for the attack aircraft. The examples of simple survivability-attrition relations for both attack and fighter aircraft are described in the Appendix A and the results are listed in Tables 7.1 and 7.2.

From these results, it can be concluded that a survivability enhancement modification that may make the modified attack aircraft more effective than the baseline aircraft, may not be appropriate for a fighter aircraft (see Tables 7.1 and 7.2). The parameter values in Table 7.1 are exactly the same for both attack and fighter aircraft. In Table 7.2, the fighter aircraft has a higher survivability,



MEASURES OF EFFECTIVENESS FOR SURVIVABILITY TRADEOFF ANALYSIS (ATTACK AIRCRAFT)

Fig. 7.4



MEASURES OF EFFECTIVENESS FOR SURVIVABILITY TRADEOFF ANALYSIS (ATTACK AIRCRAFT)

Fig. 7.5

TABLE 7.1 SURVIVABILITY TRADEOFF

PARAMETER	BASELINE	MODIFIED	REMARKS
Survivability	.96	.98	
Empty Weight	18,000	20,000	
Fuel Weight	10,000		
Payload	6,000	3,615.4	
Acquisition Cost	30,000,000	35,000,000	
Maintenance	10	12	
Sortie Rate	2	1.206	
Availability	0.5	0.417	
Number of A/C initially	1,000	857	

IPDTPL	0.205	Modified is superior
DPLCC	-1.05	Baseline is superior

TABLE 7.2 SURVIVABILITY TRADEOFF

PARAMETER	BASELINE	MODIFIED	REMARKS
Survivability			
fighter aircraft	.96	.9698	
attack aircraft	.98	.99	
Empty Weight	20,000	22,000	
Fuel Weight	12,000		
Payload	8,000	5,600	
Acquisition Cost	36,000,000	37,500,000	
Maintenance	15	16	
Sortie Rate	2	1.40	
Availability	0.5	0.47	
Number of A/C initially	1,000	960	

IPDTPL	-0.073	Baseline is superior
DPLCC	0.42	Modified is superior

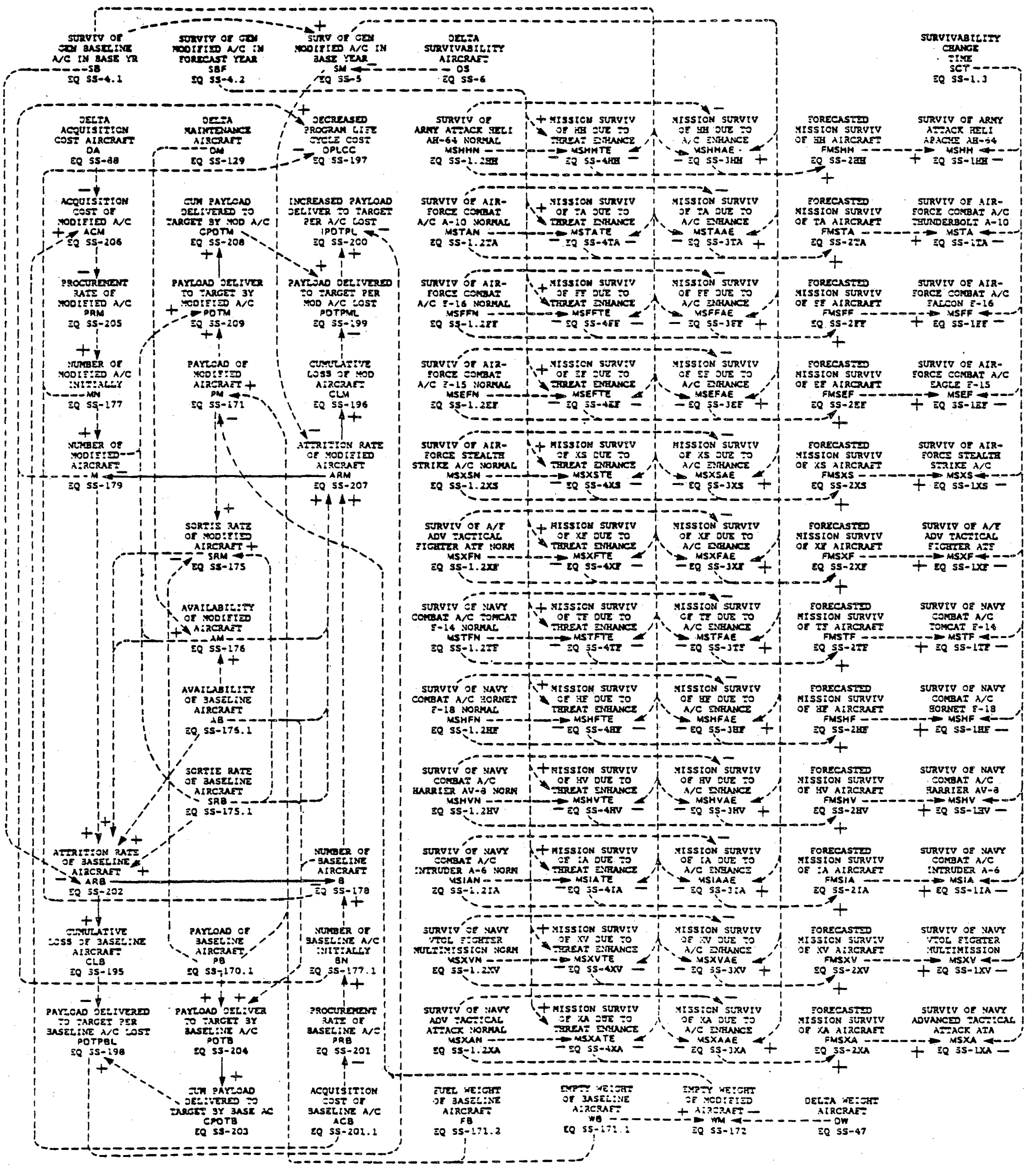
but the delta survivability for both types of aircraft are the same.

It can be noted also, that if the attack and fighter aircraft have exactly the same parameter values, the modified fighter aircraft cannot be better than the baseline aircraft unless the modified attack aircraft is better than the baseline aircraft. The basis for this is derived in Appendix A.

7.3 SURVIVABILITY-ATTRITION SIMULATION RESULTS

The ultimate technological assessment for combat aircraft is the level of attrition. If attrition is higher than expected and mission objectives cannot be fulfilled due to misguided peacetime preparations, it is too late to do anything about it after war starts. Therefore the attrition submodel cannot stand alone, but must be considered along with the other submodels which describe the peacetime buildup. In this research, it is combined directly with the survivability and procurement submodels and indirectly with the economy and budget submodels. For the purposes of this section, procurement is treated exogenously.

The causal diagram for the survivability-attrition relation is shown in Fig.7.6. A generic aircraft is utilized in the model so that the wartime results can



SURVIVABILITY TRADEOFF COMPONENT OF SURVIVABILITY SUBMODEL

Fig. 7.6

feedback to the survivability submodel where it can be applied to many types of aircraft. Only if the generic modified aircraft is better than the generic baseline aircraft should the modification be undertaken.

The test for aircraft modification feasibility is based on the forecasted mission survivability which is determined by considering both aircraft enhancement and threat enhancement.

7.3.1 Scenario Analysis Based on Aircraft Enhancement

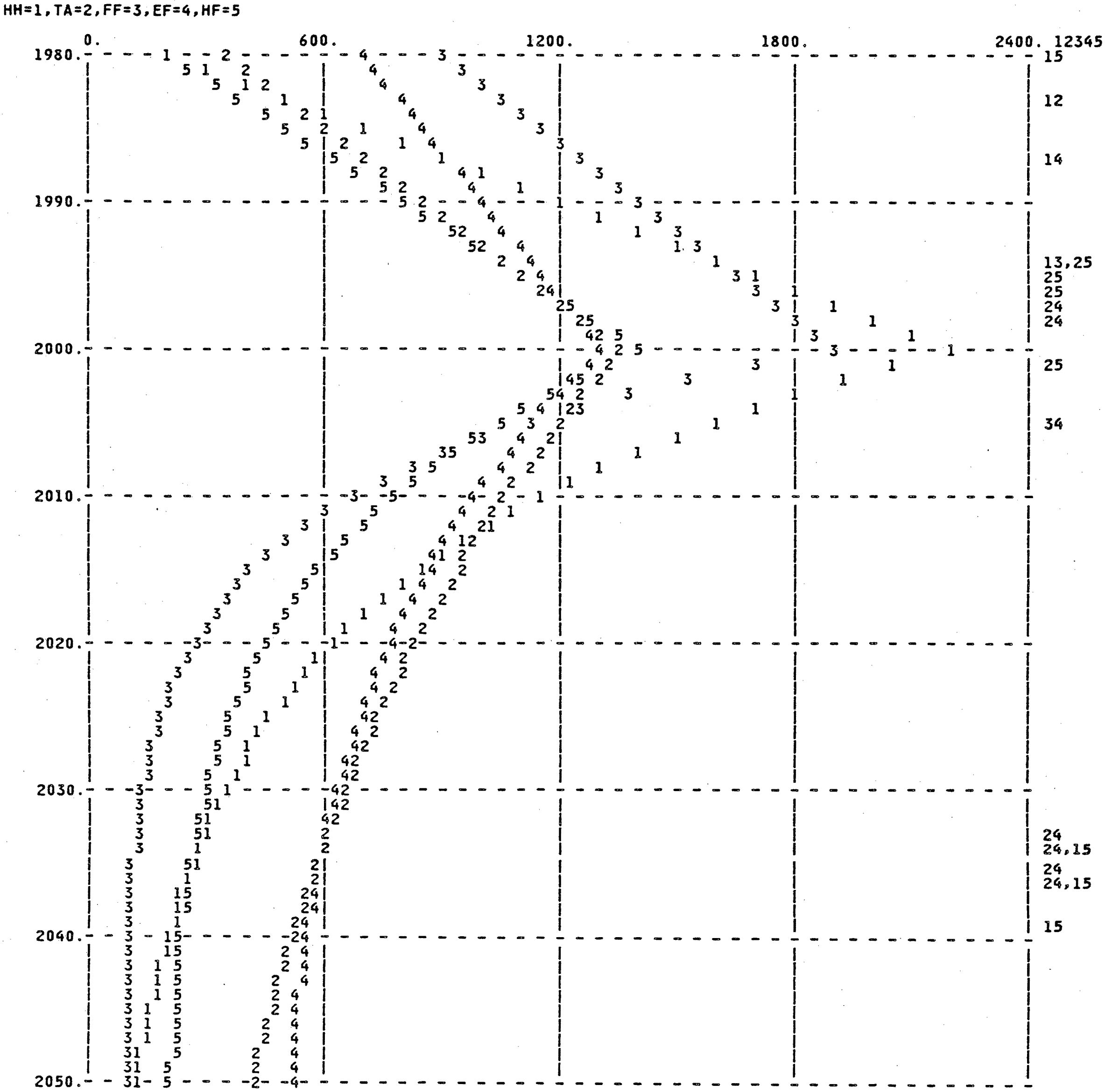
A scenario is an account of a context or situation created for use in a war game, a political or military exercise, or the analysis of a system of weapons, a strategy, or a military problem in a specific setting. A scenario describes the settings of a conflict situation and specifies the objectives of the concerned participants. It identifies the resources available to each side and identifies the appropriate temporal sequences for events; it provides the overall framework within which, in this research, tactical air power can be studied.

The following scenarios are developed to describe the effect of different methods of aircraft enhancement to the mission effectiveness. The aircraft enhancement is based on the delta survivability (DS), delta weight (DW), delta acquisition (DA) and delta maintenance (DM).

1. DS=-.0455, DW=-.0255, DA=-.0295, DM=-.016

   These deltas give the positive values of IPDTPL and DPLCC, the two measures of effectiveness to compare the baseline and the modified aircraft, and therefore the modification of U.S. aircraft is recommended and the mission survivability will be increased during the peacetime buildup. The results of this scenario are shown in Figs. 7.7, 7.8, 7.9, and 7.10. Figs. 7.7 and 7.8 depict that the number of U.S. aircraft are increased during the peacetime buildup from the year 1980 to 2000, and decreased when the war starts at the year 2000. After the war starts, the simulation time is changed from a yearly to a daily basis. A brief description of how to read the computer outputs are presented in Appendix B. In Figs. 7.7. and 7.8, it can be seen that after 50 days of war, the U.S. side still has aircraft while Figs. 7.9 and 7.10 show that the U.S.S.R. side has no more aircraft after 50 days of war. U.S tactical air forces beats U.S.S.R. tactical air forces after 45 days of war, and destroys 2.8 times as many targets as the other side does.

2. DS=-.0365, DW=-.018, DA=-.0215, DM=-.015



NOTE: HH - NUMBER OF APACHE AIRCRAFT (AH-64) TA - NUMBER OF THUNDERBOLT AIRCRAFT (A-10)
FF - NUMBER OF FALCON AIRCRAFT (F-16) EF - NUMBER OF EAGLE AIRCRAFT (F-15)
HF - NUMBER OF HORNET AIRCRAFT (F/A-18)

U.S AIRCRAFT - AIRCRAFT ENHANCEMENT SCENARIO
(DS=-.0455,DW=-.0255,DA=-.0295,DM=-.016)

Fig. 7.7

```
XF=X,XV=V,XA=A,XS=S,TF=F,HV=H,IA=I

        .0                     200.                     400.                     600.                     800. XVASFHI
   1980.X - - - - - - - -  H  - - - - - - - - - - - - - - F - - - - - - - - - - - - - - - - - - - - - - - - - XVAS,FI
        X                   H    |                        | F                      |                        | XVAS,FI
        X                    H   |                        |   IF                   |                        | XVAS
        X                      H |                        |    I F                 |                        | XVAS
        X                       H|                        |      I  F              |                        | XVAS
        X                        H                        |        I  F            |                        | XVAS
        X                        |H                       |          I  F          |                        | XVAS
        X                        | H                      |            I    F      |                        | XVAS
        X                        |   H                    |             I     F    |                        | XVAS
        X                        |    H                   |               I      F |                        | XVAS
   1990.- - - X - - - - - - - - - - -  H  - - - - - - - - - - - - - - - - - I - -  F  - - - - - - - - - - - - XVAS
        |           X            |      H                 |                    I   | F                      | XVAS
        |                  VX    |       H                |                      I |    F                   | VAS
        |                        VX        H              |                       I|      F                 | VAS
        |                        |     VX   H             |                        |I        F              | VAS
        |                        |           VX           |                        |  I        F            | VASH
        |                        |            H     V X   |                        |    I        F          | VAS
        |                        |             H          V X                      |      I          F      | VAS
        |                        |                H       |     V X                |       I           F    | VAS
        |                        |                 H      |           V X          |         I            F | VAS
   2000.- - - - - - - - - - - - - - - - - - - - - - H - - - - - - - - - - - V  -X-    - - - - -  I  - - - - - F VAS
        |                        |               H        |             VAX        |       I       F        | VS
        |                        |            H           |         VSX            |    I   F               | XA
        |                        |         H              |      VXA               | F                      | XS,FI
        |                        |       H                |  VXS A             F I |                        |
        |                        |     H                  VXS A         F     I    |                        |
        |                        |   H                 XVS| A      F      I        |                        |
        |                        |  H               XV S  A   F         I          |                        |
        |                        |H               X S   A F          I             |                        | XV
        |                       H|            XV  S   A   |       I                |                        | AF
   2010.- - - - - - - - - - -  H  - - - - -XV S  -FA - - - - - I - - - - - - - - - - - - - - - - - - - - - -
        |                     H  |        XV SF   A       |   I                    |                        | SF
        |                   H    |      XV S   A          |I                       |                        | SF
        |                  H     |    XV S   A           I|                        |                        | VF
        |                 H      |  X VS    A          I  |                        |                        | VF
        |                H       |X V S   A          I    |                        |                        |
        |              H         XFVS    A         I      |                        |                        | XF
        |             H         XV S    A         I       |                        |                        |
        |             H        XFV|S   A        I         |                        |                        |
        |            H       X VS|    A       I           |                        |                        | XF
   2020.- - - - - - H - -  -X-VS - -A- - - -I-  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - XF
        |           H     FX VS  | A      I               |                        |                        |
        |          H     FX VS   |A      I                |                        |                        |
        |         H     FX VS    A      I                 |                        |                        |
        |         H   F  XVS    A|     I                  |                        |                        |
        |        H    FX  V    A |    I                   |                        |                        | VS
        |        H   FX  VS   A  |  I                     |                        |                        |
        |        H  F XVS    A   | I                      |                        |                        |
        |       H  F X V    A    |I                       |                        |                        | VS
        |       H  F XV     A    I                        |                        |                        | VS
   2030.- - - -H- F XVS - A - -I- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
        |      H  F XV   A     I |                        |                        |                        | VS
        |      H  FXVS   A    I  |                        |                        |                        |
        |     H  F XV   A    I   |                        |                        |                        | VS
        |     H  F XV  A    I    |                        |                        |                        | VS
        |     H  FXV   A   I     |                        |                        |                        | VS
        |     H F XV  A    I     |                        |                        |                        | VS
        |     H F XV  A  I       |                        |                        |                        | XS
        |    H  F X  A  I        |                        |                        |                        | XVS
        |    H  FXV  A  I        |                        |                        |                        | VS
   2040.- - -H- FXV -A-I- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - XS
        |    H F X  A I          |                        |                        |                        | XVS
        |    H F X  A I          |                        |                        |                        | XVS
        |   H  FSX A I           |                        |                        |                        | XV
        |   H  FSX A I           |                        |                        |                        | XV
        |   H  FX  AI            |                        |                        |                        | XVS
        |   H  FX A I            |                        |                        |                        | XVS
        |   H  SX AI             |                        |                        |                        | XV,SF
        |   H  SX AI             |                        |                        |                        | XV,SF
        |   H  SXAI              |                        |                        |                        | XV,SF
   2050.- - H -SXAI - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - XV,SF

          NOTE: TF - NUMBER OF TOMCAT AIRCRAFT (F-14)      HV - NUMBER OF HARRIER AIRCRAFT (AV-8)
                IA - NUMBER OF INTRUDER AIRCRAFT (A-6)     XV - NUMBER OF VTOL FIGHTER MULTIMISSION
                XF - NUMBER OF ADVANCED TACTICAL FIGHTER  XS - NUMBER OF STEALTH STRIKE AIRCRAFT
                XA - NUMBER OF ADVANCED TACTICAL ATTACK AIRCRAFT
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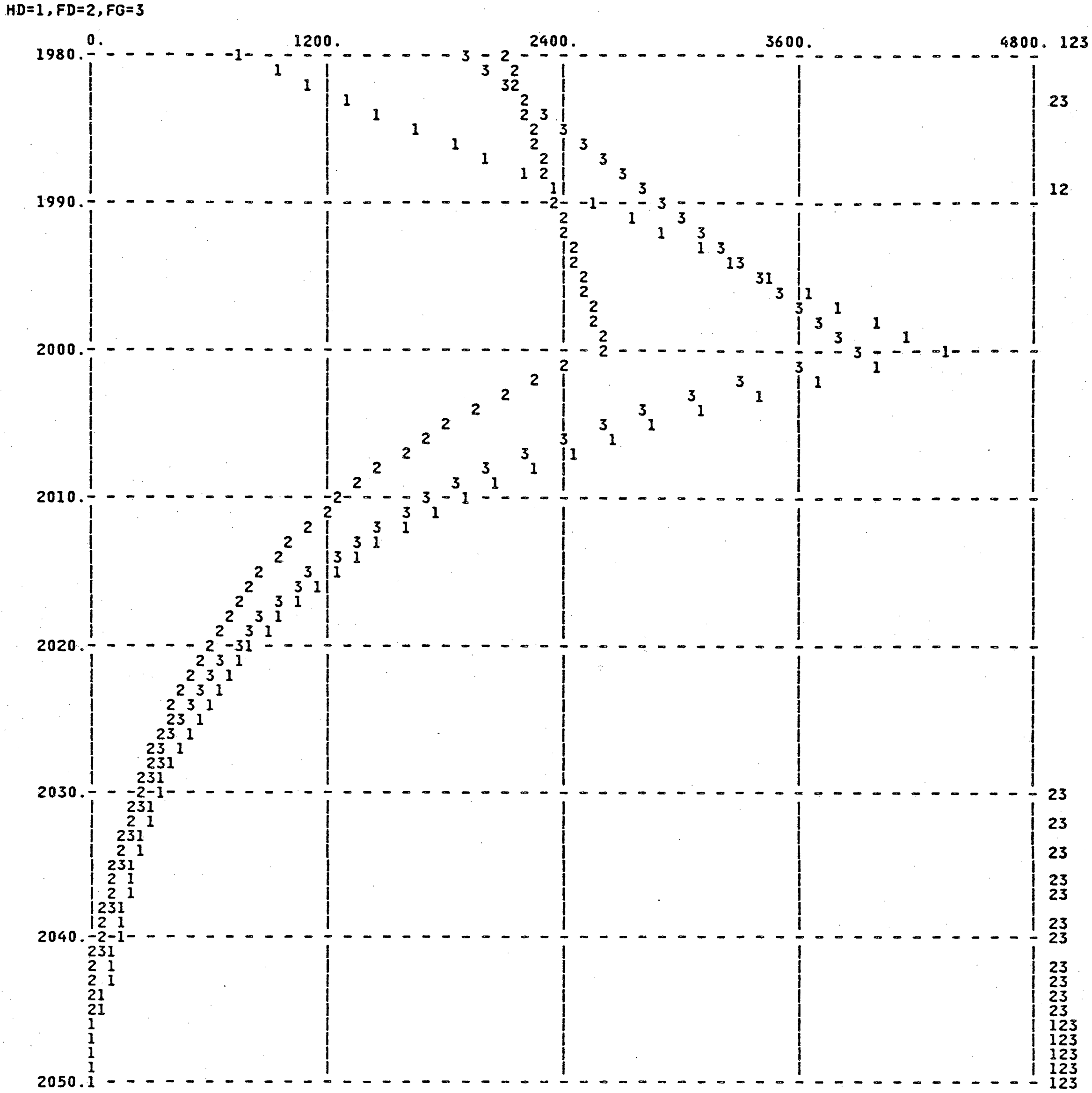
U.S AIRCRAFT - AIRCRAFT ENHANCEMENT SCENARIO
(DS=-.0455,DW=-.0255,DA=-.0295,DM=-.016)

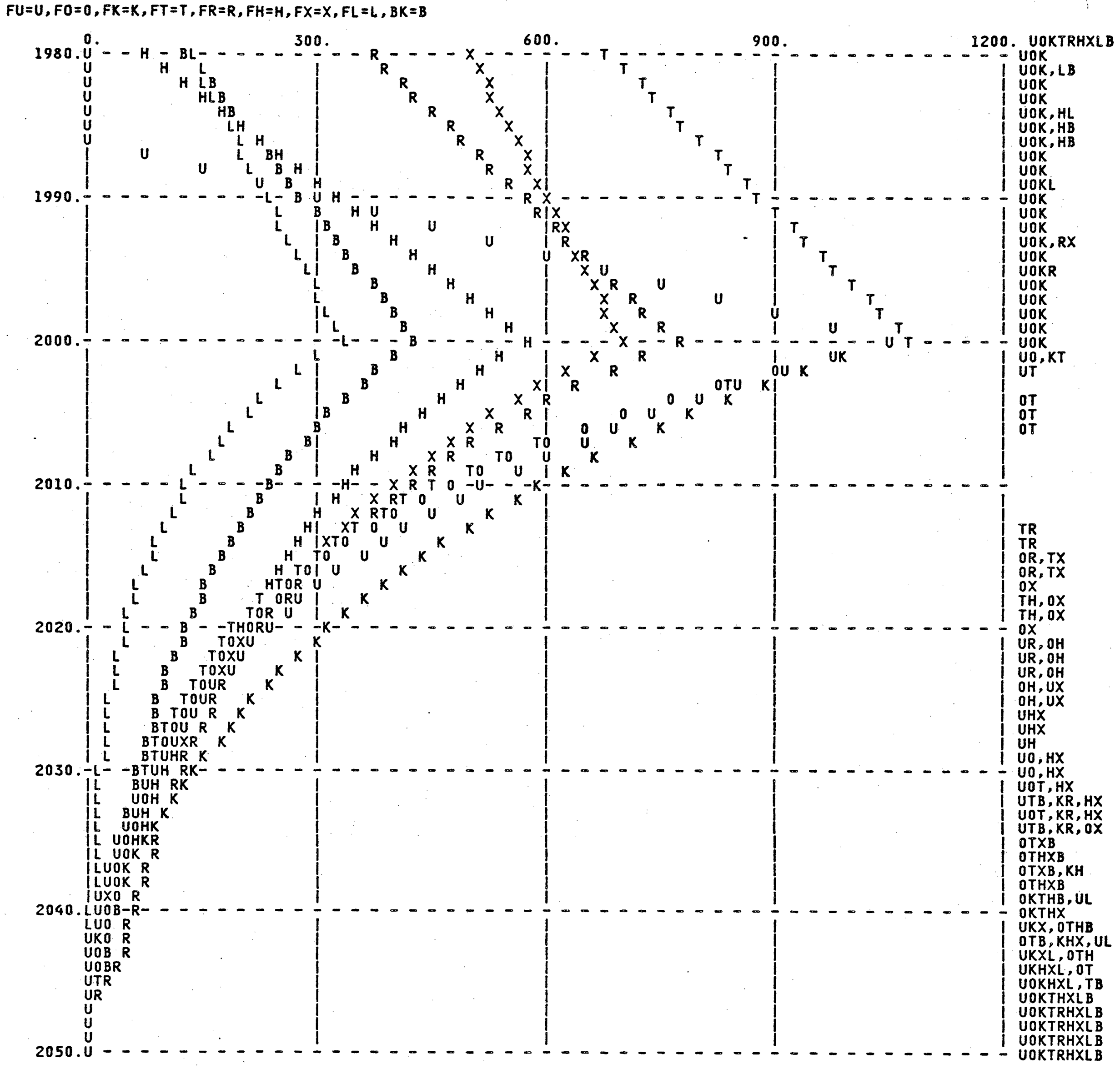
Fig. 7.8



NOTE: HD - NUMBER OF HIND AIRCRAFT (MI-24) FD - NUMBER OF FISHBED AIRCRAFT (MIG-21)
FG - NUMBER OF FLOGGER AIRCRAFT (MIG-23/MIG-27)

U.S.S.R. AIRCRAFT - AIRCRAFT ENHANCEMENT SCENARIO
(DS=-.0455,DW=-.0255,DA=-.0295,DM=-.016)

Fig. 7.9



NOTE:
FU - NUMBER OF FULCRUM AIRCRAFT (MIG-29)
FO - NUMBER OF FROGFOOT AIRCRAFT (SU-25)
FK - NUMBER OF FLANKER AIRCRAFT (SU-27)
FX - NUMBER OF FOXBAT AIRCRAFT (MIG-25)
BK - NUMBER OF BACKFIRE AIRCRAFT (TU-22M/TU-26)
FT - NUMBER OF FITTER AIRCRAFT (SU-17/SU-20/SU-22)
FR - NUMBER OF FENCER AIRCRAFT (SU-19/SU-24)
FH - NUMBER OF FOXHOUND AIRCRAFT (MIG-25M)
FL - NUMBER OF FIDDLER AIRCRAFT (TU-28P/TU-128)

U.S.S.R. AIRCRAFT - AIRCRAFT ENHANCEMENT SCENARIO
(DS=-.0455,DW=-.0255,DA=-.0295,DM=-.016)

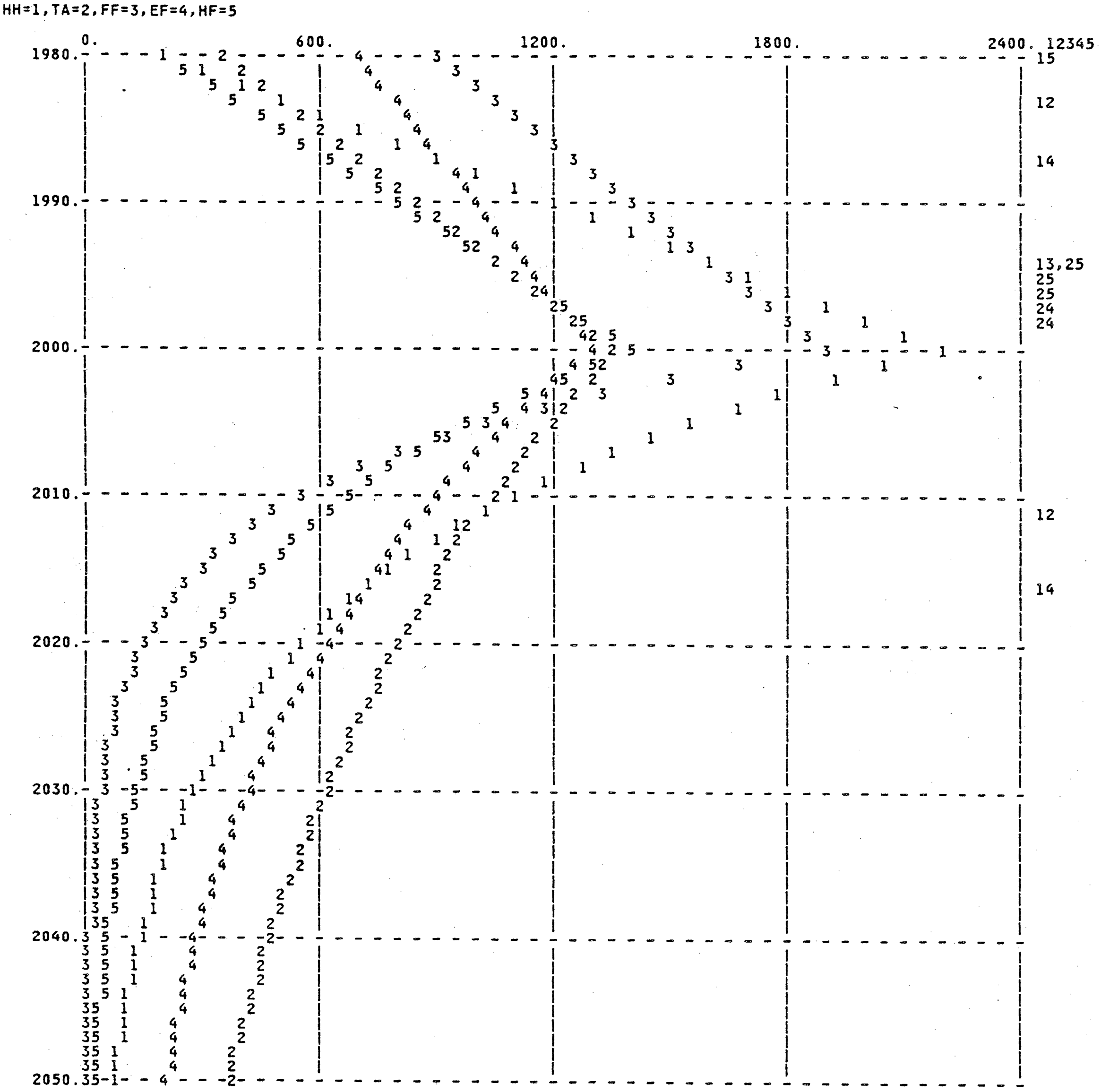
Fig. 7.10

This method of aircraft enhancement is recommended since the IPDTPL and DPLCC are greater than zero. From the computer results which are presented in Figs. 7.11, 7.12, 7.13, and 7.14, it can be seen that this aircraft enhancement is not as effective as the one which is described in the previous scenario; the U.S. side has less aircraft after 50 days of war. However, the U.S. air power is still be able to defeat the U.S.S.R. air power and destroys 2.6 times as many targets as the other side does.

7.3.2 Scenario Analysis Based on Threat Enhancement

The following scenarios are developed to describe the effect of threat enhancement on mission survivability as represented by the parameters, the Survivability of generic Baseline aircraft in base year (SB) and the Survivability of generic Baseline aircraft in Forecast year (SBF).

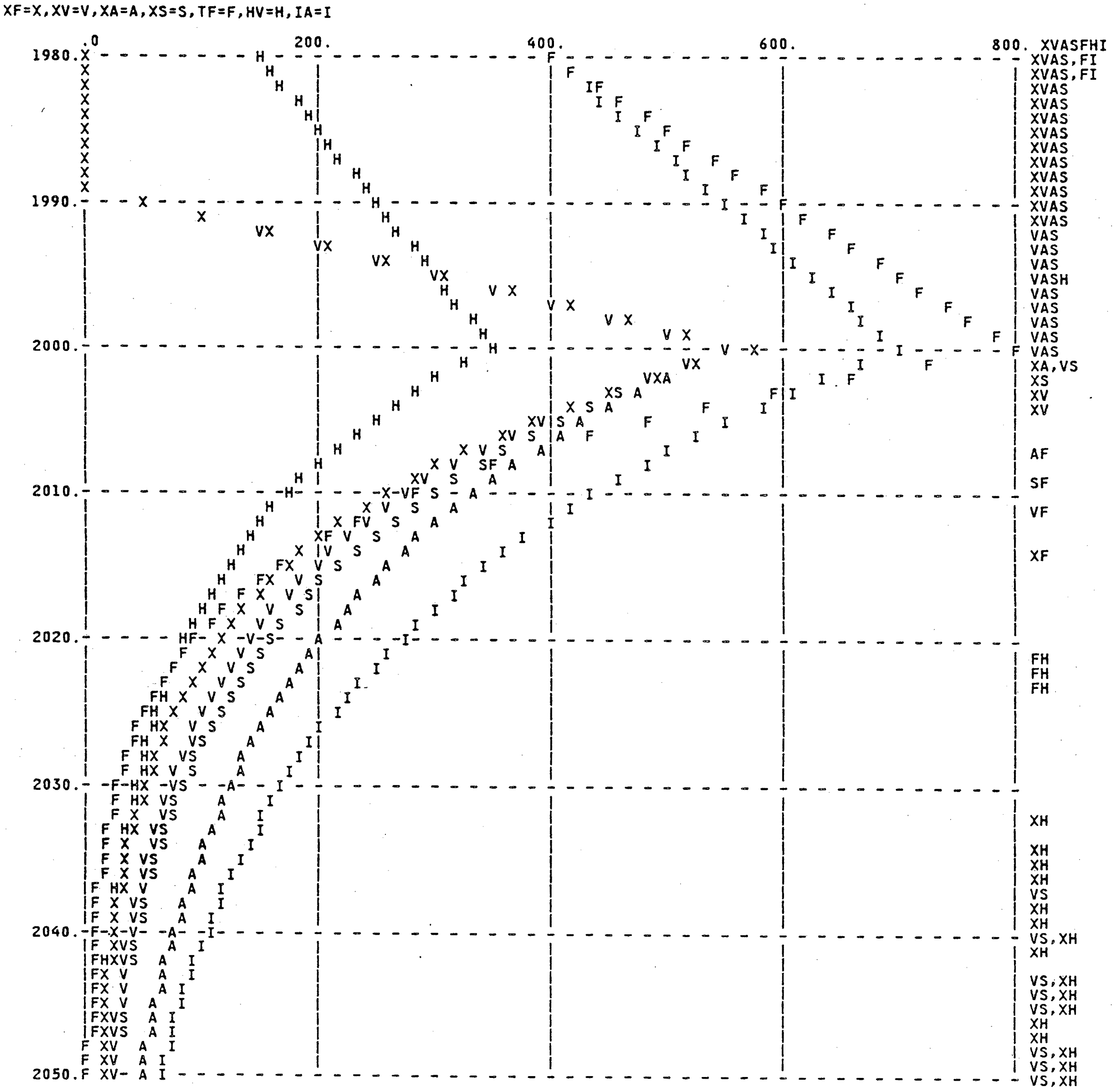
The first scenario in subsection 7.3.1 is chosen to be the proposed aircraft modification method for the U.S. aircraft in these scenarios. If there is no threat enhancement during the peacetime buildup, the survivability of baseline aircraft is the same for base and forecasted year (SBF=SB=.95) and this condition is the same as the first scenario which is described in subsection 7.3.1.



NOTE: HH - NUMBER OF APACHE AIRCRAFT (AH-64) TA - NUMBER OF THUNDERBOLT AIRCRAFT (A-10)
FF - NUMBER OF FALCON AIRCRAFT (F-16) EF - NUMBER OF EAGLE AIRCRAFT (F-15)
HF - NUMBER OF HORNET AIRCRAFT (F/A-18)

U.S. AIRCRAFT - AIRCRAFT ENHANCEMENT SCENARIO
(DS=-.0365,DW=-.018,DA=-.0215,DM=-.015)

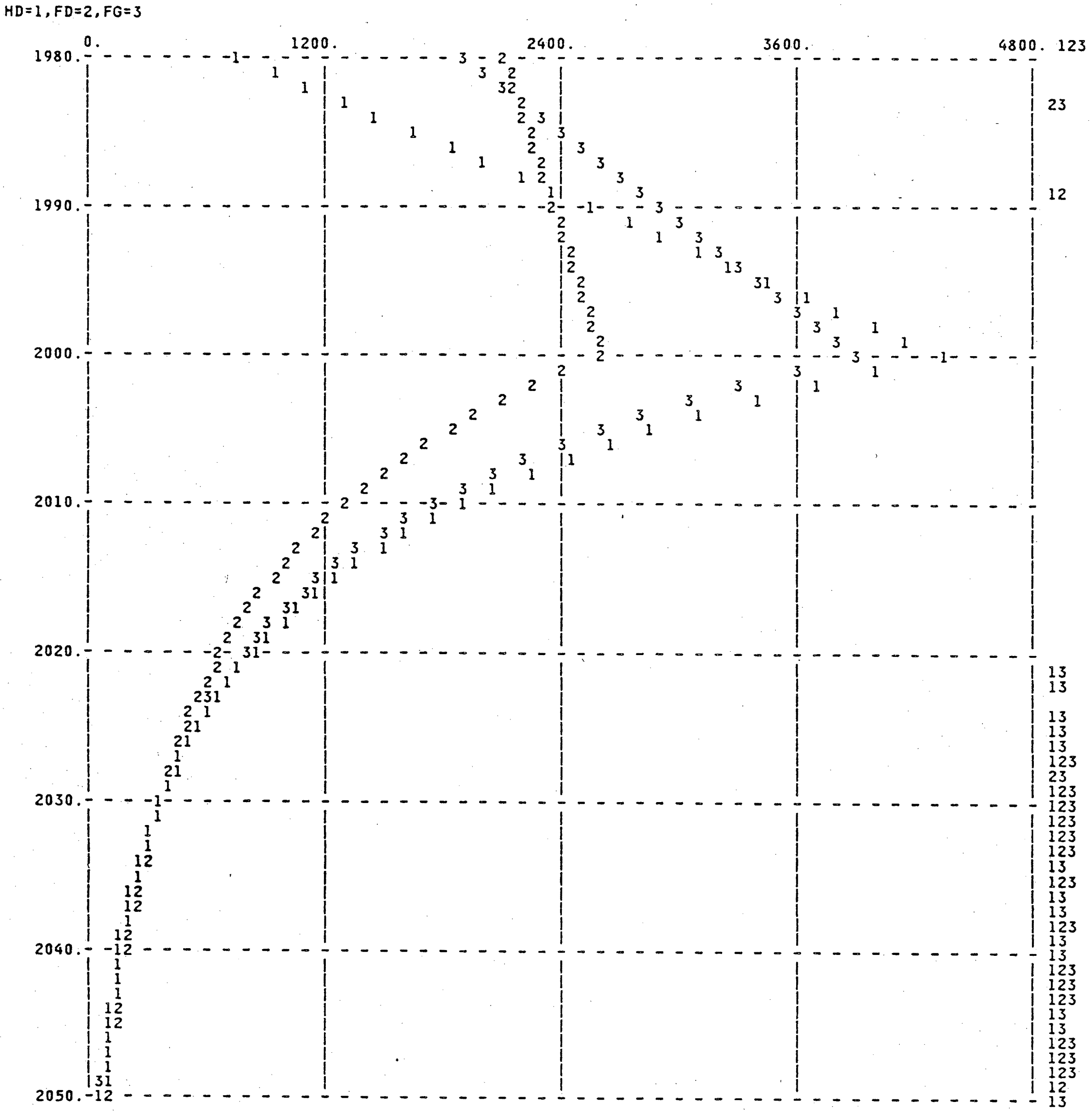
Fig. 7.11



NOTE: TF - NUMBER OF TOMCAT AIRCRAFT (F-14)
IA - NUMBER OF INTRUDER AIRCRAFT (A-6)
XF - NUMBER OF ADVANCED TACTICAL FIGHTER
XA - NUMBER OF ADVANCED TACTICAL ATTACK AIRCRAFT
HV - NUMBER OF HARRIER AIRCRAFT (AV-8)
XV - NUMBER OF VTOL FIGHTER MULTIMISSION
XS - NUMBER OF STEALTH STRIKE AIRCRAFT

U.S. AIRCRAFT - AIRCRAFT ENHANCEMENT SCENARIO
(DS=-.0365,DW=-.018,DA=-.0215,DM=-.015)

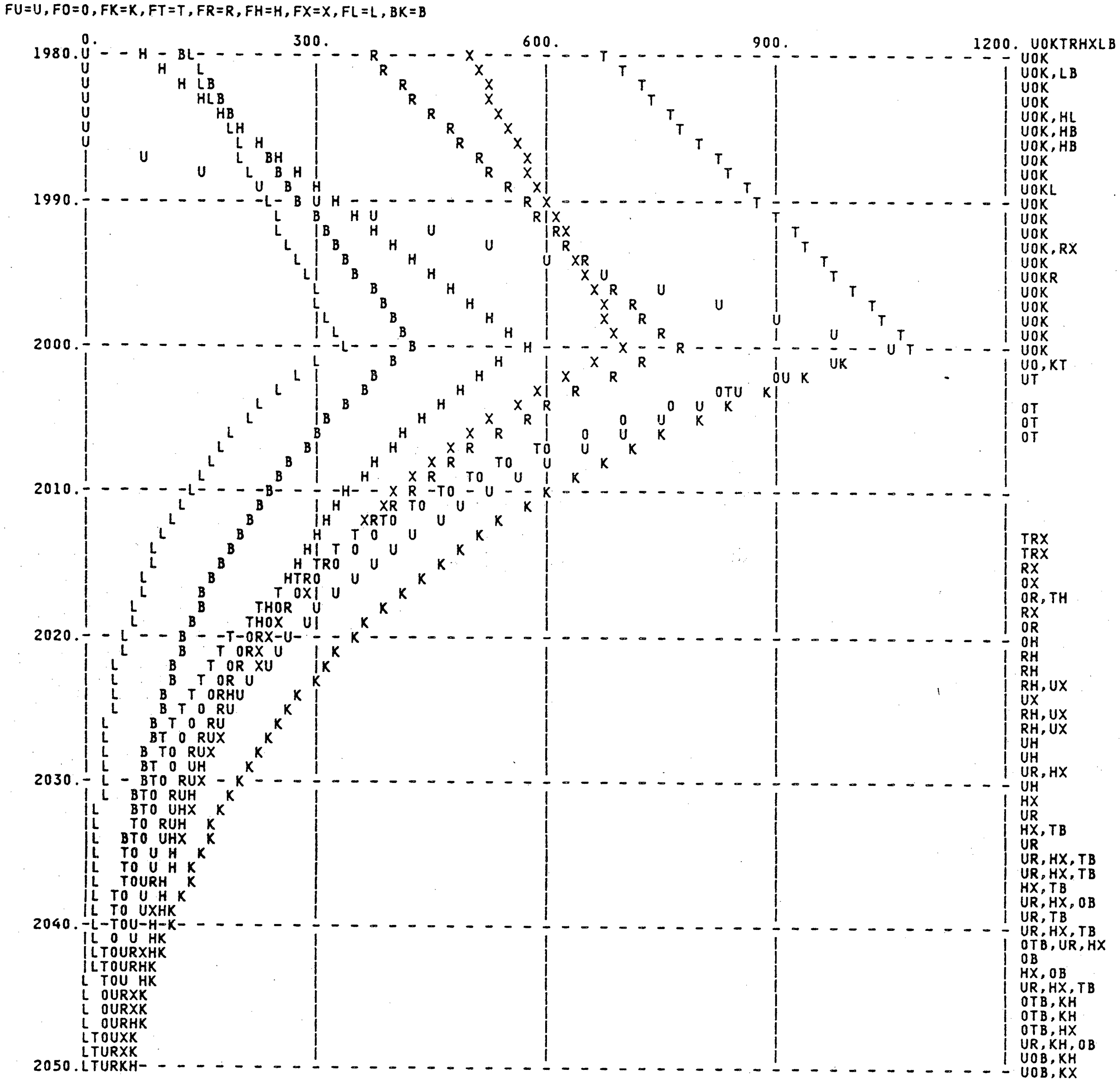
Fig. 7.12



NOTE: HD - NUMBER OF HIND AIRCRAFT (MI-24) FD - NUMBER OF FISHBED AIRCRAFT (MIG-21)
FG - NUMBER OF FLOGGER AIRCRAFT (MIG-23/MIG-27)

U.S.S.R. AIRCRAFT - AIRCRAFT ENHANCEMENT SCENARIO
(DS=-.0365,DW=-.018,DA=-.0215,DM=-.015)

Fig. 7.13



NOTE:
FU - NUMBER OF FULCRUM AIRCRAFT (MIG-29)
FO - NUMBER OF FROGFOOT AIRCRAFT (SU-25)
FK - NUMBER OF FLANKER AIRCRAFT (SU-27)
FX - NUMBER OF FOXBAT AIRCRAFT (MIG-25)
BK - NUMBER OF BACKFIRE AIRCRAFT (TU-22M/TU-26)
FT - NUMBER OF FITTER AIRCRAFT (SU-17/SU-20/SU-22)
FR - NUMBER OF FENCER AIRCRAFT (SU-19/SU-24)
FH - NUMBER OF FOXHOUND AIRCRAFT (MIG-25M)
FL - NUMBER OF FIDDLER AIRCRAFT (TU-28P/TU-128)

U.S.S.R. AIRCRAFT - AIRCRAFT ENHANCEMENT SCENARIO
(DS=-.0365,DW=-.018,DA=-.0215,DM=-.015)

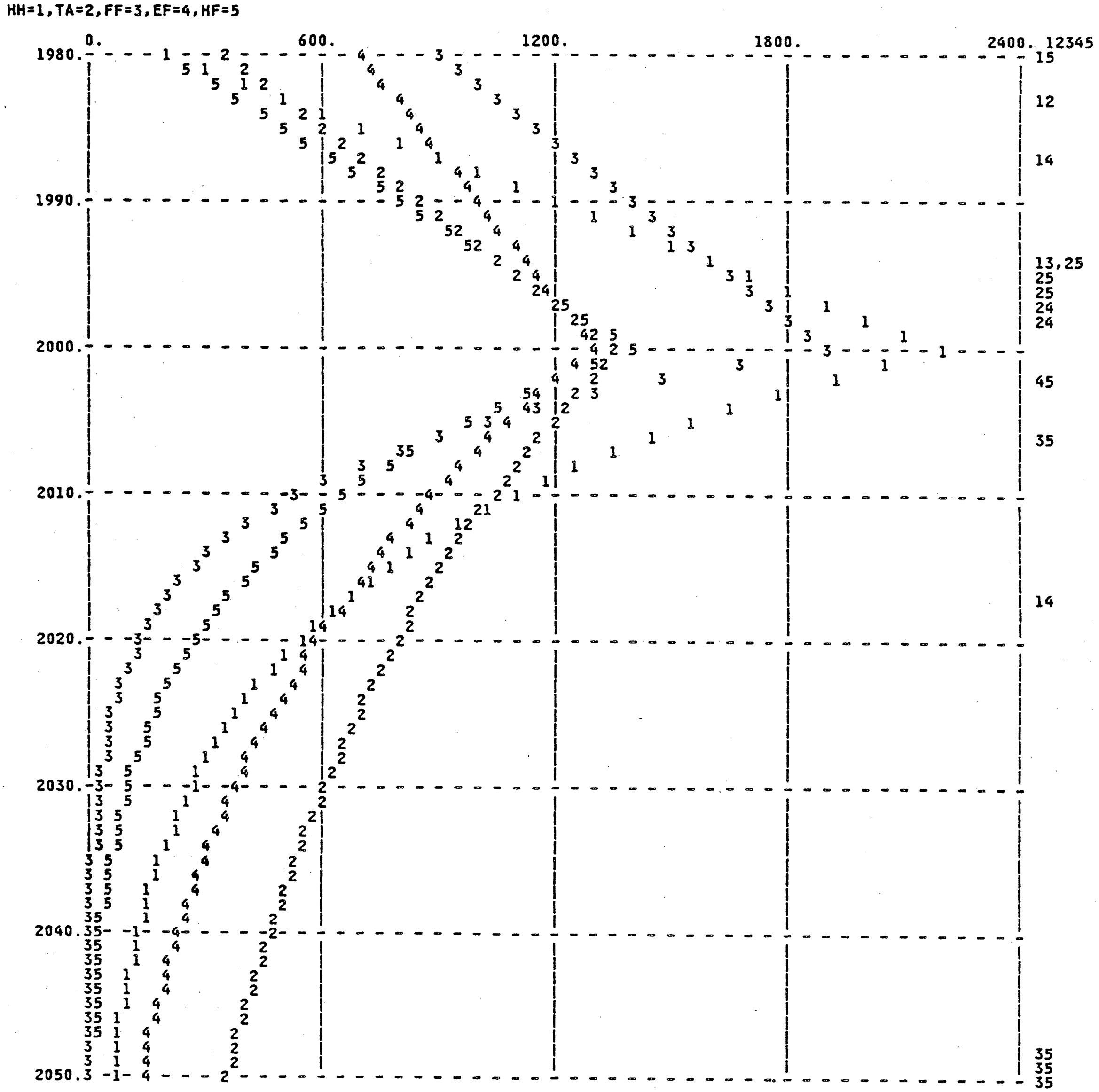
Fig. 7.14

1. SBF=.94 and SB=.95

   In this scenario, the enemy threat is being improved during the peacetime buildup, therefore the SBF is less than the SB. Although the enemy threat is enhanced, the U.S. modified aircraft are still more superior than the U.S.S.R. aircraft. In this case, the aircraft enhancement is more effective compared with the threat enhancement. From the results in Figs. 7.15 ,7.16, 7.17, and 7.18, it can be seen that after a 50 days war, the U.S. side has more aircraft compared with the U.S.S.R. side. Figs. 7.15 and 7.16 show that the fighter aircraft F-15 and the attack aircraft A-10 seems to be the most superior compared with the other aircraft. The U.S. can destroy land targets 2.5 times as many as the U.S.S.R. does during the 50 days war.

2. SBF=.93 and SB=.95

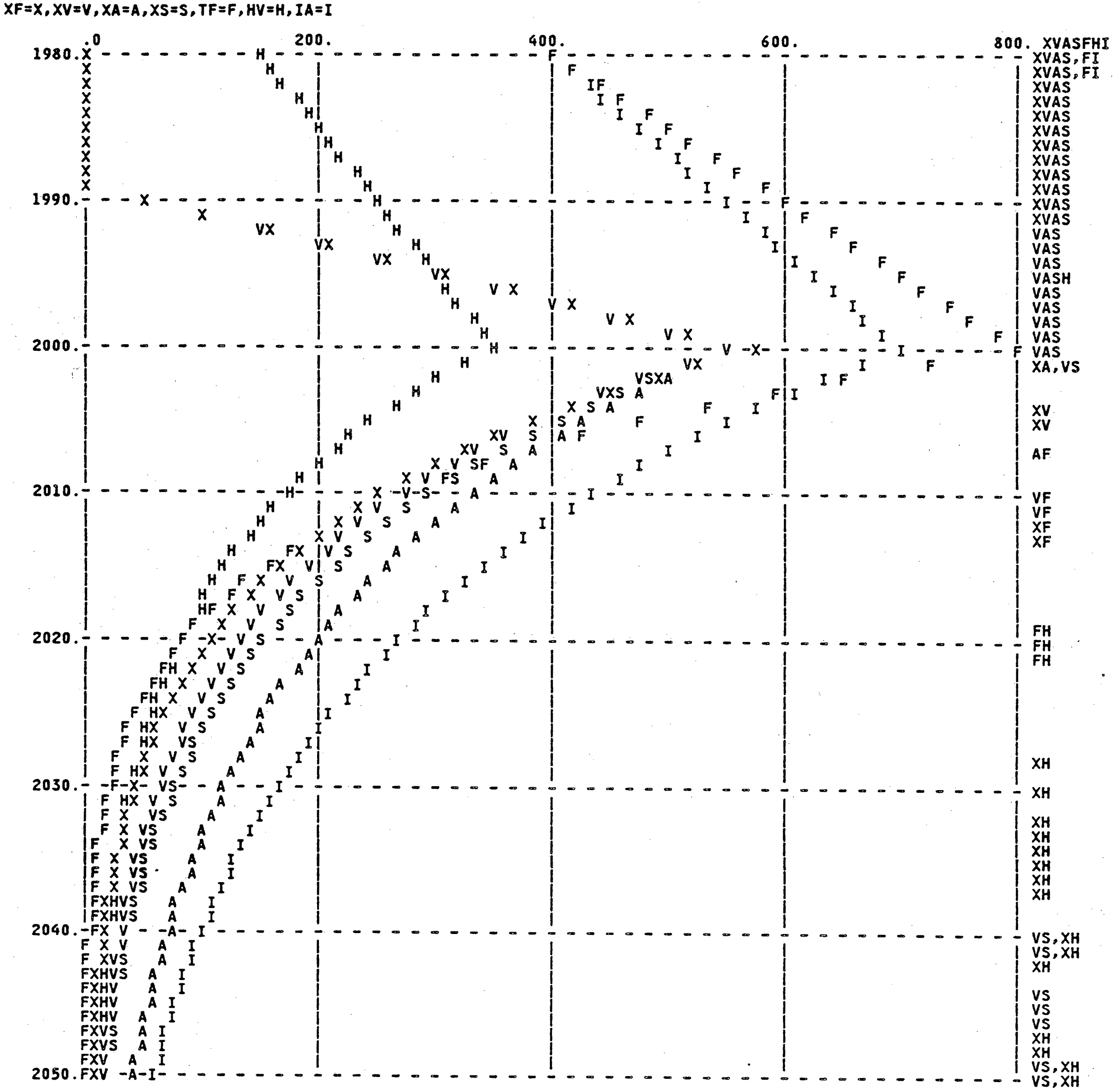
   In this scenario, the enemy's threat enhancement is more effective than in the previous scenario. It is considered that the SBF is .93. In this case, the modification of the aircraft seems to be neutralized by the enhancement of the enemy's threat. The results of this scenario are presented in Figs. 7.19, 7.20, 7.21 and 7.22. Figs 7.15 and 7.16 show that the U.S.



NOTE: HH - NUMBER OF APACHE AIRCRAFT (AH-64) TA - NUMBER OF THUNDERBOLT AIRCRAFT (A-10)
FF - NUMBER OF FALCON AIRCRAFT (F-16) EF - NUMBER OF EAGLE AIRCRAFT (F-15)
HF - NUMBER OF HORNET AIRCRAFT (F/A-18)

U.S. AIRCRAFT - THREAT ENHANCEMENT SCENARIO
(SBF=.94, SB=.95)

Fig. 7.15



NOTE: TF - NUMBER OF TOMCAT AIRCRAFT (F-14)
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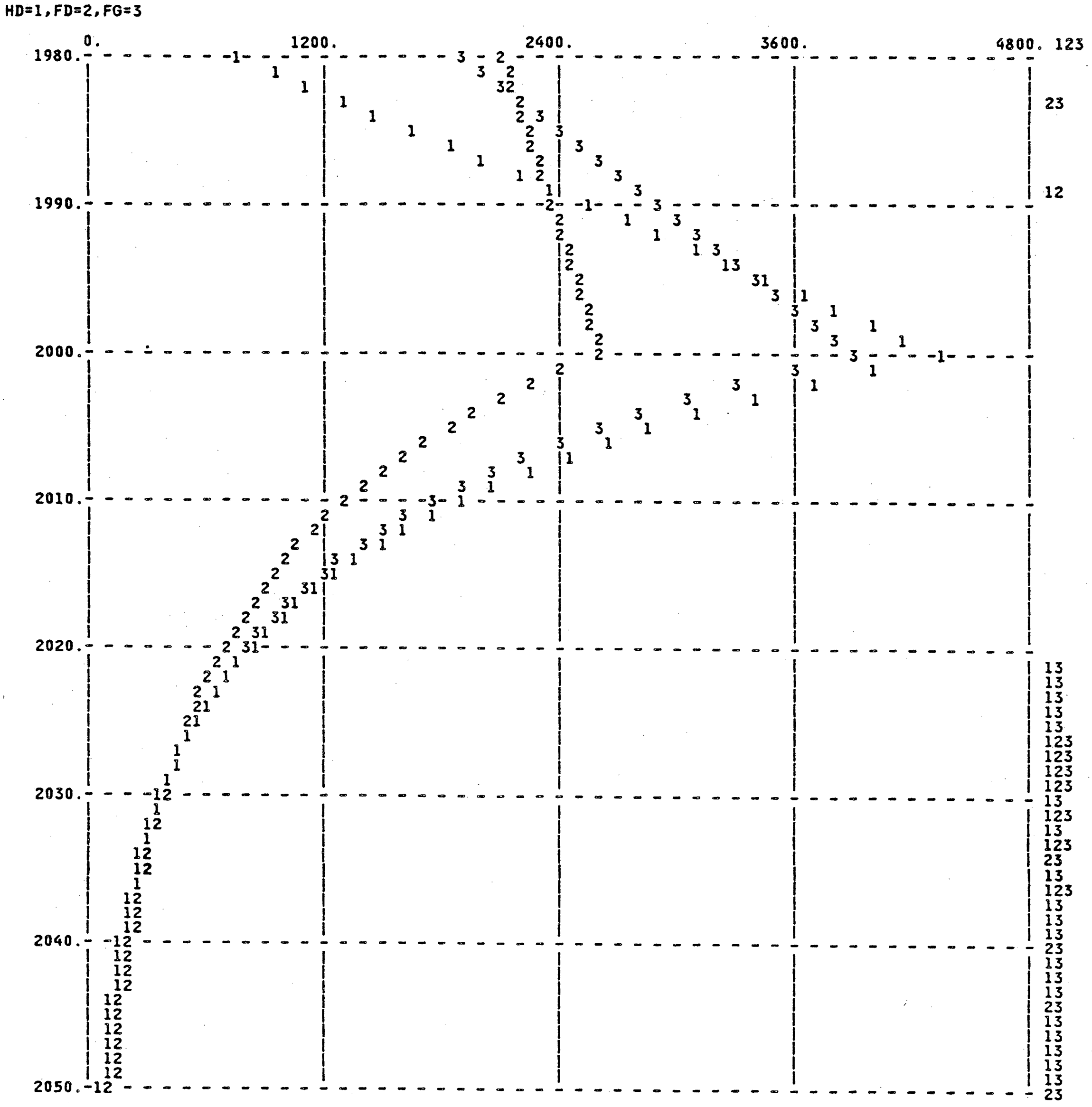
XF - NUMBER OF ADVANCED TACTICAL FIGHTER
XA - NUMBER OF ADVANCED TACTICAL ATTACK AIRCRAFT
HV - NUMBER OF HARRIER AIRCRAFT (AV-8)
XV - NUMBER OF VTOL FIGHTER MULTIMISSION
XS - NUMBER OF STEALTH STRIKE AIRCRAFT

U.S. AIRCRAFT - THREAT ENHANCEMENT SCENARIO
(SBF=.94, SB=.95)

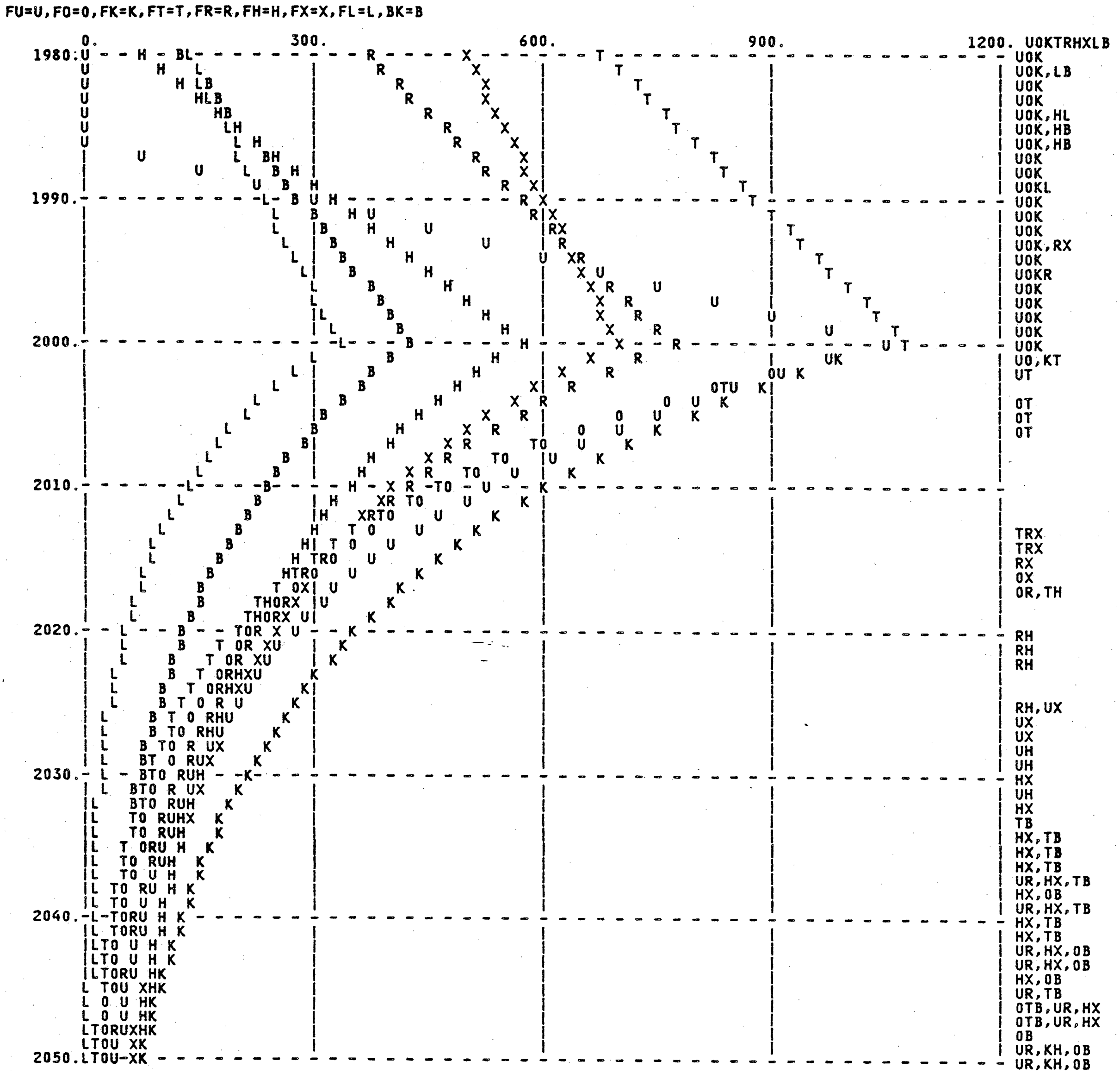
Fig. 7.16



NOTE: HD - NUMBER OF HIND AIRCRAFT (MI-24) FD - NUMBER OF FISHBED AIRCRAFT (MIG-21)
FG - NUMBER OF FLOGGER AIRCRAFT (MIG-23/MIG-27)

U.S.S.R. AIRCRAFT - THREAT ENHANCEMENT SCENARIO
(SBF=.94, SB=.95)

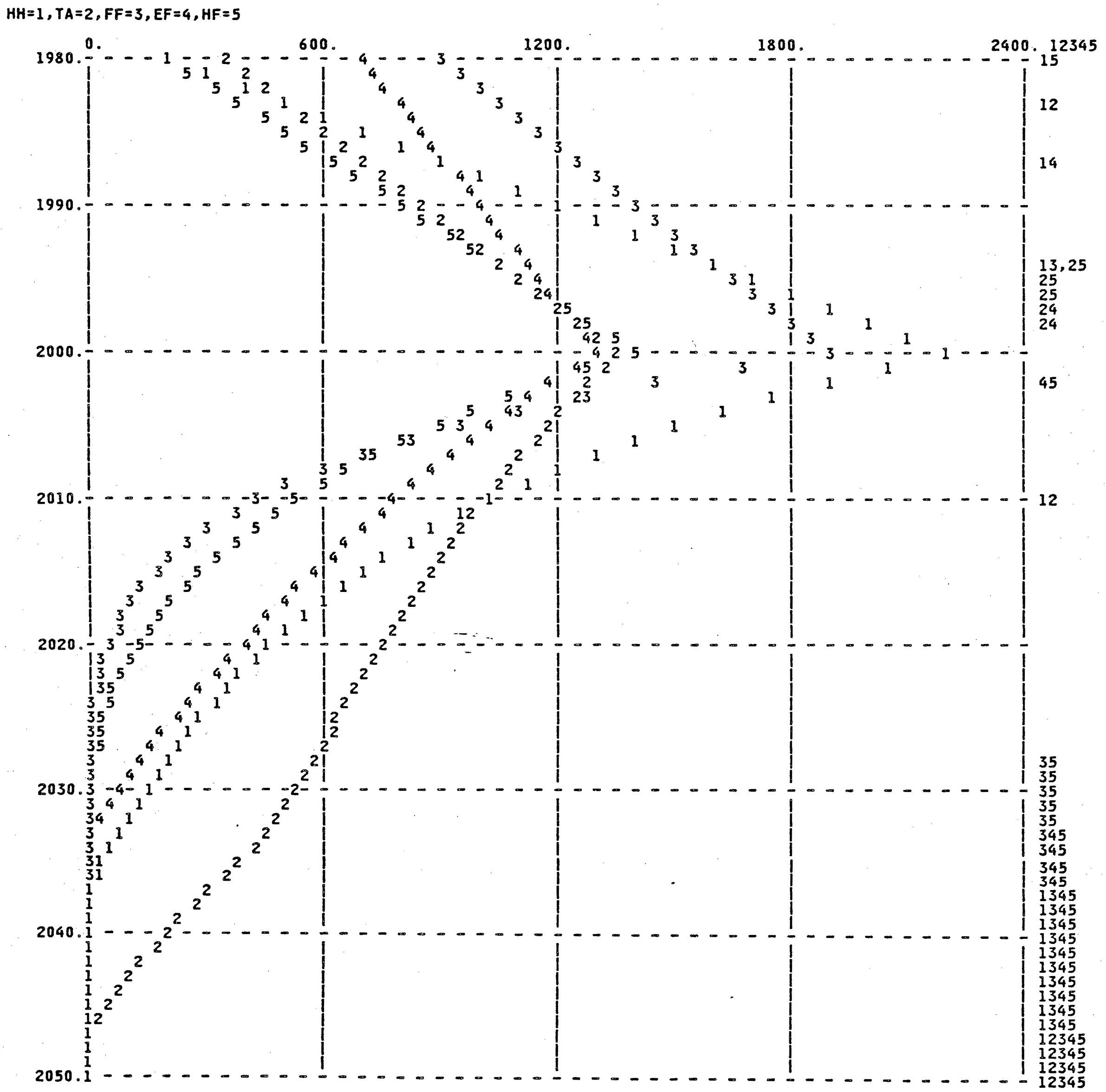
Fig. 7.17



NOTE:
FU - NUMBER OF FULCRUM AIRCRAFT (MIG-29)
FO - NUMBER OF FROGFOOT AIRCRAFT (SU-25)
FK - NUMBER OF FLANKER AIRCRAFT (SU-27)
FX - NUMBER OF FOXBAT AIRCRAFT (MIG-25)
BK - NUMBER OF BACKFIRE AIRCRAFT (TU-22M/TU-26)
FT - NUMBER OF FITTER AIRCRAFT (SU-17/SU-20/SU-22)
FR - NUMBER OF FENCER AIRCRAFT (SU-19/SU-24)
FH - NUMBER OF FOXHOUND AIRCRAFT (MIG-25M)
FL - NUMBER OF FIDDLER AIRCRAFT (TU-28P/TU-128)

U.S.S.R. AIRCRAFT - THREAT ENHANCEMENT SCENARIO
(SBF=.94, SB=.95)

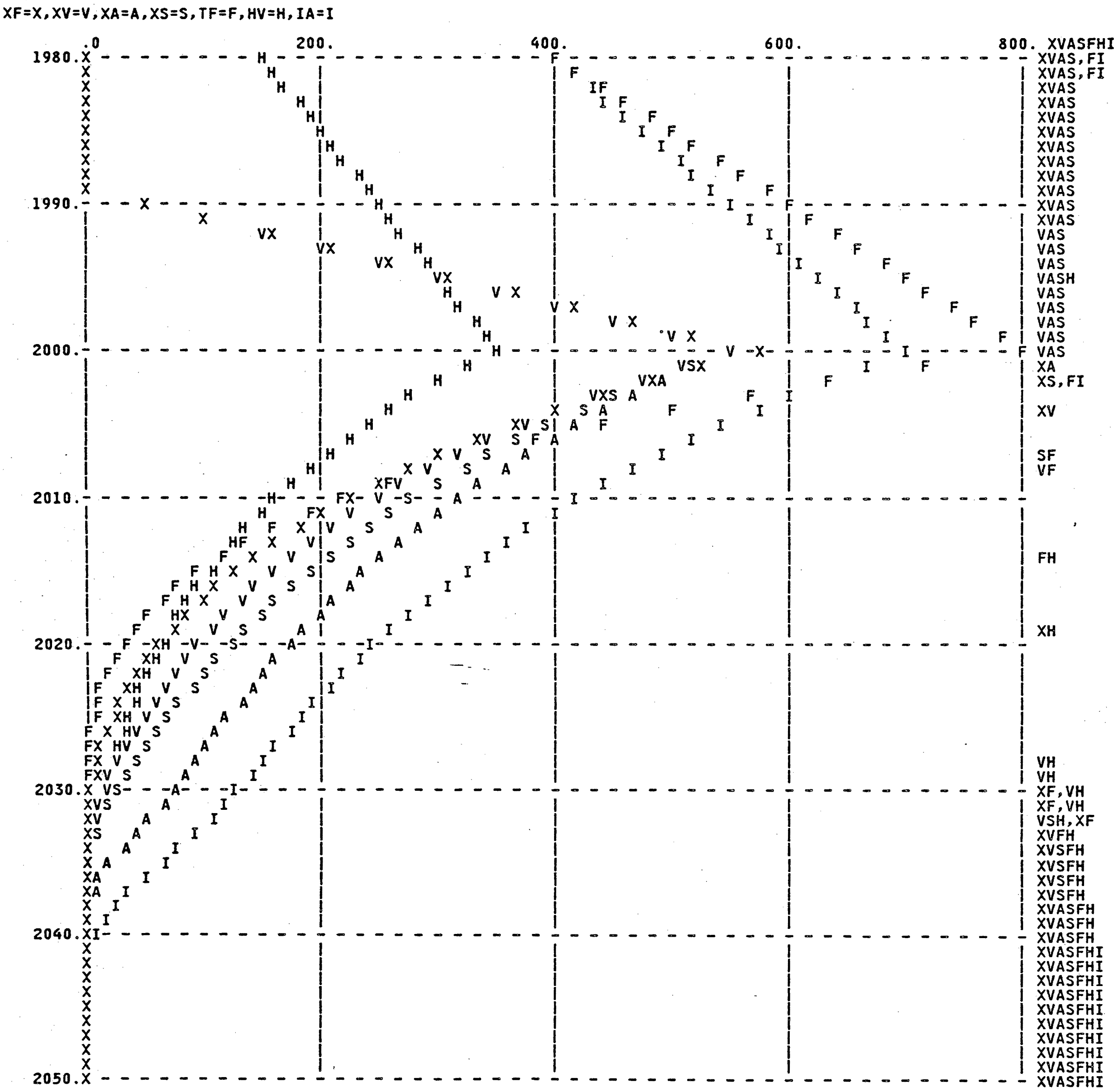
Fig. 7.18



NOTE: HH - NUMBER OF APACHE AIRCRAFT (AH-64) TA - NUMBER OF THUNDERBOLT AIRCRAFT (A-10)
FF - NUMBER OF FALCON AIRCRAFT (F-16) EF - NUMBER OF EAGLE AIRCRAFT (F-15)
HF - NUMBER OF HORNET AIRCRAFT (F/A-18)

U.S. AIRCRAFT - THREAT ENHANCEMENT SCENARIO
(SBF=.93, SB=.95)

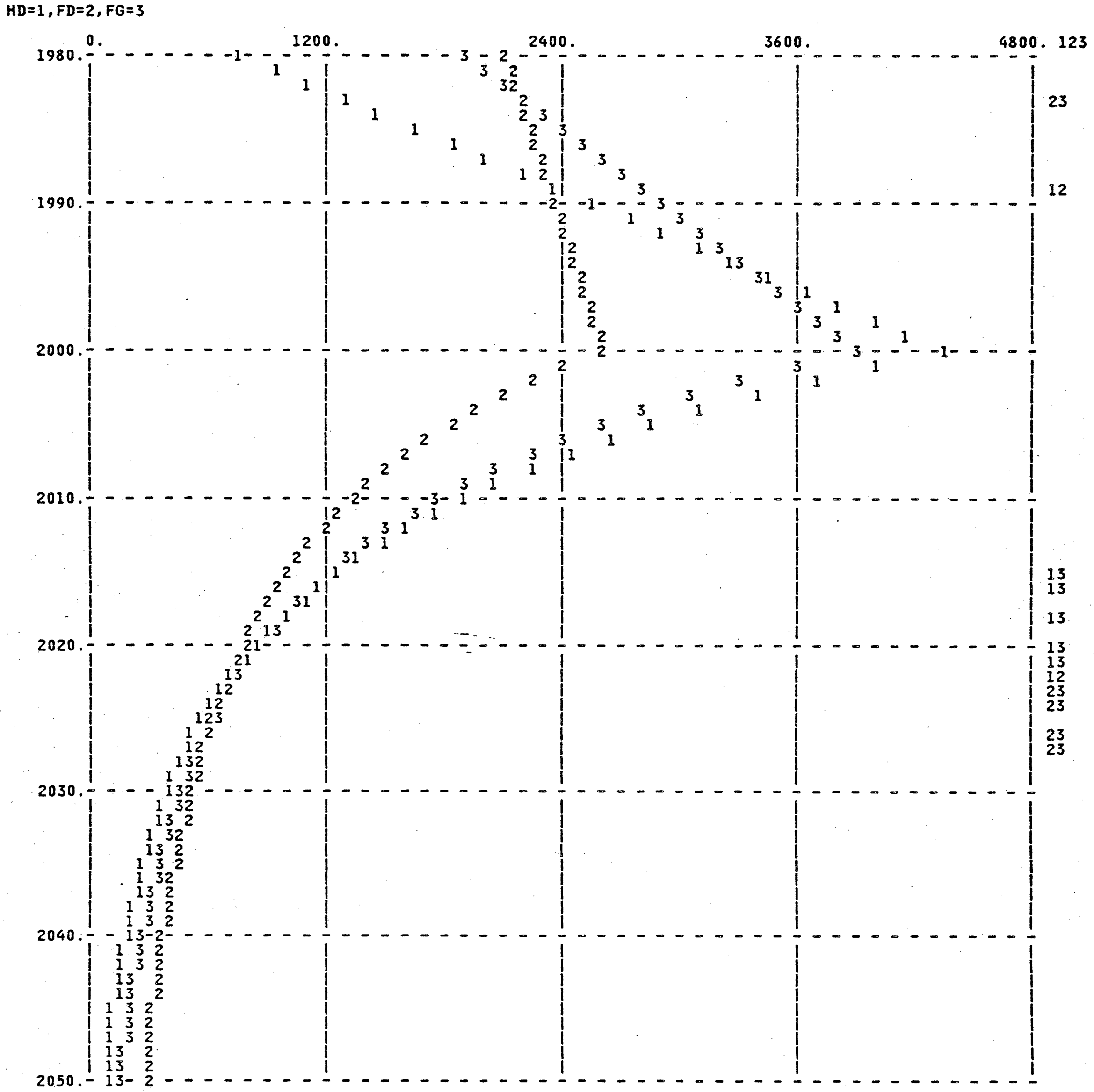
Fig. 7.19



NOTE: TF - NUMBER OF TOMCAT AIRCRAFT (F-14) HV - NUMBER OF HARRIER AIRCRAFT (AV-8)
IA - NUMBER OF INTRUDER AIRCRAFT (A-6) XV - NUMBER OF VTOL FIGHTER MULTIMISSION
XF - NUMBER OF ADVANCED TACTICAL FIGHTER XS - NUMBER OF STEALTH STRIKE AIRCRAFT
XA - NUMBER OF ADVANCED TACTICAL ATTACK AIRCRAFT

U.S. AIRCRAFT - THREAT ENHANCEMENT SCENARIO
(SBF=.93, SB=.95)

Fig. 7.20

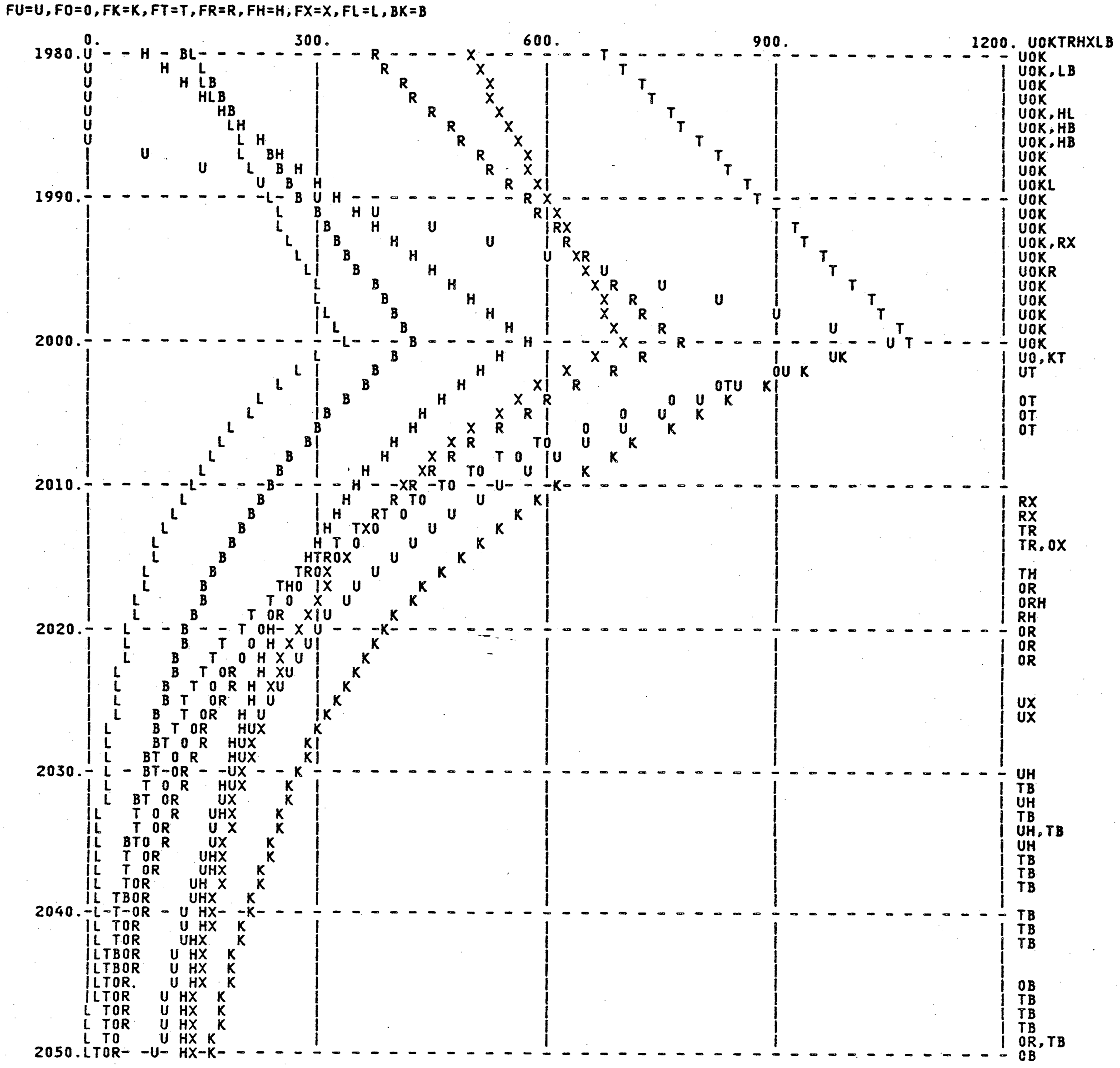


NOTE: HD - NUMBER OF HIND AIRCRAFT (MI-24) FD - NUMBER OF FISHBED AIRCRAFT (MIG-21)
FG - NUMBER OF FLOGGER AIRCRAFT (MIG-23/MIG-27)

U.S.S.R. AIRCRAFT - THREAT ENHANCEMENT SCENARIO

(SBF=.93, SB=.95)

Fig. 7.21



NOTE:
FU - NUMBER OF FULCRUM AIRCRAFT (MIG-29)
FO - NUMBER OF FROGFOOT AIRCRAFT (SU-25)
FK - NUMBER OF FLANKER AIRCRAFT (SU-27)
FX - NUMBER OF FOXBAT AIRCRAFT (MIG-25)
BK - NUMBER OF BACKFIRE AIRCRAFT (TU-22M/TU-26)
FT - NUMBER OF FITTER AIRCRAFT (SU-17/SU-20/SU-22)
FR - NUMBER OF FENCER AIRCRAFT (SU-19/SU-24)
FH - NUMBER OF FOXHOUND AIRCRAFT (MIG-25M)
FL - NUMBER OF FIDDLER AIRCRAFT (TU-28P/TU-128)

U.S.S.R. AIRCRAFT -THREAT ENHANCEMENT SCENARIO
(SBF=.93, SB=.95)

Fig. 7.22

air power is dominated by the U.S.S.R. air power after 40 days of war. The U.S. can destroy land targets at twice the rate of the U.S.S.R., but it must be remembered that the U.S.S.R. has more tanks than the U.S. that have to be destroyed.

7.3.3 Scenario Analysis Based on Availability

The following scenarios describe the effects of availability to the mission effectiveness. Availability or readiness influences effectiveness because the more likely the aircraft is available to be sent to the mission, the more likely the target will be killed.

1. U.S. Aircraft Availability is .6

   In this scenario, the enhancement method in subsection 7.3.1 is also utilized and the availability of U.S. aircraft is increased from 0.5 to 0.6. There is no threat consideration in this scenario. By doing this, the U.S. can destroy all the Soviet's aircraft at time=40 (compared with time=45 when the availability is 0.5) and the cumulative targets destroyed is 3 times the number of the targets destroyed by the U.S.S.R.

2. Availability=.67

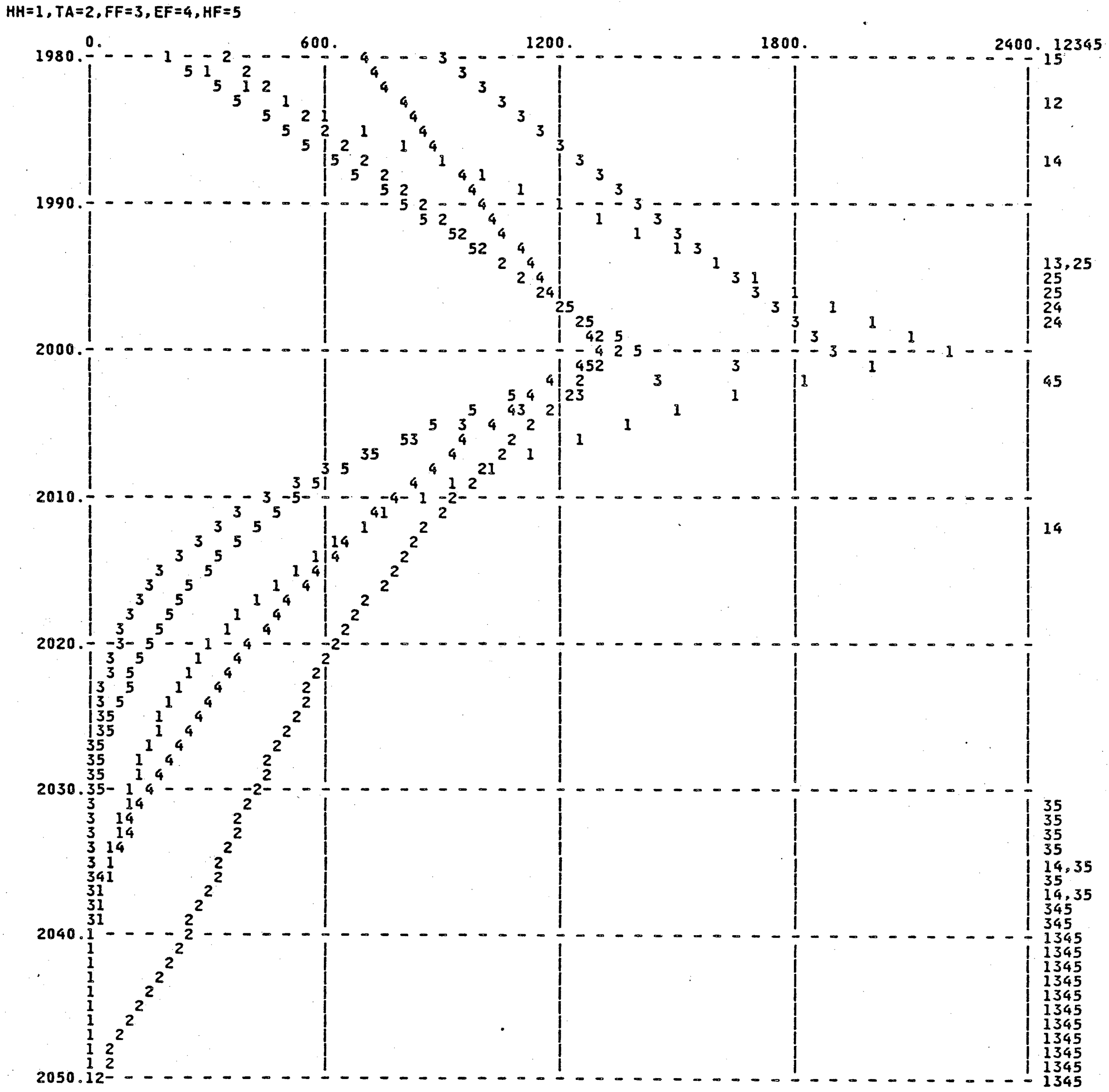
Increasing the availability of U.S. aircraft to 0.67 leads to a higher mission effectiveness. The U.S. air power can destroy all of the U.S.S.R. aircraft within 36 days of war and in the same time the U.S. aircraft can destroy targets 3.4 times the number destroyed by the U.S.S.R. aircraft.

In the following scenarios, the threat enhancement is also being considered to counter the increase in availability. These scenarios therefore will show the effect of availability and threat enhancement to the mission effectiveness of each sides.

3. Availability=.67 and SBF=.93

   In this scenario, the availability of U.S. aircraft is .67 and the SBF=.93 is selected. Although the U.S. air power increases its availability, the enhancement of U.S.S.R.'s threat still can overcome the strength of the U.S. air power and the U.S.S.R can destroy all the U.S. aircraft. The results of this scenario are presented in Figs. 7.23, 7.24, 7.25, and 7.26, which show that after 50 days of war the U.S. lost all of the aircraft.

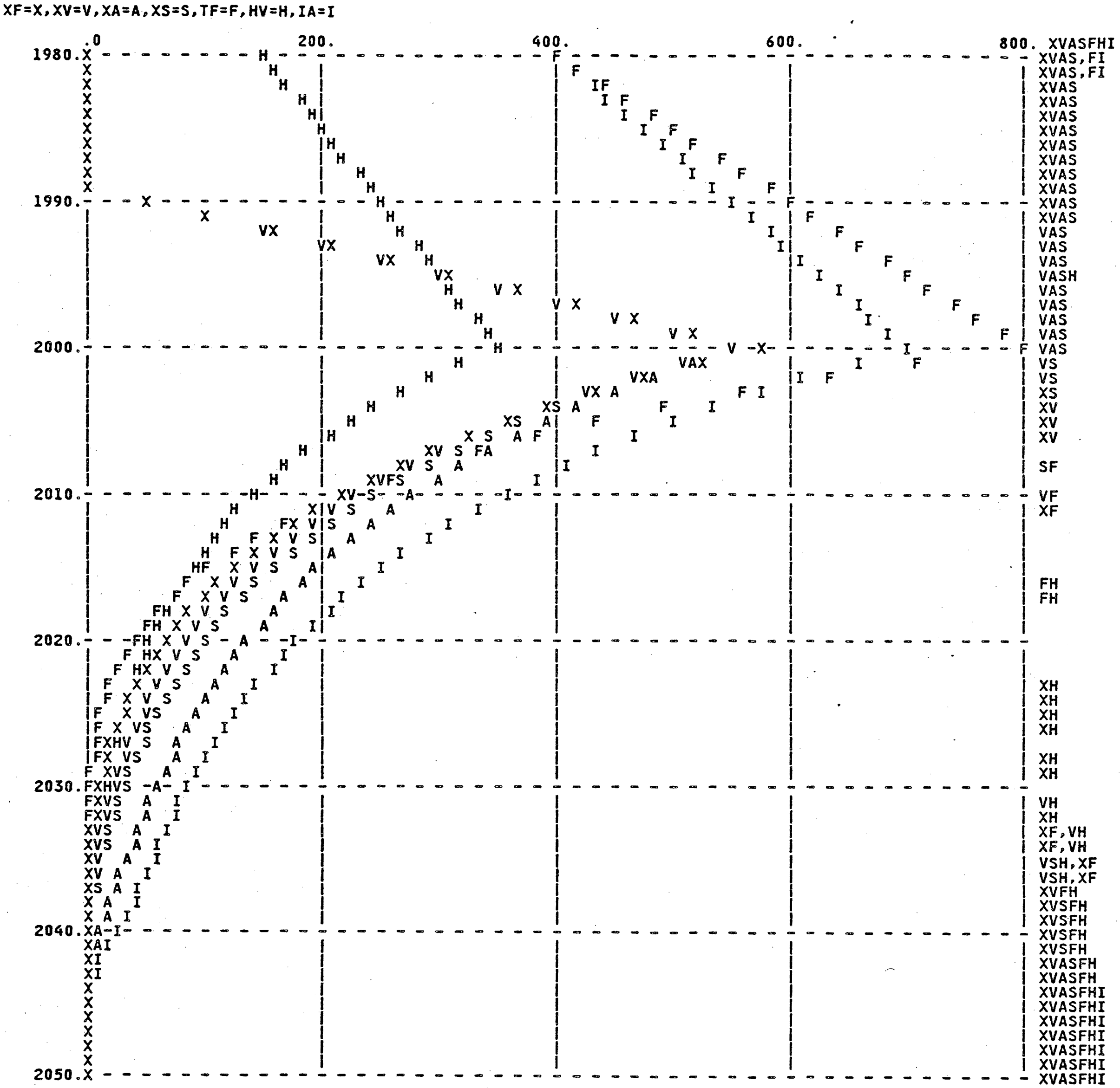
4. Availability=.67 and SBF=.935



NOTE: HH - NUMBER OF APACHE AIRCRAFT (AH-64)
TA - NUMBER OF THUNDERBOLT AIRCRAFT (A-10)
FF - NUMBER OF FALCON AIRCRAFT (F-16)
EF - NUMBER OF EAGLE AIRCRAFT (F-15)
HF - NUMBER OF HORNET AIRCRAFT (F/A-18)

U.S. AIRCRAFT - AVAILABILITY SCENARIO
(AVAILABILITY=.67,SBF=.93)

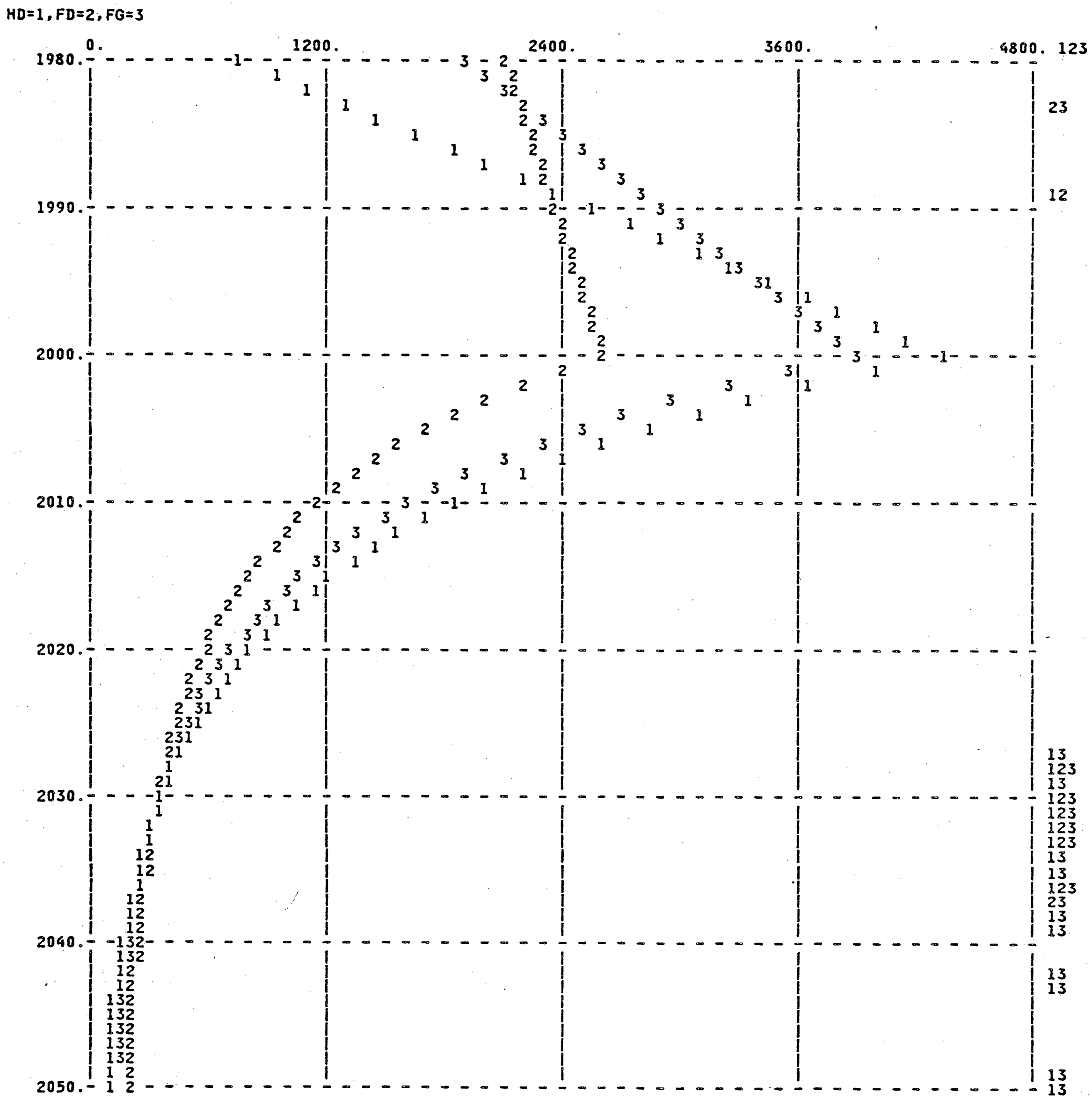
Fig. 7.23



NOTE: TF - NUMBER OF TOMCAT AIRCRAFT (F-14)
IA - NUMBER OF INTRUDER AIRCRAFT (A-6)
XF - NUMBER OF ADVANCED TACTICAL FIGHTER
XA - NUMBER OF ADVANCED TACTICAL ATTACK AIRCRAFT
HV - NUMBER OF HARRIER AIRCRAFT (AV-8)
XV - NUMBER OF VTOL FIGHTER MULTIMISSION
XS - NUMBER OF STEALTH STRIKE AIRCRAFT

U.S. AIRCRAFT - AVAILABILITY SCENARIO
(AVAILABILITY=.67, SBF=.93)

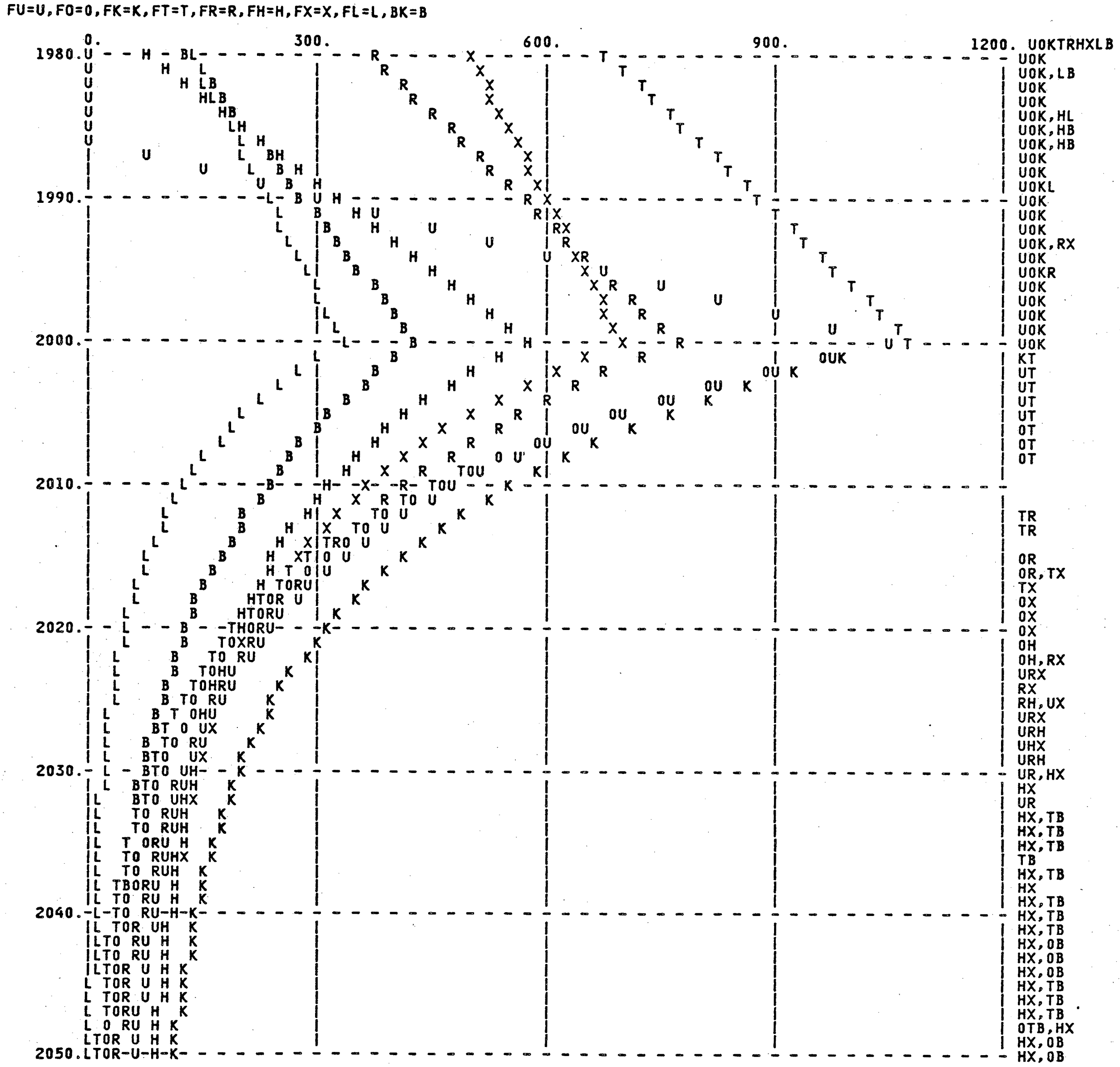
Fig. 7.24



NOTE: HD - NUMBER OF HIND AIRCRAFT (MI-24) FD - NUMBER OF FISHBED AIRCRAFT (MIG-21)
FG - NUMBER OF FLOGGER AIRCRAFT (MIG-23/MIG-27)

U.S.S.R. AIRCRAFT AVAILABILITY SCENARIO
(AVAILABILITY=.67, SBF=.93)

Fig. 7.25



NOTE:
FU - NUMBER OF FULCRUM AIRCRAFT (MIG-29)
FO - NUMBER OF FROGFOOT AIRCRAFT (SU-25)
FK - NUMBER OF FLANKER AIRCRAFT (SU-27)
FX - NUMBER OF FOXBAT AIRCRAFT (MIG-25)
BK - NUMBER OF BACKFIRE AIRCRAFT (TU-22M/TU-26)
FT - NUMBER OF FITTER AIRCRAFT (SU-17/SU-20/SU-22)
FR - NUMBER OF FENCER AIRCRAFT (SU-19/SU-24)
FH - NUMBER OF FOXHOUND AIRCRAFT (MIG-25M)
FL - NUMBER OF FIDDLER AIRCRAFT (TU-28P/TU-128)

U.S.S.R. AIRCRAFT - AVAILABILITY SCENARIO
(AVAILABILITY=.67, SBF=.93)

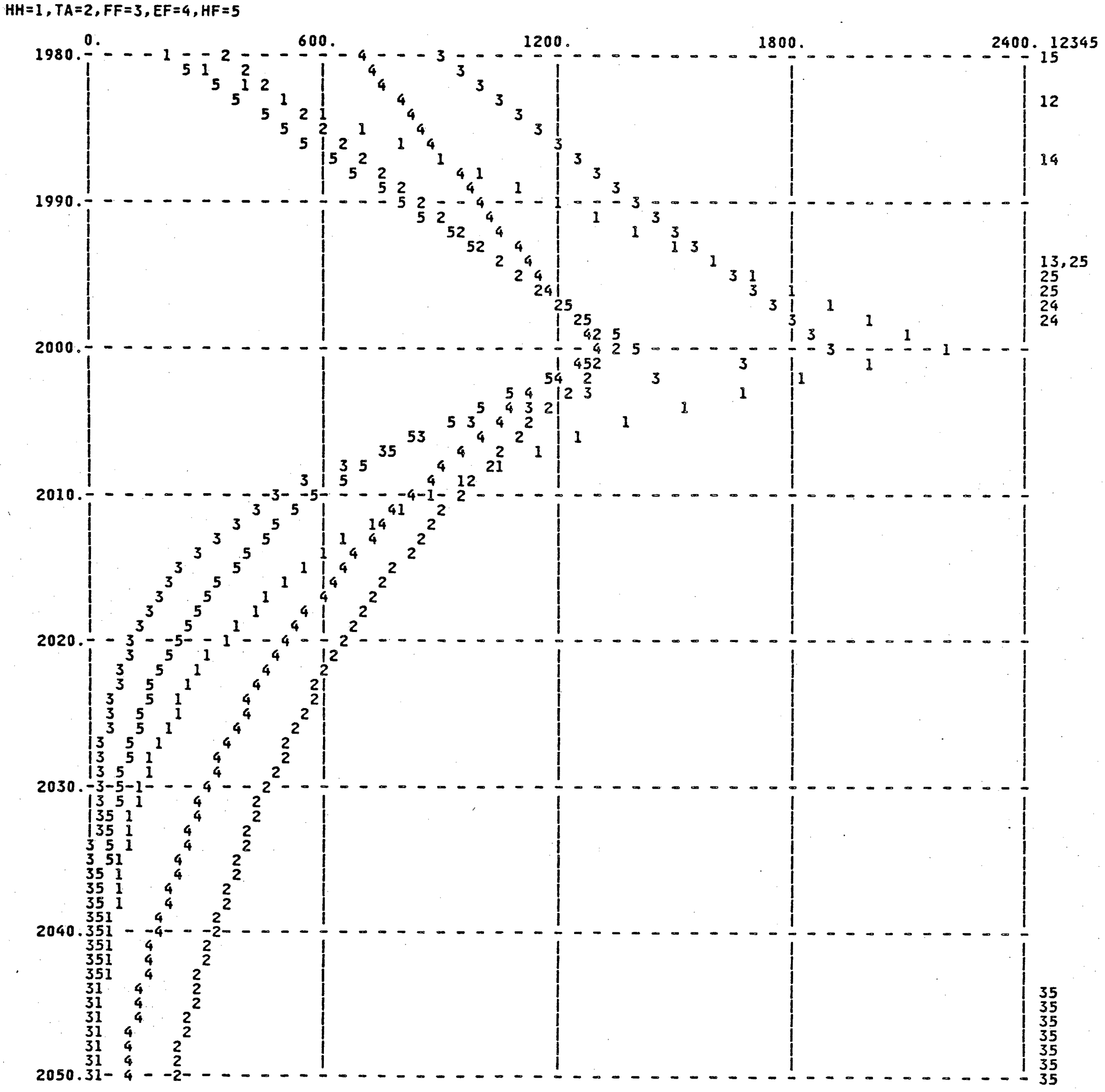
Fig. 7.26

If the availability of U.S. aircraft is .67 and the SBF=.935, the U.S.S.R. air power cannot dominate the U.S. air power anymore. From the results in Figs. 7.27, 7.28, 7.29 and 7.30, it can be seen that after 50 days of war the U.S. air power and the U.S.S.R. air power are almost in the equilibrium condition. However, the U.S. side has a tendency to destroy all the U.S.S.R. aircraft since the U.S. combat value is higher than the U.S.S.R. combat value as seen from Fig. 7.31.

7.4 THE OVERALL MODEL SIMULATION RESULT

In the overall model simulation, the attrition submodel affects not only the survivability submodel but also the economy, the budget and procurement submodels. By recognizing the combat value of the Russian's side and comparing it with what the U.S. side has, it can be decided not only whether the modifications of various aircraft are needed, but if the modification budget should be adjusted. By adjusting the budget of the Department of Defense in this way, the U.S. side should be able to balance Russia's power.

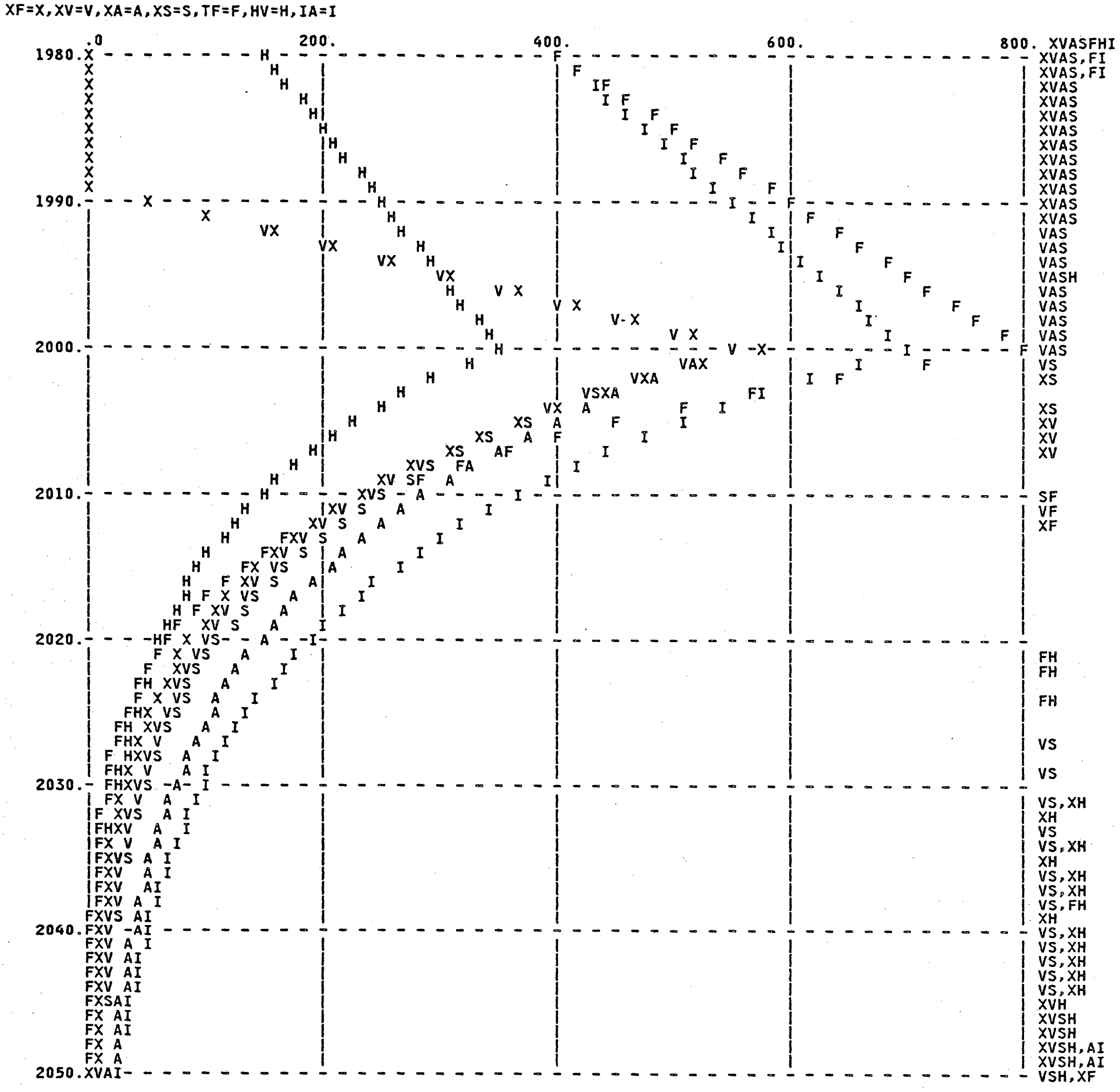
In this model, there are twenty-five types of aircraft considered during the peacetime buildup, but when the war starts at time=2000 there are only twelve types of aircraft left while the others are phased out.



NOTE: HH - NUMBER OF APACHE AIRCRAFT (AH-64) TA - NUMBER OF THUNDERBOLT AIRCRAFT (A-10)
FF - NUMBER OF FALCON AIRCRAFT (F-16) EF - NUMBER OF EAGLE AIRCRAFT (F-15)
HF - NUMBER OF HORNET AIRCRAFT (F/A-18)

U.S. AIRCRAFT - AVAILABILITY SCENARIO
(AVAILABILITY=.67, SBF=.935)

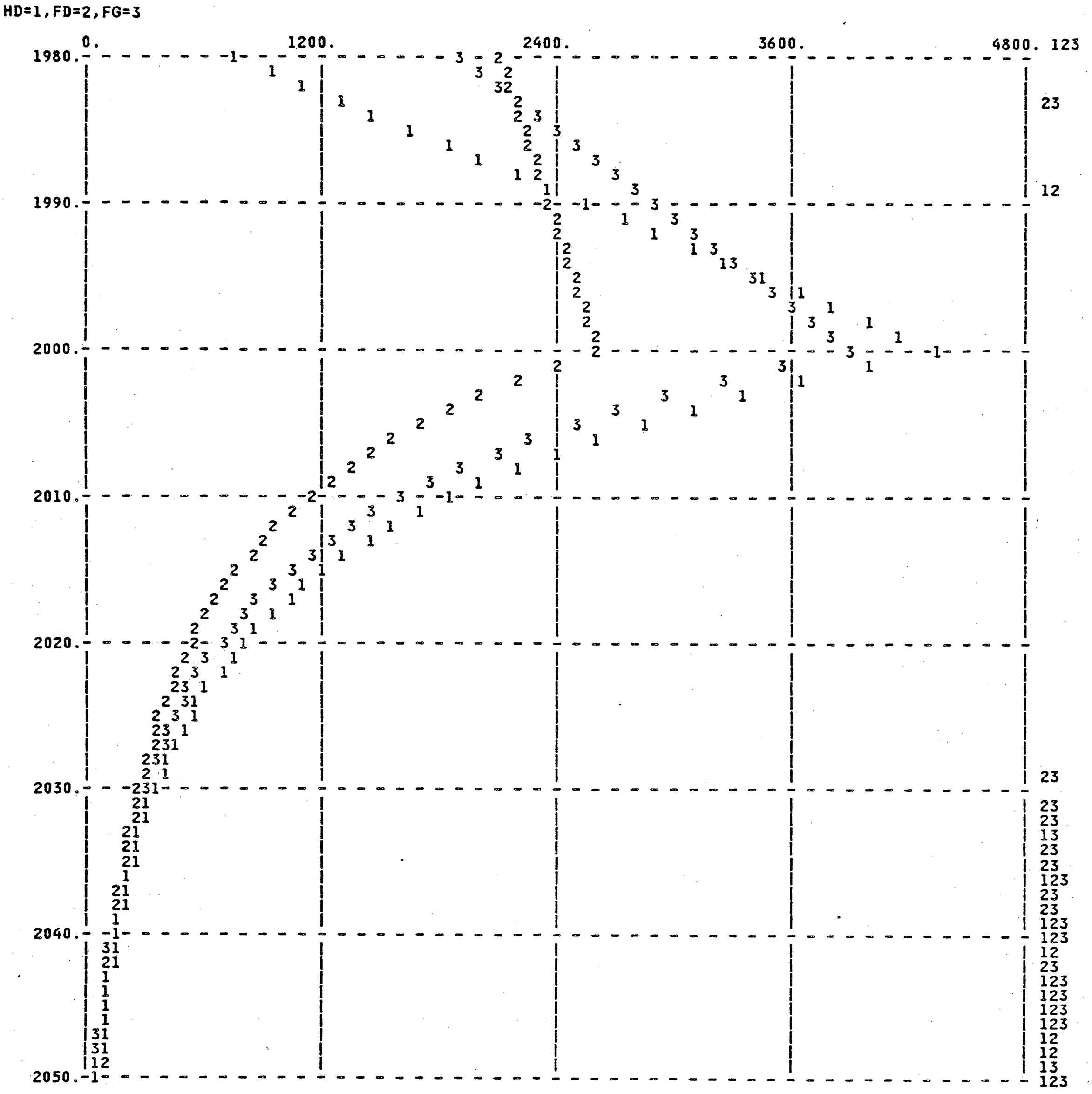
Fig. 7.27



NOTE: TF - NUMBER OF TOMCAT AIRCRAFT (F-14) HV - NUMBER OF HARRIER AIRCRAFT (AV-8)
IA - NUMBER OF INTRUDER AIRCRAFT (A-6) XV - NUMBER OF VTOL FIGHTER MULTIMISSION
XF - NUMBER OF ADVANCED TACTICAL FIGHTER XS - NUMBER OF STEALTH STRIKE AIRCRAFT
XA - NUMBER OF ADVANCED TACTICAL ATTACK AIRCRAFT

U.S. AIRCRAFT - AVAILABILITY SCENARIO
(AVAILABILITY = .67, SBF=.935)

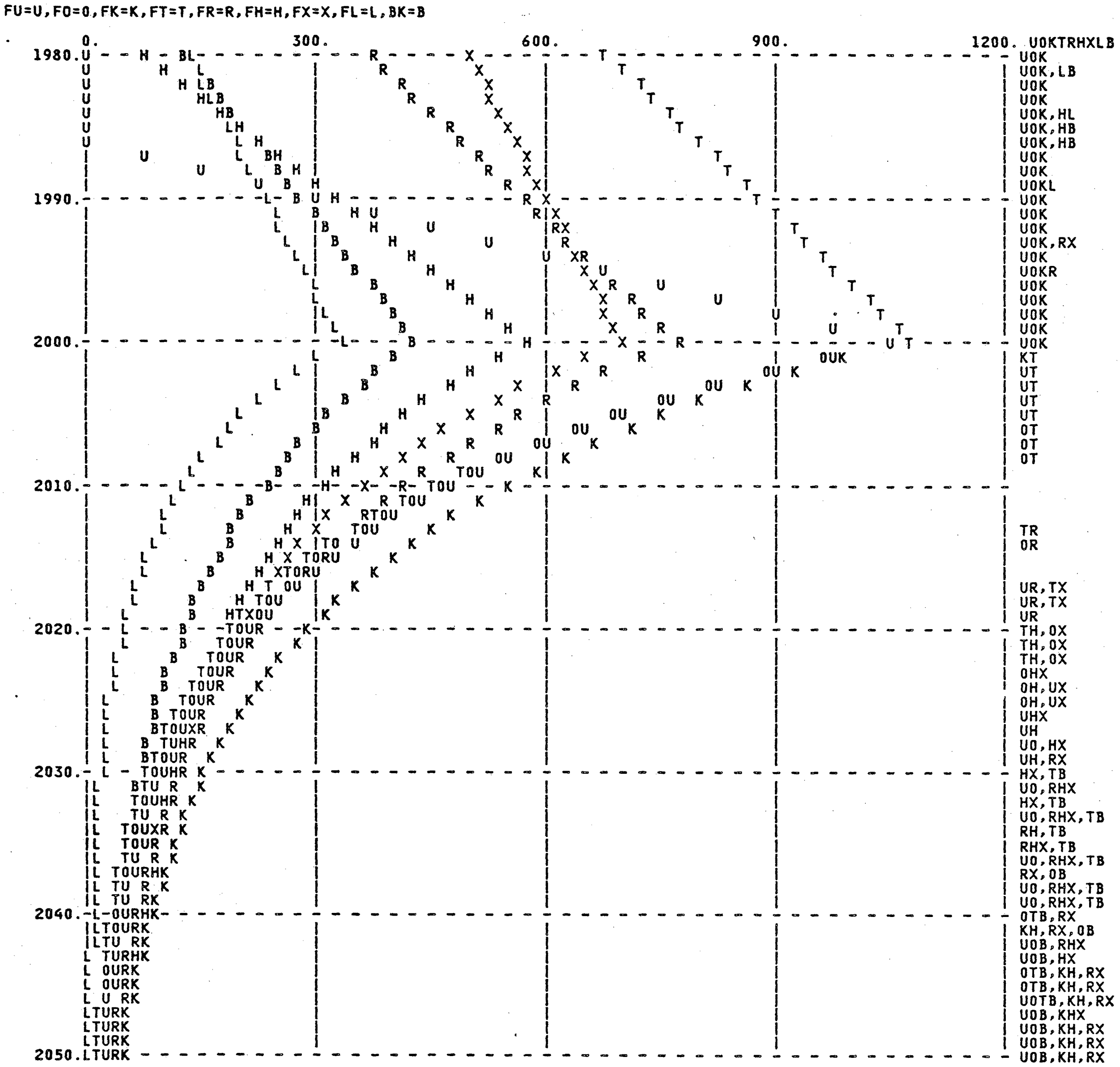
Fig. 7.28



NOTE: HD - NUMBER OF HIND AIRCRAFT (MI-24) FD - NUMBER OF FISHBED AIRCRAFT (MIG-21)
FG - NUMBER OF FLOGGER AIRCRAFT (MIG-23/MIG-27)

U.S.S.R. AIRCRAFT - AVAILABILITY SCENARIO
(AVAILABILITY=.67, SBF=.935)

Fig. 7.29



NOTE:
FU - NUMBER OF FULCRUM AIRCRAFT (MIG-29)
FO - NUMBER OF FROGFOOT AIRCRAFT (SU-25)
FK - NUMBER OF FLANKER AIRCRAFT (SU-27)
FX - NUMBER OF FOXBAT AIRCRAFT (MIG-25)
BK - NUMBER OF BACKFIRE AIRCRAFT (TU-22M/TU-26)
FT - NUMBER OF FITTER AIRCRAFT (SU-17/SU-20/SU-22)
FR - NUMBER OF FENCER AIRCRAFT (SU-19/SU-24)
FH - NUMBER OF FOXHOUND AIRCRAFT (MIG-25M)
FL - NUMBER OF FIDDLER AIRCRAFT (TU-28P/TU-128)

U.S.S.R. AIRCRAFT -AVAILABILITY SCENARIO
(AVAILABILITY=.67, SBF=.935)

Fig. 7.30

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 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
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     HF=     21.     HV=    10.4     IA=    49.4     XF=    10.5     XV=    18.0     XA=    38.6
     HD=    153.     FT=     34.     FR=    66.2     FD=    138.     FH=    73.9     FG=    130.     FX=    66.0
     FL=     7.9     BK=    38.1     FU=     48.     FO=     42.     FK=     85.
 CTDBXX=  216.0T CTDB$$=  626.6T TDPXXL=   12.64 TDP$$L=   54.09  KP$$L=   1.475  KPXXL=    .678
 USSRCV=    221.  USACV=    462.                                                                   USAA=    486.
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   TIME=   2042.     HH=     44.     TA=    293.     XS=    17.2     FF=      3.     EF=    151.     TF=     2.2
     HF=     16.     HV=     8.7     IA=    43.1     XF=     8.5     XV=    15.2     XA=    33.8
     HD=    130.     FT=     28.     FR=    58.6     FD=    122.     FH=    68.1     FG=    110.     FX=    59.4
     FL=     6.7     BK=    33.9     FU=     41.     FO=     36.     FK=     75.
 CTDBXX=  217.8T CTDB$$=  634.7T TDPXXL=   12.67 TDP$$L=   54.41  KP$$L=   1.474  KPXXL=    .678
 USSRCV=    193.  USACV=    417.
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

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     HF=     12.     HV=     7.3     IA=    37.6     XF=     7.0     XV=    12.9     XA=    29.7
     HD=    111.     FT=     24.     FR=    51.9     FD=    108.     FH=    62.8     FG=     94.     FX=    53.4
     FL=     5.6     BK=    30.1     FU=     36.     FO=     31.     FK=     66.
 CTDBXX=  219.5T CTDB$$=  642.0T TDPXXL=   12.69 TDP$$L=   54.71  KP$$L=   1.474  KPXXL=    .678
 USSRCV=    169.  USACV=    377.
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   TIME=   2046.     HH=     31.     TA=    253.     XS=    12.3     FF=      2.     EF=    119.     TF=     1.3
     HF=      9.     HV=     6.2     IA=    32.8     XF=     5.7     XV=    11.0     XA=    26.0
     HD=     95.     FT=     20.     FR=    45.9     FD=     95.     FH=    57.9     FG=     81.     FX=    48.1
     FL=     4.7     BK=    26.8     FU=     31.     FO=     27.     FK=     59.
 CTDBXX=  220.9T CTDB$$=  648.7T TDPXXL=   12.71 TDP$$L=   54.99  KP$$L=   1.474  KPXXL=    .679
 USSRCV=    149.  USACV=    341.
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
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     HF=      7.     HV=     5.2     IA=    28.6     XF=     4.7     XV=     9.4     XA=    22.8
     HD=     81.     FT=     17.     FR=    40.7     FD=     84.     FH=    53.5     FG=     69.     FX=    43.2
     FL=     4.0     BK=    23.8     FU=     27.     FO=     23.     FK=     52.
 CTDBXX=  222.2T CTDB$$=  654.8T TDPXXL=   12.72 TDP$$L=   55.25  KP$$L=   1.473  KPXXL=    .679
 USSRCV=    131.  USACV=    310.
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   TIME=   2050.     HH=     22.     TA=    219.     XS=     8.9     FF=      1.     EF=     93.     TF=      .8
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     HD=     69.     FT=     14.     FR=    36.0     FD=     74.     FH=    49.4     FG=     59.     FX=    38.9
     FL=     3.4     BK=    21.2     FU=     24.     FO=     20.     FK=     47.
 CTDBXX=  223.3T CTDB$$=  660.4T TDPXXL=   12.74 TDP$$L=   55.49  KP$$L=   1.473  KPXXL=    .679
 USSRCV=    115.  USACV=    282.
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

COMPUTER SIMULATION OUTPUT - AVAILABILITY SCENARIO
(AVAILABILITY=.67, SBF=.935)

Fig. 7.31

The result of this simulation is basically the same as the previous results, except that there are more interactions between submodels. From the result, it can be shown that the U.S. aircraft can dominate the Russian's aircraft after 30 days of war.

7.5 SUMMARY

In the environment of the Department of Defense, the kinds of problems to which systems analysis is applied are largely these: force composition, research and development, the selection of weapons, and the development of preferred manpower and logistical policies. These are different in a very marked degree from the operational problems studied in World War II. There is less emphasis today on the best tactical employment of weapons and much more upon the major decisions of how to allocate resources to various force mixes, and to the development and procurement of one weapon as opposed to another.

In World War II, operations research activities were focused on improving the combat effectiveness of existing weapons. The availability of operational statistics contributed to the success of that work in two important ways. First, it made the problem largely one of statistical inference; and second, it provided the analytical setting needed to evaluate the weapon's effectiveness in the context of real world battle. In other words, operations research dealt with rigorously, or at least reasonably, quantifiable problems.

Today the situation is more complex. There are no combat statistics for new weapons, but numerous decisions must be made during their development. Moreover, most front line existing systems -- in the case of aircraft, say the A-6, A-10, F-14, F-15 and F-16 systems -- have seen too little combat to make modification decisions based on statistically verifiable data. Yet, the enemy threat is continually being enhanced and therefore aircraft enhancement modification decisions must be made to maintain the necessary aircraft survivability. Fig. 7.32 illustrates a hierarchy of analysis supporting this process [101]. Notice how the assessment of a weapon's effectiveness changes between the "engineering" and "battle" levels of analysis. At the "engineering" and "operations" levels of analysis, the problems are, in general, reasonably quantifiable. As we cross the line into and through the "engagement" level, however the problems become increasingly more subjective. Because of the lack of combat statistics for a new or proposed modified weapon, its performance in battle is often simulated through the use of a combat model. The attrition and survivability submodels

Level of analysis	Assessments of effectiveness	Trade-offs
Battle		
Units Weather Topography	Casualties Movement Rates Weapons Attrition	Numbers and Types of Unit Unit Tactics
Encounter		
Multiple Weapons Types Ceiling/Visibility Terrain	Targets Killed per Day/Sortie Exchange Ratios	Weapons Mixes Sub-unit Tactics
Engagement		
Single Weapons Types Controlled Conditions	Probability of Killing a Single Target Probability of Loss to Single Attritor Type	Weapons Tactics and Design Features
Operations		
Weapon Properties	Endurance Range/Speed Fire Rate	Design Specifications
Engineering		
Weapon Configuration	Weight Power Size	Design Features

A HIERARCHY OF WEAPON SYSTEM ANALYSIS

Fig. 7.32

developed in this dissertation fall at the top of hierarchy in Fig. 7.32 in the "battle" and "encounter" levels.

This dissertation is written to describe the modeling process for performing survivability-attrition analysis and to describe the usage of the model itself. The model developed here fulfills the objectives of this research. It can determine who is the winner and who is the loser for battles, encounters or engagements for air warfare after a certain period of fighting. At the same time, the model can also be utilized to perform survivability tradeoffs to evaluate the necessity of proposed aircraft modifications. The model can be combined with three companion peacetime submodels, Economy, Budget, and Procurement, to provide feedback about wartime scenarios to help national security planners to decide what to do during the peacetime buildup.

7.5.1 Conclusions

From a scientific point of view, the present understanding of war -- insofar as the effectiveness of conventional military forces is concerned -- is in a relatively primitive state. In this research a start has been made toward the systematic application of quantitative techniques to answering the following questions:

What is the effectiveness of various combat aircraft systems?

How can this effectiveness be measured for attack aircraft and fighter aircraft?

How can individual aircraft systems be modified to improve their effectiveness?

How can these considerations be linked to the broader objective of determining the most effective mix of tactical air forces that can be bought and maintained for some budget, say $50 billion per year?

Defense decisions -- whether based on military judgements or sophisticated analytical techniques -- are critically dependent on the knowledge of what a military force can reasonably be expected to do. That knowledge is essential, not only to permit realistic force comparisons, but also for gauging the individual contributions of new weapons and tactical concepts.

From the various aspects of this research experience ranging from system dynamics methodology familiarization to survivability-attrition model development to scenario generation and analysis, the following conclusions are drawn:

1. Within the structure of the battle fixed by circumstance and choice, e.g. the decision to fight,

the necessity of a particular type of battle and the number of fighting units available, the U.S. and U.S.S.R. have several strategies available to them by altering the parameters under their control. In this manner they may affect the victory probabilities, the expected numbers of survivors as a function of time and the expected duration of the battle.

2. The approach used to model attrition dominates all facets of a combat model. Not only does it determine winners and losers, it also drives casualty levels, aircraft losses, targets destroyed, ammunition expenditures, and resupply/reinforcement requirements.
3. Aircraft survivability-attrition relationships depicted in Military Handbook 336-1, the verbal description or point of departure for this research, are oversimplified and misleading. Their applicability is limited to attack aircraft on purely close-air support missions and bombers on interdiction missions.
4. Lanchester's theory of combat, another approach to attrition modeling, provides a good basis for modeling fighter aircraft and their missions. From this it follows that the effective strength of one

side is proportional to the first power of aircraft force "efficiency" and proportional to the square of the aircraft force inventory entering the engagement. Two opposing forces are then equally matched when the exchange rate is equal to square of the number of combatants. "Efficiency" depends on aircraft survivability and the number of combatants depends on the aircraft inventory. Sortie rate and aircraft availability are also incorporated as measures of efficiency. Consequently, for fighter aircraft, it is more profitable to increase the number of participants in an engagement than it is to increase (by the same amount) the exchange rate (by increasing the effectiveness of the individual weapons on the aircraft). This is not an argument against increased aircraft efficiency (survivability, availability and sortie rate); it is simply a statement that a tactical or strategical use of concentration may counterbalance any moderate advantage in aircraft survivability.

5. Managed attrition, the way that attrition is managed may have an effect on the result of the conflict. The side that utilizes a very low managed attrition may avoid losses compared to the other side, but at the

same time, the other side may destroy an abundance of targets which is also very important. It should be noted that air forces cannot occupy ground and cannot seize or even defend cities

6. To analyze the overall mission effectiveness, it is better to observe several appropriate measures of effectiveness rather than just sticking to one. In this model, measures of effectiveness that can be used to evaluate the mission effectiveness are number of aircraft lost, kills per aircraft lost, cumulative targets destroyed, cumulative targets destroyed per aircraft lost, and combat values.
7. When an addition or modification is made to an existing baseline aircraft to enhance survivability, some penalties may be incurred due to additional costs, maintainability, reliability, logistics, or other pertinent operational factors associated with the modification. If the modification is large in terms of installation size and weight, it may also have a significant impact on the performance of existing operational aircraft. These tradeoffs are handled in the model through the use of "deltas." A force of hypothetical aircraft with a proposed modification is created using the same resources

available to the baseline aircraft without the modification. If the force of modified aircraft can out perform the force of baseline aircraft, the proposed modification is obviously cost-effective since cost has been held constant.

8. Proposals for modification must be treated objectively, not emotionally. The single-minded pursuit after greater aircraft survivability may be self-defeating. A proposal for modification may not lead to an aircraft that is superior to the baseline aircraft. It depends on the measures of effectiveness such as IPDTPL for the attack aircraft and the DPLCC for the fighter aircraft. If the values of IPDTPL and DPLCC are greater than zero, the modified aircraft is more effective than the baseline aircraft.
9. The improvement of enemy threat should be considered, because the full value of the modification of an aircraft system will not be realized if the threat is also being improved. There is a possibility that the modification of aircraft and the improvement of the threat will place the two sides in relative balance over time.
10. Scenario analysis is a critical aspect of model use. A scenario represents the model builder's basic

conception of the process or system being analyzed; it is a positive statement of assumptions about its operating environment. After all, it is from our anticipations of the environments in which our systems are to operate -- the state of the world, the conflict situations, and the tasks these systems are expected to accomplish -- that many of our criteria for evaluating the performance of a given system emerge. In this research our scenarios treat not only the important items selected for consideration -- aircraft enhancement, threat enhancement, availability, etc., -- but are also introduced for purposes of testing and evaluation.

7.5.2 Discussion

The single most fundamental assumption concerning the military balance is that of Soviet conventional-warfare superiority. This assumption conditions Western thinking on the need for nuclear parity and mutual self-destruction. Is this assumption warranted? The prevailing level of defense debate is inadequate to answer this question. While this issue is obviously beyond the scope of this research, it is believed that it is one of many small steps that will be taken in reassessing the U.S. response to the Soviet threat.

This research is believed to be significant in one important respect -- in distinguishing between what might be referred to as "inputs" and "outputs." It is believed that virtually the entire defense debate concerns itself not with wartime outputs, but with peacetime inputs -- static inventories of men and machines, often referred to in the defense establishment as "bean counts." Negligible attention is paid to the operational factors involved in taking those peacetime inputs (tanks, planes, etc.) and producing a wartime output -- achieving military goals. This research is an attempt to integrate inputs (aircraft inventories), technological factors (aircraft survivability and target destruction capability), and operational factors (aircraft availability and sortie rate) in such a way that they can be brought to bear on output. Recognizing that each of these must be a component of analysis, their isolated treatment simply cannot come to grips with the real issue. This dissertation tries to suggest a general approach to this issue, a way of thinking systematically about it.

Needless to say, statistical confidence of a sort that might be obtained from a random sample of U.S.-U.S.S.R. wars is (thankfully) unattainable. Though data exist on a variety of much narrower subproblems, macrolevel threat assessment for a future war must rely on judgements of plausibility. The object of this research in stressing mathematical modeling is not to eliminate judgement but to ensure that judgements are examined against the most explicit criteria of plausibility that can be conceived on the limited information base available. The approach allows one to identify assumptions for scrutiny and debate as a step toward concensus. It does not purport to eliminate uncertainty, but to identify it in such a way that its consequences can be gauged and, where possible, its extent reduced.

The output of this dissertation is a model; the inputs from which it was derived are Forrester's system dynamics methodology and Lanchester's theory of combat attrition. The model is the synthesized representation of the author's mental conception of the air combat phenomena. System dynamics is the means by which that conception was transformed into the model. It would be difficult to replicate this model using a different methodology; another modeler using system dynamics would almost certainly devise a different model. By analogy, a painter's style and technique is the methodology by which he synthesizes paints into a model -- the painting. Theory refers to the principles used to explain the nature or behavior of a specified set of phenomena, more than anything else, this dissertation rests on the foundation of the works of Forrester and Lanchester.

Many of the usual qualms with quantification and extension of theory through mathematical modeling rest on an unfair double standard, as one of these two mentors, Lanchester, observed almost a century ago:

> There are many who will be inclined to cavil at any mathematical or semi-mathematical treatment of the present subject, on the ground that with so many unknown factors, such as morale or leadership of the men, the unaccounted merits or demerits of the weapons, and the still more unknown "chances of war," it is ridiculous to pretend to calculate anything. The answer to this is simple: the direct numerical comparison of the force engaging in conflict or available in the event of war is almost universal. It is a factor always carefully reckoned with by the various military authorities; it is discussed ad nauseam in the Press. Yet such direct counting of forces is in itself a tacit acceptance of the applicability of mathematical principles, but confined to a special case. To accept, without reserve the mere "counting of the pieces" as a value, and to deny the more extended application of mathematical theory, is as illogical and unintelligent as to accept broadly and indiscriminantly to balance and the weighing-machine as intruments of precision, but to decline to permit in the latter case any allowance for the known inequality of leverage [30].

Beyond this issue is the more familiar question of what numbers to plug into one's idealizing model equations. Where trustworthy data are available, they are obviously used. Where, as is almost always the case, they are not available, two options are available. First, one can stop, "throw in the towel," and regress to bean counting. Or, one can try to proceed with rationality by resisting the conditioned response that perfect measurements are necessary to make a reasoned judgement on bounds by drawing the most intelligent inferences one can from the data that are available, and by varying one's assumptions so that the consequences of irreducible uncertainty may be gauged (sensitivity analysis). At the very least, the procedure will identify the critical areas of uncertainty, perhaps inspiring the collection of more useful information. At most, it will reduce uncertainty itself. But it will never eliminate uncertainty or the need for judgement.

The overall research effort of which this dissertation is a part is charged with developing a mathematical model for managing aircraft survivability using Military Handbook 336, the three volume "bible" of U.S. aircraft survivability concepts. The system dynamics methodology was specified in the terms of reference of the research contract in recognition of the role that data (the lack of it) would play in the modeling effort. Many methodologies are oriented toward gathering and testing data; system dynamics is a methodology that is philosophically committed to serve as a guide to action.

Data is a problem in military modeling. The amount of data available for each weapon, is a function of the availability of the weapon, test specimens, priorities, funds, and development status. Unfortunately, no single source for weapon data exists in any one service, let alone for weapons used by all four services such as aircraft systems. The best sources for data are the laboratories, arsenals, and testing facilities which are charged with the development of a particular weapon, munition, or weapon system. For foreign data the best sources are the Defense Intelligence Agency, the Army Foreign Science and Technological Center, the Air Force Foreign Technology Division, and the Army Missile Intelligence Agency. Moreover, a true "reference" data base would have to include all the input data required by the model -- not only aircraft weapons data, but also aircraft performance data, tactics, supply, order of battle, and terrain. It was understood from the outset that these sources would not be made available for this research and that a useful model could be developed without the data that they could provide.

A mathematical model of U.S. national security planning with regard to tactical air power should aid in understanding that broad complex phenomenon. It should be a useful guide to judgement and intuitive decisions. It should helps establish desirable policies such as, in the case of this research, the survivability trade-off analysis with respect to proposed modifications of existing combat aircraft. Using such a model implies the following:

- We have some knowledge about the detailed characteristics of the system.
- These known and assumed facts interact to influence the way in which the system will evolve with time.
- Our intuitive ability to visualize the interaction of the parts is less reliable than our knowledge of the parts individually.
- By constructing the model and watching the interplay of the factors within it, we shall come to a better understanding of the system with which we are dealing.

The preceding comments imply that a useful model of a real system should be able to represent the nature of the system; it should show how changes in policy or structure will produce better or worse behavior. It should show the kinds of external disturbance to which the system is vulnerable. It is a guide to improving management effectiveness.

Many persons, especially those unfamiliar with military modeling and its special data problems, will discount the potential utility of this model on the assumption that there is inadequate data on which to base the model. They believe that the first step should have been the extensive collecting of statistical data. It can be argued that exactly the reverse is true.

Using Handbook 336 and many other unclassified sources, we were equipped with enough descriptive information to begin the construction of a highly useful model. Indeed one of the principal uses of the model by the sponsor, the Joint Technical Coordinating Group for Aircraft Survivability, will be to prioritize research and data collection efforts. Using the model, important questions can be answered such as: What is the relative importance of many different variables? How accurately is the information needed? What will be the consequences and risks of incorrect data?

The end product of this research is a policy assisting model -- a quantitative structure of fact and conjecture, fashioned to represent a problem that does not have a scientific or objective solution [102]. The aim is to enhance and extend judgement. Questions that can be asked of such a model of a system so complex that the correct answers are not evident by inspection are: What would the situation be like if the real system corresponds to our basic assumptions? What would a proposed system be like if we designed it to agree with the model? What changes in the model would give it more nearly the characteristic of the existing system that it presumably represents?

Because of a policy assisting model's potential for distortion, adversary analysis can be useful. Application of this refutationist method requires search for causal explanations. Causal models, such the one developed here, are important because they are refutable. Critics of the model must express their criticism in the form of causal explanations. A causal explanation of a criticism constitutes a universal statement that is refutable at the point of criticism. If the new universal statement is attached to the original model or takes the place of another universal statement in the original model, an adjusted model is formed. The adjusted model will be an improvement if it is corroborated at the original point of criticism. If the improved model has more universal statements than its predecessor, that is, if variables have been added, then so much the better because the improved model will have even more refutable points for further testing and improvement.

In this context, criticism is not only welcomed, but it is invited.

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APPENDIX A

	BASELINE	MODIFIED	DELTA
SURVIVABILITY	.96	.98	-.021 (DS)
WEIGHT (EMPTY)	18000	20000	-.111 (DW)
FUEL WEIGHT	10000		
PAYLOAD	6000	3615.4	.397 (DP)
ACQUISITION COST	30,000,000	35,000,000	-.167 (DA)
MAINTENANCE	10	12	-.20 (DM)
SORTIE RATE	2	SRB*(1-DP)=2*(1-.397)=1.206	
AVAILABILITY	0.5	AB/(1-DM)= 0.5/1.2 = .417	
PROCUREMENT	3.33	PRB/(1-DA)=3.33/1.67= 2.856	
NUMBER OF AIRCRAFT INITIALLY	1000	857	

ATTACK AIRCRAFT

Measures of Effectiveness: IPDTPL

(increased payload deliver to target per a/c lost)

$$\text{IPDTPL} = \frac{\text{PDTPML} - \text{PDTPBL}}{\text{PDTPBL}}$$

$$\text{PDTPML} = \frac{3615.4}{1-.98} = 180{,}770 \quad , \quad \text{PDTPBL} = \frac{6000}{1-.96} = 150{,}000$$

$\text{IPDTPL} = 0.205 > 0$

Modified aircraft is better than the baseline aircraft

FIGHTER AIRCRAFT

Measures of Effectiveness : DPLCC

(decreased program life cycle cost)

$$\text{DPLCC} = \frac{(\$\$\text{BN}*\$\$\text{M}) - (\$\$\text{MN}*\$\$\text{B})}{\$\$\text{MN}\ (\$\$\text{BN}-\$\$\text{B})}$$

$$\$\$\text{B} = \$\$\text{BN} \cosh \sqrt{BC}\ t - \$\$\text{MN} \sqrt{C/B} \sinh \sqrt{BC}\ t$$
$$\$\$\text{M} = \$\$\text{MN} \cosh \sqrt{BC}\ t - \$\$\text{MN} \sqrt{B/C} \sinh \sqrt{BC}\ t$$

$$B = \text{SRB} * \text{AB} * (1-\text{SM}) = 2 * 0.5 * (1-.98) = .02$$
$$C = \text{SRM} * \text{AM} * (1-\text{SB}) = 1.206 * 0.417 * (1-.96) = .0201$$

After 40 days of war:

$\$\$B = 1339.2 - 765.3 = 573.9$; $\$\$M = 1147.7 - 888.6 = 259.1$

DPLCC = -.64 < 0

Baseline aircraft is better than the modified aircraft

At the end of the war (condition at which $\$\$M = 0$) ,

$$\tanh \sqrt{BC}\, t = \frac{\$\$MN}{\$\$BN \sqrt{B/C}} = 0.8591$$

$$t = 64.33 \quad ; \quad \$\$B = 511.7$$

$$DPLCC = \$\$B/(\$\$BN-\$\$B) = -1.05 < 0$$

NOTE:

$$\text{PM (payload modified)} = \frac{\dfrac{WB+PB+FB-WM}{FB}\,(2\,WB+PB) - 2\,WM}{1 + \dfrac{2\,WB + PB}{FB}}$$

WB - empty weight of baseline aircraft
WM - empty weight of modified aircraft
PB - payload of baseline aircraft
FB - fuel weight of baseline aircraft

	BASELINE	MODIFIED	DELTA
SURVIVABILITY			
- attack aircraft	.96	.9698	-.010 (DS)
- fighter aircraft	.98	.99	-.010 (DS)
WEIGHT (EMPTY)	20000	22000	-.100 (DW)
FUEL WEIGHT	12000		
PAYLOAD	8000	5600	.300 (DP)
ACQUISITION COST	36,000,000	37,500,000	-.042 (DA)
MAINTENANCE	15	16	-.067 (DM)
SORTIE RATE	2	SRB*(1-DP)=2*(1-.30) = 1.40	
AVAILABILITY	0.5	AB/(1-DM)= 0.5/1.067 = .47	
PROCUREMENT	3.33	PRB/(1-DA)=3.33/1.042= 3.199	
NUMBER OF AIRCRAFT INITIALLY	1000	960	

<u>ATTACK AIRCRAFT</u>

Measures of Effectiveness: IPDTPL
(increased payload deliver to target per a/c lost)

$$IPDTPL = \frac{PDTPML - PDTPBL}{PDTPBL}$$

$$PDTPML = \frac{5600}{1-.9698} = 185,430 \quad , \quad PDTPBL = \frac{8000}{1-.96} = 200,000$$

$IPDTPL = -0.073 < 0$

Baseline aircraft is better than the modified aircraft

<u>FIGHTER AIRCRAFT</u>

Measures of Effectiveness : DPLCC
(decreased program life cycle cost)

$$DPLCC = \frac{(\$\$BN*\$\$M) - (\$\$MN*\$\$B)}{\$\$MN\ (\$\$BN-\$\$B)}$$

$$\$\$B = \$\$BN \cosh \sqrt{BC}\ t - \$\$MN \sqrt{C/B} \sinh \sqrt{BC}\ t$$
$$\$\$M = \$\$MN \cosh \sqrt{BC}\ t - \$\$MN \sqrt{B/C} \sinh \sqrt{BC}\ t$$

$$B = SRB * AB * (1-SM) = 2 * 0.5 * (1-.99) = .01$$
$$C = SRM * AM * (1-SB) = 1.4 * 0.47 * (1-.98) = .0132$$

After 40 days of war:

$\$\$B = 1107.1 - 524.1 = 583.0$; $\$\$M = 1062.9 - 413.6 = 649.3$

DPLCC = 0.224 > 0

Modified aircraft is better than the baseline aircraft

At the end of the war (condition at which $\$\$B = 0$) ,

$$\tanh \sqrt{BC}\, t = \frac{\$\$MN}{\$\$BN \sqrt{B/C}} = 0.9066 \quad ; \quad \sqrt{BC}\, t = 1.508$$

$$t = 131.2 \quad ; \quad \$\$B = 405$$

$DPLCC = \$\$M/\$\$MN = 0.42 > 0$

ATTACK AIRCRAFT

$$\text{PDTPML (payload deliver to target per a/c lost)} = \frac{PM}{1-SM}$$

$$\text{PDTPBL} = \frac{PB}{1-SB}$$

if $\frac{PB}{1-SB} > \frac{PM}{1-SM}$, then

$$\begin{aligned} PB\ (1-SM) &> PM\ (1-SB) \\ (1-SM) &> (PM/PB)(1-SM) \\ SRB\ (1-SM) &> SRB\ (PM/PB)(1-SB) \\ SRB\ (1-SM) &> SRM\ (1-SB) \end{aligned}$$

FIGHTER AIRCRAFT

$B = SRB * (1-SM) * AB$
$C = SRM * (1-SB) * AM$

if $SRB * (1-SM) > SRM * (1-SB)$
then $B > C$

That means the modified aircraft is not as effective as baseline aircraft

From these explanation, it can be concluded that:
If all the data of attack and fighter aircraft are the same, and baseline attack aircraft is better than modified, then the modified fighter aircraft cannot be better than the baseline aircraft.

APPENDIX B

How To Read Computer Outputs

To illustrate how the computer graphs are read, consider Fig. 7.7. In the line of type at the top-left of the figure are the variables that are plotted, HH, TA, FF, EF and HF, and the symbols used for each 1, 2, 3, 4 and 5 respectively. This means, for example, that the number of Eagle (F-15) EF appears on the graph as the symbol 4. The variables, like HH, TA, FF, EF and HF, are expressed in these abbreviations used uniformly in the causal diagram (Figs. 6.1 - 6.12), in the mathematical description of the model (Appendix C), and in the outputs.

The scale along the left side is in years until 2000, and in days from 2000 to 2050. The scale(s) along the top is identified by the plotting symbols corresponding to the lines on the graph.

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NOTE                         - APPENDIX C -
NOTE    ***************************************************************
NOTE    ***    COMBAT AIRCRAFT ATTRITION SUBMODEL FOR US AIRCRAFT    ***
NOTE    ***************************************************************
NOTE
L   HH.K=MAX(0,HH.J+(DT)(PRHH.JK-ARHH.JK))                    (A-1HH)
L   TA.K=MAX(0,TA.J+(DT)(PRTA.JK-ARTA.JK))                    (A-1TA)
L   XS.K=MAX(0,XS.J+(DT)(PRXS.JK-ARXS.JK))                    (A-1XS)
L   FF.K=MAX(0,FF.J+(DT)(PRFF.JK-ARFF.JK))                    (A-1FF)
L   EF.K=MAX(0,EF.J+(DT)(PREF.JK-AREF.JK))                    (A-1EF)
L   TF.K=MAX(0,TF.J+(DT)(PRTF.JK-ARTF.JK))                    (A-1TF)
L   HF.K=MAX(0,HF.J+(DT)(PRHF.JK-ARHF.JK))                    (A-1HF)
L   HV.K=MAX(0,HV.J+(DT)(PRHV.JK-ARHV.JK))                    (A-1HV)
L   IA.K=MAX(0,IA.J+(DT)(PRIA.JK-ARIA.JK))                    (A-1IA)
L   XF.K=MAX(0,XF.J+(DT)(PRXF.JK-ARXF.JK))                    (A-1XF)
L   XV.K=MAX(0,XV.J+(DT)(PRXV.JK-ARXV.JK))                    (A-1XV)
L   XA.K=MAX(0,XA.J+(DT)(PRXA.JK-ARXA.JK))                    (A-1XA)
N   HH=HHN                                                   (A-1.1HH)
N   TA=TAN                                                   (A-1.1TA)
N   XS=XSN                                                   (A-1.1XS)
N   FF=FFN                                                   (A-1.1FF)
N   EF=EFN                                                   (A-1.1EF)
N   TF=TFN                                                   (A-1.1TF)
N   HF=HFN                                                   (A-1.1HF)
N   HV=HVN                                                   (A-1.1HV)
N   IA=IAN                                                   (A-1.1IA)
N   XF=XFN                                                   (A-1.1XF)
N   XV=XVN                                                   (A-1.1XV)
N   XA=XAN                                                   (A-1.1XA)
NOTE HH - ARMY AIRCRAFT APACHE AH-64  (AIRCRAFT)
NOTE TA - AIRFORCE AIRCRAFT THUNDERBOLT A-10 (AIRCRAFT)
NOTE XS - AIRFORCE AIRCRAFT STEALTH STRIKE (AIRCRAFT)
NOTE FF - AIRFORCE AIRCRAFT FALCON F-16  (AIRCRAFT)
NOTE EF - AIRFORCE AIRCRAFT EAGLE F-15  (AIRCRAFT)
NOTE TF - NAVY AIRCRAFT TOMCAT F-14  (AIRCRAFT)
NOTE HF - NAVY AIRCRAFT HORNET F/A-18  (AIRCRAFT)
NOTE HV - NAVY AIRCRAFT HARRIER AV-8  (AIRCRAFT)
NOTE IA - NAVY AIRCRAFT INTRUDER A-6  (AIRCRAFT)
NOTE XF - AIRFORCE ADVANCED TACTICAL FIGHTER ATF (AC)
NOTE XV - NAVY VTOL FIGHTER MULTIMISSION VFMX (AIRCRAFT)
NOTE XA - NAVY ADVANCED TACTICAL ATTACK ATA (AIRCRAFT)
C   HHN=200                                                  (A-1.2HH)
C   TAN=360                                                  (A-1.2TA)
C   XSN=0                                                    (A-1.2XS)
C   FFN=900                                                  (A-1.2FF)
C   EFN=700                                                  (A-1.2EF)
C   TFN=400                                                  (A-1.2TF)
C   HFN=200                                                  (A-1.2HF)
C   HVN=150                                                  (A-1.2HV)
C   IAN=400                                                  (A-1.2IA)
C   XFN=0                                                    (A-1.2XF)
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```
C    XVN=0                                                 (A-1.2XV)
C    XAN=0                                                 (A-1.2XA)
NOTE  $$N - NUMBER OF $$ AIRCRAFT INITIALLY (AIRCRAFT)
R    PRHH.KL=CLIP(0.25,100,TIME.K,WAR)                     (A-2HH)
R    PRTA.KL=CLIP(0.15,50,TIME.K,WAR)                      (A-2TA)
R    PRXS.KL=CLIP(0.0,XXS.K,1988,TIME.K)                   (A-2XS)
A    XXS.K=CLIP(.15,50,TIME.K,WAR)
R    PRFF.KL=CLIP(0.15,50,TIME.K,WAR)                      (A-2FF)
R    PREF.KL=CLIP(0.1,30,TIME.K,WAR)                       (A-2EF)
R    PRTF.KL=CLIP(0.1,20,TIME.K,WAR)                       (A-2TF)
R    PRHF.KL=CLIP(0.2,60,TIME.K,WAR)                       (A-2HF)
R    PRHV.KL=CLIP(0.03,10,TIME.K,WAR)                      (A-2HV)
R    PRIA.KL=CLIP(0.05,15,TIME.K,WAR)                      (A-2IA)
R    PRXF.KL=CLIP(0.0,XXF.K,1988,TIME.K)                   (A-2XF)
A    XXF.K=CLIP(.15,52,TIME.K,WAR)
R    PRXV.KL=CLIP(0,XXV.K,1988,TIME.K)                     (A-2XV)
A    XXV.K=CLIP(.15,50,TIME.K,WAR)
R    PRXA.KL=CLIP(0,XXA.K,1988,TIME.K)                     (A-2XA)
A    XXA.K=CLIP(.15,50,TIME.K,WAR)
NOTE  PR$$ - PROCUREMENT RATE OF $$ AIRCRAFT (AIRCRAFT/DAY)
R    ARHH.KL=CLIP(HH.K*SRHHST.K*(1-MSHHST.K)+HH.K*SRHHLT.K*(1-MSHHLT.K)+
X      HD.K*SRHDHH.K*(1-MSHHHD.K)+FT.K*SRFTHH.K*(1-MSHHFT.K)+
X      FR.K*SRFRHH.K*(1-MSHHFR.K)+FD.K*SRFDHH.K*(1-MSHHFD.K)+
X      FH.K*SRFHHH.K*(1-MSHHFH.K)+FG.K*SRFGHH.K*(1-MSHHFG.K)+
X      FX.K*SRFXHH.K*(1-MSHHFX.K)+FL.K*SRFLHH.K*(1-MSHHFL.K)+BK.K
X      *SRBKHH.K*(1-MSHHBK.K)+FU.K*SRFUHH.K*(1-MSHHFU.K)+FO.K*SRFOHH.K
X      *(1-MSHHFO.K)+FK.K*SRFKHH.K*(1-MSHHFK.K),0,TIME.K,WAR)   (A-3HH)
R    ARTA.KL=CLIP(TA.K*SRTAST.K*(1-MSTAST.K)+TA.K*SRTALT.K*(1-MSTALT.K)+
X      HD.K*SRHDTA.K*(1-MSTAHD.K)+FT.K*SRFTTA.K*(1-MSTAFT.K)+
X      FR.K*SRFRTA.K*(1-MSTAFR.K)+FD.K*SRFDTA.K*(1-MSTAFD.K)+
X      FH.K*SRFHTA.K*(1-MSTAFH.K)+FG.K*SRFGTA.K*(1-MSTAFG.K)+
X      FX.K*SRFXTA.K*(1-MSTAFX.K)+FL.K*SRFLTA.K*(1-MSTAFL.K)+BK.K
X      *SRBKTA.K*(1-MSTABK.K)+FU.K*SRFUTA.K*(1-MSTAFU.K)+FO.K*SRFOTA.K
X      *(1-MSTAFO.K)+FK.K*SRFKTA.K*(1-MSTAFK.K),0,TIME.K,WAR)   (A-3TA)
R    ARXS.KL=CLIP(XS.K*SRXSST.K*(1-MSXSST.K)+XS.K*SRXSLT.K*(1-MSXSLT.K)+
X      HD.K*SRHDXS.K*(1-MSXSHD.K)+FT.K*SRFTXS.K*(1-MSXSFT.K)+
X      FR.K*SRFRXS.K*(1-MSXSFR.K)+FD.K*SRFDXS.K*(1-MSXSFD.K)+
X      FH.K*SRFHXS.K*(1-MSXSFH.K)+FG.K*SRFGXS.K*(1-MSXSFG.K)+
X      FX.K*SRFXXS.K*(1-MSXSFX.K)+FL.K*SRFLXS.K*(1-MSXSFL.K)+BK.K
X      *SRBKXS.K*(1-MSXSBK.K)+FU.K*SRFUXS.K*(1-MSXSFU.K)+FO.K*SRFOXS.K
X      *(1-MSXSFO.K)+FK.K*SRFKXS.K*(1-MSXSFK.K),0,TIME.K,WAR)   (A-3XS)
R    ARFF.KL=CLIP(FF.K*SRFFST.K*(1-MSFFST.K)+FF.K*SRFFLT.K*(1-MSFFLT.K)+
X      HD.K*SRHDFF.K*(1-MSFFHD.K)+FT.K*SRFTFF.K*(1-MSFFFT.K)+
X      FR.K*SRFRFF.K*(1-MSFFFR.K)+FD.K*SRFDFF.K*(1-MSFFFD.K)+
X      FH.K*SRFHFF.K*(1-MSFFFH.K)+FG.K*SRFGFF.K*(1-MSFFFG.K)+
X      FX.K*SRFXFF.K*(1-MSFFFX.K)+FL.K*SRFLFF.K*(1-MSFFFL.K)+BK.K
X      *SRBKFF.K*(1-MSFFBK.K)+FU.K*SRFUFF.K*(1-MSFFFU.K)+FO.K*SRFOFF.K
X      *(1-MSFFFO.K)+FK.K*SRFKFF.K*(1-MSFFFK.K),0,TIME.K,WAR)   (A-3FF)
R    AREF.KL=CLIP(EF.K*SREFST.K*(1-MSEFST.K)+EF.K*SREFLT.K*(1-MSEFLT.K)+
X      HD.K*SRHDEF.K*(1-MSEFHD.K)+FT.K*SRFTEF.K*(1-MSEFFT.K)+
X      FR.K*SRFREF.K*(1-MSEFFR.K)+FD.K*SRFDEF.K*(1-MSEFFD.K)+
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X      FH.K*SRFHEF.K*(1-MSEFFH.K)+FG.K*SRFGEF.K*(1-MSEFFG.K)+
X      FX.K*SRFXEF.K*(1-MSEFFX.K)+FL.K*SRFLEF.K*(1-MSEFFL.K)+BK.K
X      *SRBKEF.K*(1-MSEFBK.K)+FU.K*SRFUEF.K*(1-MSEFFU.K)+FO.K*SRFOEF.K
X      *(1-MSEFFO.K)+FK.K*SRFKEF.K*(1-MSEFFK.K),0,TIME.K,WAR)    (A-3EF)
R    ARTF.KL=CLIP(TF.K*SRTFST.K*(1-MSTFST.K)+TF.K*SRTFLT.K*(1-MSTFLT.K)+
X      HD.K*SRHDTF.K*(1-MSTFHD.K)+FT.K*SRFTTF.K*(1-MSTFFT.K)+
X      FR.K*SRFRTF.K*(1-MSTFFR.K)+FD.K*SRFDTF.K*(1-MSTFFD.K)+
X      FH.K*SRFHTF.K*(1-MSTFFH.K)+FG.K*SRFGTF.K*(1-MSTFFG.K)+
X      FX.K*SRFXTF.K*(1-MSTFFX.K)+FL.K*SRFLTF.K*(1-MSTFFL.K)+BK.K
X      *SRBKTF.K*(1-MSTFBK.K)+FU.K*SRFUTF.K*(1-MSTFFU.K)+FO.K*SRFOTF.K
X      *(1-MSTFFO.K)+FK.K*SRFKTF.K*(1-MSTFFK.K),0,TIME.K,WAR)    (A-3TF)
R    ARHF.KL=CLIP(HF.K*SRHFST.K*(1-MSHFST.K)+HF.K*SRHFLT.K*(1-MSHFLT.K)+
X      HD.K*SRHDHF.K*(1-MSHFHD.K)+FT.K*SRFTHF.K*(1-MSHFFT.K)+
X      FR.K*SRFRHF.K*(1-MSHFFR.K)+FD.K*SRFDHF.K*(1-MSHFFD.K)+
X      FH.K*SRFHHF.K*(1-MSHFFH.K)+FG.K*SRFGHF.K*(1-MSHFFG.K)+
X      FX.K*SRFXHF.K*(1-MSHFFX.K)+FL.K*SRFLHF.K*(1-MSHFFL.K)+BK.K
X      *SRBKHF.K*(1-MSHFBK.K)+FU.K*SRFUHF.K*(1-MSHFFU.K)+FO.K*SRFOHF.K
X      *(1-MSHFFO.K)+FK.K*SRFKHF.K*(1-MSHFFK.K),0,TIME.K,WAR)    (A-3HF)
R    ARHV.KL=CLIP(HV.K*SRHVST.K*(1-MSHVST.K)+HV.K*SRHVLT.K*(1-MSHVLT.K)+
X      HD.K*SRHDHV.K*(1-MSHVHD.K)+FT.K*SRFTHV.K*(1-MSHVFT.K)+
X      FR.K*SRFRHV.K*(1-MSHVFR.K)+FD.K*SRFDHV.K*(1-MSHVFD.K)+
X      FH.K*SRFHHV.K*(1-MSHVFH.K)+FG.K*SRFGHV.K*(1-MSHVFG.K)+
X      FX.K*SRFXHV.K*(1-MSHVFX.K)+FL.K*SRFLHV.K*(1-MSHVFL.K)+BK.K
X      *SRBKHV.K*(1-MSHVBK.K)+FU.K*SRFUHV.K*(1-MSHVFU.K)+FO.K*SRFOHV.K
X      *(1-MSHVFO.K)+FK.K*SRFKHV.K*(1-MSHVFK.K),0,TIME.K,WAR)    (A-3HV)
R    ARIA.KL=CLIP(IA.K*SRIAST.K*(1-MSIAST.K)+IA.K*SRIALT.K*(1-MSIALT.K)+
X      HD.K*SRHDIA.K*(1-MSIAHD.K)+FT.K*SRFTIA.K*(1-MSIAFT.K)+
X      FR.K*SRFRIA.K*(1-MSIAFR.K)+FD.K*SRFDIA.K*(1-MSIAFD.K)+
X      FH.K*SRFHIA.K*(1-MSIAFH.K)+FG.K*SRFGIA.K*(1-MSIAFG.K)+
X      FX.K*SRFXIA.K*(1-MSIAFX.K)+FL.K*SRFLIA.K*(1-MSIAFL.K)+BK.K
X      *SRBKIA.K*(1-MSIABK.K)+FU.K*SRFUIA.K*(1-MSIAFU.K)+FO.K*SRFOIA.K
X      *(1-MSIAFO.K)+FK.K*SRFKIA.K*(1-MSIAFK.K),0,TIME.K,WAR)    (A-3IA)
R    ARXF.KL=CLIP(XF.K*SRXFST.K*(1-MSXFST.K)+XF.K*SRXFLT.K*(1-MSXFLT.K)+
X      HD.K*SRHDXF.K*(1-MSXFHD.K)+FT.K*SRFTXF.K*(1-MSXFFT.K)+
X      FR.K*SRFRXF.K*(1-MSXFFR.K)+FD.K*SRFDXF.K*(1-MSXFFD.K)+
X      FH.K*SRFHXF.K*(1-MSXFFH.K)+FG.K*SRFGXF.K*(1-MSXFFG.K)+
X      FX.K*SRFXXF.K*(1-MSXFFX.K)+FL.K*SRFLXF.K*(1-MSXFFL.K)+BK.K
X      *SRBKXF.K*(1-MSXFBK.K)+FU.K*SRFUXF.K*(1-MSXFFU.K)+FO.K*SRFOXF.K
X      *(1-MSXFFO.K)+FK.K*SRFKXF.K*(1-MSXFFK.K),0,TIME.K,WAR)    (A-3XF)
R    ARXV.KL=CLIP(XV.K*SRXVST.K*(1-MSXVST.K)+XV.K*SRXVLT.K*(1-MSXVLT.K)+
X      HD.K*SRHDXV.K*(1-MSXVHD.K)+FT.K*SRFTXV.K*(1-MSXVFT.K)+
X      FR.K*SRFRXV.K*(1-MSXVFR.K)+FD.K*SRFDXV.K*(1-MSXVFD.K)+
X      FH.K*SRFHXV.K*(1-MSXVFH.K)+FG.K*SRFGXV.K*(1-MSXVFG.K)+
X      FX.K*SRFXXV.K*(1-MSXVFX.K)+FL.K*SRFLXV.K*(1-MSXVFL.K)+BK.K
X      *SRBKXV.K*(1-MSXVBK.K)+FU.K*SRFUXV.K*(1-MSXVFU.K)+FO.K*SRFOXV.K
X      *(1-MSXVFO.K)+FK.K*SRFKXV.K*(1-MSXVFK.K),0,TIME.K,WAR)    (A-3XV)
R    ARXA.KL=CLIP(XA.K*SRXAST.K*(1-MSXAST.K)+XA.K*SRXALT.K*(1-MSXALT.K)+
X      HD.K*SRHDXA.K*(1-MSXAHD.K)+FT.K*SRFTXA.K*(1-MSXAFT.K)+
X      FR.K*SRFRXA.K*(1-MSXAFR.K)+FD.K*SRFDXA.K*(1-MSXAFD.K)+
X      FH.K*SRFHXA.K*(1-MSXAFH.K)+FG.K*SRFGXA.K*(1-MSXAFG.K)+
X      FX.K*SRFXXA.K*(1-MSXAFX.K)+FL.K*SRFLXA.K*(1-MSXAFL.K)+BK.K
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X     *SRBKXA.K*(1-MSXABK.K)+FU.K*SRFUXA.K*(1-MSXAFU.K)+FO.K*SRFOXA.K
X     *(1-MSXAFO.K)+FK.K*SRFKXA.K*(1-MSXAFK.K),0,TIME.K,WAR)   (A-3XA)
NOTE  ARHH - ATTRITION RATE APACHE AH-64 AIRCRAFT (AC/DAY)
NOTE  ARTA - ATTRITION RATE THUNDERBOLT A-10 AIRCRAFT (AC/DAY)
NOTE  ARXS - ATTRITION RATE STEALTH STRIKE AIRCRAFT (AC/DAY)
NOTE  ARFF - ATTRITION RATE FALCON F-16 AIRCRAFT (AC/DAY)
NOTE  ARHH - ATTRITION RATE EAGLE F-15 AIRCRAFT (AC/DAY)
NOTE  ARTF - ATTRITION RATE TOMCAT F-14 AIRCRAFT (AC/DAY)
NOTE  ARHF - ATTRITION RATE HORNET F/A-18 AIRCRAFT (AC/DAY)
NOTE  ARHV - ATTRITION RATE HARRIER AV-8 AIRCRAFT (AC/DAY)
NOTE  ARIA - ATTRITION RATE INTRUDER A-6 AIRCRAFT (AC/DAY)
NOTE  ARXF - ATTRITION RATE ADVANCED TACTICAL FIGHTER ATF (AC/DAY)
NOTE  ARXV - ATTRITION RATE VTOL FIGHTER MULTIMISSION VFMX (AC/DAY)
NOTE  ARXA - ATTRITION RATE ADVANCED TACTICAL ATTACK ATA (AC/DAY)
L    CLHH.K=CLHH.J+(DT)(ARHH.JK)                                 (A-4HH)
L    CLTA.K=CLTA.J+(DT)(ARTA.JK)                                 (A-4TA)
L    CLXS.K=CLXS.J+(DT)(ARXS.JK)                                 (A-4XS)
L    CLFF.K=CLFF.J+(DT)(ARFF.JK)                                 (A-4FF)
L    CLEF.K=CLEF.J+(DT)(AREF.JK)                                 (A-4EF)
L    CLTF.K=CLTF.J+(DT)(ARTF.JK)                                 (A-4TF)
L    CLHF.K=CLHF.J+(DT)(ARHF.JK)                                 (A-4HF)
L    CLHV.K=CLHV.J+(DT)(ARHV.JK)                                 (A-4HV)
L    CLIA.K=CLIA.J+(DT)(ARIA.JK)                                 (A-4IA)
L    CLXF.K=CLXF.J+(DT)(ARXF.JK)                                 (A-4XF)
L    CLXV.K=CLXV.J+(DT)(ARXV.JK)                                 (A-4XV)
L    CLXA.K=CLXA.J+(DT)(ARXA.JK)                                 (A-4XA)
N    CLHH=.01                                                   (A-4.1HH)
N    CLTA=.01                                                   (A-4.1TA)
N    CLXS=.01                                                   (A-4.1XS)
N    CLFF=.01                                                   (A-4.1FF)
N    CLEF=.01                                                   (A-4.1EF)
N    CLTF=.01                                                   (A-4.1TF)
N    CLHF=.01                                                   (A-4.1HF)
N    CLHV=.01                                                   (A-4.1HV)
N    CLIA=.01                                                   (A-4.1IA)
N    CLXF=.01                                                   (A-4.1XF)
N    CLXV=.01                                                   (A-4.1XV)
N    CLXA=.01                                                   (A-4.1XA)
NOTE  CL$$ - CUMULATIVE LOSSES $$ AIRCRAFT (AIRCRAFT)
A    CL$$.K=CLHH.K+CLTA.K+CLXS.K+CLFF.K+CLEF.K+CLTF.K+CLHF.K+CLHV.K
X      +CLIA.K+CLXF.K+CLXV.K+CLXA.K                              (A-5)
NOTE  CL$$ - TOTAL CUMULATIVE LOSSES OF U.S. AIRCRAFT (AIRCRAFT)
NOTE
NOTE      +-------------------------------------------+
NOTE      |    MISSION     VS.    SEA    TARGETS       |
NOTE      +-------------------------------------------+
NOTE
A    SRHHST.K=FSHHST*MIN(AAHHST/(1-MSHHST.K),SRHHM*AVHH)        (A-6HH)
A    SRTAST.K=FSTAST*MIN(AATAST/(1-MSTAST.K),SRTAM*AVTA)        (A-6TA)
A    SRXSST.K=FSXSST*MIN(AAXSST/(1-MSXSST.K),SRXSM*AVXS)        (A-6XS)
A    SRFFST.K=FSFFST*MIN(AAFFST/(1-MSFFST.K),SRFFM*AVFF)        (A-6FF)
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A    SREFST.K=FSEFST*MIN(AAEFST/(1-MSEFST.K),SREFM*AVEF)          (A-6EF)
A    SRTFST.K=FSTFST*MIN(AATFST/(1-MSTFST.K),SRTFM*AVTF)          (A-6TF)
A    SRHFST.K=FSHFST*MIN(AAHFST/(1-MSHFST.K),SRHFM*AVHF)          (A-6HF)
A    SRHVST.K=FSHVST*MIN(AAHVST/(1-MSHVST.K),SRHVM*AVHV)          (A-6HV)
A    SRIAST.K=FSIAST*MIN(AAIAST/(1-MSIAST.K),SRIAM*AVIA)          (A-6IA)
A    SRXFST.K=FSXFST*MIN(AAXFST/(1-MSXFST.K),SRXFM*AVXF)          (A-6XF)
A    SRXVST.K=FSXVST*MIN(AAXVST/(1-MSXVST.K),SRXVM*AVXV)          (A-6XV)
A    SRXAST.K=FSXAST*MIN(AAXAST/(1-MSXAST.K),SRXAM*AVXA)          (A-6XA)
NOTE  SRHHST - SORTIE RATE AH-1 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRTAST - SORTIE RATE A-10 VS SEA  TARGETS (AC/AC-DAY)
NOTE  SRXSST - SORTIE RATE STEALTH STRIKE VS SEA  TARGETS (AC/AC-DAY)
NOTE  SRFFST - SORTIE RATE F-16 VS SEA TARGETS (AC/AC-DAY)
NOTE  SREFST - SORTIE RATE F-15 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRTFST - SORTIE RATE F-14 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRHFST - SORTIE RATE F/A-18 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRHVST - SORTIE RATE AV-8 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRIAST - SORTIE RATE A-6 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRXFST - SORTIE RATE ATF VS SEA TARGETS (AC/AC-DAY)
NOTE  SRXVST - SORTIE RATE VFMX VS SEA TARGETS (AC/AC-DAY)
NOTE  SRXAST - SORTIE RATE ATA VS SEA TARGETS (AC/AC-DAY)
C    SRHHM=4                                                    (A-6.1HH)
C    SRTAM=4                                                    (A-6.1TA)
C    SRXSM=4                                                    (A-6.1XS)
C    SRFFM=4                                                    (A-6.1FF)
C    SREFM=4                                                    (A-6.1EF)
C    SRTFM=4                                                    (A-6.1TF)
C    SRHFM=4                                                    (A-6.1HF)
C    SRHVM=4                                                    (A-6.1HV)
C    SRIAM=4                                                    (A-6.1IA)
C    SRXFM=4                                                    (A-6.1XF)
C    SRXVM=4                                                    (A-6.1XV)
C    SRXAM=4                                                    (A-6.1XA)
NOTE  SR$$M - SORTIE RATE MAXIMUM $$ (AC/AC-DAY)
C    AVHH=.67                                                    (A-6.2HH)
C    AVTA=.67                                                    (A-6.2TA)
C    AVXS=.67                                                    (A-6.2XS)
C    AVFF=.67                                                    (A-6.2FF)
C    AVEF=.67                                                    (A-6.2EF)
C    AVTF=.67                                                    (A-6.2TF)
C    AVHF=.67                                                    (A-6.2HF)
C    AVHV=.67                                                    (A-6.2HV)
C    AVIA=.67                                                    (A-6.2IA)
C    AVXF=.67                                                    (A-6.2XF)
C    AVXV=.67                                                    (A-6.2XV)
C    AVXA=.67                                                    (A-6.2XA)
NOTE  AV$$ - AVAILABILITY OF $$ (PROB)
C    FSHHST=0                                                   (A-6.3HH)
C    FSTAST=.30                                                 (A-6.3TA)
C    FSXSST=0                                                   (A-6.3XS)
C    FSFFST=.1                                                  (A-6.3FF)
C    FSEFST=.2                                                  (A-6.3EF)
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C    FSTFST=.2                                                   (A-6.2TF)
C    FSHFST=.4                                                   (A-6.3HF)
C    FSHVST=.6                                                   (A-6.3HV)
C    FSIAST=.75                                                  (A-6.3IA)
C    FSXFST=0                                                    (A-6.3XF)
C    FSXVST=.2                                                   (A-6.3XV)
C    FSXAST=.35                                                  (A-6.3XA)
NOTE  FS$$ST - FRACT SORTIE $$ VS SEA TARGETS (DIM)
C    AAHHST=.10                                                  (A-6.4HH)
C    AATAST=.10                                                  (A-6.4TA)
C    AAXSST=.10                                                  (A-6.4XS)
C    AAFFST=.10                                                  (A-6.4FF)
C    AAEFST=.10                                                  (A-6.4EF)
C    AATFST=.10                                                  (A-6.4TF)
C    AAHFST=.10                                                  (A-6.4HF)
C    AAHVST=.10                                                  (A-6.4HV)
C    AAIAST=.10                                                  (A-6.4IA)
C    AAXFST=.10                                                  (A-6.4XF)
C    AAXVST=.10                                                  (A-6.4XV)
C    AAXAST=.10                                                  (A-6.4XA)
NOTE  AA$$ST - ALLOWABLE ATTRITION $$ VS SEA THREATS (FRACT/DAY)
A    MSHHST.K=MSHH.K*SHHSTM                                        (A-7HH)
A    MSTAST.K=MSTA.K*STASTM                                        (A-7TA)
A    MSXSST.K=MSXS.K*SXSSTM                                        (A-7XS)
A    MSFFST.K=MSFF.K*SFFSTM                                        (A-7FF)
A    MSEFST.K=MSEF.K*SEFSTM                                        (A-7EF)
A    MSTFST.K=MSTF.K*STFSTM                                        (A-7TF)
A    MSHFST.K=MSHF.K*SHFSTM                                        (A-7HF)
A    MSHVST.K=MSHV.K*SHVSTM                                        (A-7HV)
A    MSIAST.K=MSIA.K*SIASTM                                        (A-7IA)
A    MSXFST.K=MSXF.K*SXFSTM                                        (A-7XF)
A    MSXVST.K=MSXV.K*SXVSTM                                        (A-7XV)
A    MSXAST.K=MSXA.K*SXASTM                                        (A-7XA)
NOTE  MSHHST - MISSION SURVIVABILITY AH-64 VS SEA THREATS (PROB)
NOTE  MLTAST - MISSION SURVIVABILITY A-10 VS SEA THREATS (PROB)
NOTE  MSXSST - MISSION SURVIVABILITY STEALTH STRIKE VS SEA THREATS (PROB)
NOTE  MSFFST - MISSION SURVIVABILITY F-16 VS SEA THREATS (PROB)
NOTE  MSEFST - MISSION SURVIVABILITY F-15 VS SEA THREATS (PROB)
NOTE  MLTFST - MISSION SURVIVABILITY F-14 VS SEA THREATS (PROB)
NOTE  MSHFST - MISSION SURVIVABILITY F/A-18 VS SEA THREATS (PROB)
NOTE  MSHVST - MISSION SURVIVABILITY AV-8 VS SEA THREATS (PROB)
NOTE  MSIAST - MISSION SURVIVABILITY A-6 VS SEA THREATS (PROB)
NOTE  MSXFST - MISSION SURVIVABILITY ATF VS SEA THREATS (PROB)
NOTE  MSXVST - MISSION SURVIVABILITY VFMX VS SEA THREATS (PROB)
NOTE  MSXAST - MISSION SURVIVABILITY ATA VS SEA THREATS (PROB)
C    SHHSTM=.996                                                (A-7.1HH)
C    STASTM=.996                                                (A-7.1TA)
C    SXSSTM=.996                                                (A-7.1XS)
C    SFFSTM=.996                                                (A-7.1FF)
C    SEFSTM=.996                                                (A-7.1EF)
C    STFSTM=.996                                                (A-7.1TF)
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C    SHFSTM=.996                                              (A-7.1HF)
C    SHVSTM=.996                                              (A-7.1HV)
C    SIASTM=.996                                              (A-7.1IA)
C    SXFSTM=.996                                              (A-7.1XF)
C    SXVSTM=.996                                              (A-7.1XV)
C    SXASTM=.996                                              (A-7.1XA)
NOTE  SHHSTM - SURVIVABILITY AH-64 VS SEA THREATS MULT (DIM)
NOTE  STASTM - SURVIVABILITY A-10 VS SEA THREATS MULT (DIM)
NOTE  SXSSTM - SURVIVABILITY STEALTH STRIKE VS SEA THREATS MULT (DIM)
NOTE  SFFSTM - SURVIVABILITY F-16 VS SEA THREATS MULT (DIM)
NOTE  SEFSTM - SURVIVABILITY F-15 VS SEA THREATS MULT (DIM)
NOTE  STFSTM - SURVIVABILITY F-14 VS SEA THREATS MULT (DIM)
NOTE  SHFSTM - SURVIVABILITY F/A-18 VS SEA THREATS MULT (DIM)
NOTE  SHVSTM - SURVIVABILITY AV-8 VS SEA THREATS MULT (DIM)
NOTE  SIASTM - SURVIVABILITY A-6 VS SEA THREATS MULT (DIM)
NOTE  SXFSTM - SURVIVABILITY ATF VS SEA THREATS MULT (DIM)
NOTE  SXVSTM - SURVIVABILITY VFMX VS SEA THREATS MULT (DIM)
NOTE  SXASTM - SURVIVABILITY ATA VS SEA THREATS MULT (DIM)
NOTE
NOTE      +-------------------------------------------+
NOTE      |      MISSION    VS.   LAND   TARGETS      |
NOTE      +-------------------------------------------+
NOTE
A    SRHHLT.K=FSHHLT*MIN(AAHHLT/(1-MSHHLT.K),SRHHM*AVHH)         (A-23HH)
A    SRTALT.K=FSTALT*MIN(AATALT/(1-MSTALT.K),SRTAM*AVTA)         (A-23TA)
A    SRXSLT.K=FSXSLT*MIN(AAXSLT/(1-MSXSLT.K),SRXSM*AVXS)         (A-23XS)
A    SRFFLT.K=FSFFLT*MIN(AAFFLT/(1-MSFFLT.K),SRFFM*AVFF)         (A-23FF)
A    SREFLT.K=FSEFLT*MIN(AAEFLT/(1-MSEFLT.K),SREFM*AVEF)         (A-23EF)
A    SRTFLT.K=FSTFLT*MIN(AATFLT/(1-MSTFLT.K),SRTFM*AVTF)         (A-23TF)
A    SRHFLT.K=FSHFLT*MIN(AAHFLT/(1-MSHFLT.K),SRHFM*AVHF)         (A-23HF)
A    SRHVLT.K=FSHVLT*MIN(AAHVLT/(1-MSHVLT.K),SRHVM*AVHV)         (A-23HV)
A    SRIALT.K=FSIALT*MIN(AAIALT/(1-MSIALT.K),SRIAM*AVIA)         (A-23IA)
A    SRXFLT.K=FSXFLT*MIN(AAXFLT/(1-MSXFLT.K),SRXFM*AVXF)         (A-23XF)
A    SRXVLT.K=FSXVLT*MIN(AAXVLT/(1-MSXVLT.K),SRXVM*AVXV)         (A-23XV)
A    SRXALT.K=FSXALT*MIN(AAXALT/(1-MSXALT.K),SRXAM*AVXA)         (A-23XA)
NOTE  SRHHLT - SORTIE RATE AH-1 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRTALT - SORTIE RATE A-10 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRXSLT - SORTIE RATE STEALTH STRIKE VS LAND TARGETS (AC/AC-DAY)
NOTE  SRFFLT - SORTIE RATE F-16 VS LAND TARGETS (AC/AC-DAY)
NOTE  SREFLT - SORTIE RATE F-15 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRTFLT - SORTIE RATE F-14 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRHFLT - SORTIE RATE F/A-18 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRHVLT - SORTIE RATE AV-8 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRIALT - SORTIE RATE A-6 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRXFLT - SORTIE RATE ATF VS LAND TARGETS (AC/AC-DAY)
NOTE  SRXVLT - SORTIE RATE VFMX VS LAND TARGETS (AC/AC-DAY)
NOTE  SRXALT - SORTIE RATE ATA VS LAND TARGETS (AC/AC-DAY)
C    FSHHLT=.9                                                 (A-23.1HH)
C    FSTALT=.6                                                 (A-23.1TA)
C    FSXSLT=.85                                                (A-23.1XS)
C    FSFFLT=.1                                                 (A-23.1FF)
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C    FSEFLT=.1                                                   (A-23.1EF)
C    FSTFLT=.1                                                   (A-23.1TF)
C    FSHFLT=0                                                    (A-23.1HF)
C    FSHVLT=0                                                    (A-23.1HV)
C    FSIALT=.2                                                   (A-23.1IA)
C    FSXFLT=.3                                                   (A-23.1XF)
C    FSXVLT=.4                                                   (A-23.1XV)
C    FSXALT=.5                                                   (A-23.1XA)
NOTE  FS$$LT - FRACT SORTIE $$ VS LAND TARGETS  (DIM)
C    AAHHLT=.10                                                  (A-23.2HH)
C    AATALT=.10                                                  (A-23.2TA)
C    AAXSLT=.10                                                  (A-23.2XS)
C    AAFFLT=.10                                                  (A-23.2FF)
C    AAEFLT=.10                                                  (A-23.2EF)
C    AATFLT=.10                                                  (A-23.2TF)
C    AAHFLT=.10                                                  (A-23.2HF)
C    AAHVLT=.10                                                  (A-23.2HV)
C    AAIALT=.10                                                  (A-23.2IA)
C    AAXFLT=.10                                                  (A-23.2XF)
C    AAXVLT=.10                                                  (A-23.2XV)
C    AAXALT=.10                                                  (A-23.2XA)
NOTE  AA$$LT - ALLOWABLE ATTRITION $$ VS LAND THREATS (FRACT/DAY)
A    MSHHLT.K=MSHH.K*SHHLTM                                      (A-24HH)
A    MSTALT.K=MSTA.K*STALTM                                      (A-24TA)
A    MSXSLT.K=MSXS.K*SXSLTM                                      (A-24XS)
A    MSFFLT.K=MSFF.K*SFFLTM                                      (A-24FF)
A    MSEFLT.K=MSEF.K*SEFLTM                                      (A-24EF)
A    MSTFLT.K=MSTF.K*STFLTM                                      (A-24TF)
A    MSHFLT.K=MSHF.K*SHFLTM                                      (A-24HF)
A    MSHVLT.K=MSHV.K*SHVLTM                                      (A-24HV)
A    MSIALT.K=MSIA.K*SIALTM                                      (A-24IA)
A    MSXFLT.K=MSXF.K*SXFLTM                                      (A-24JV)
A    MSXVLT.K=MSXV.K*SXVLTM                                      (A-24AT)
A    MSXALT.K=MSXA.K*SXALTM                                      (A-24VF)
NOTE  MSHHLT - MISSION SURVIVABILITY AH-64 VS LAND THREATS (PROB)
NOTE  MLTALT - MISSION SURVIVABILITY A-10 VS LAND THREATS (PROB)
NOTE  MSXSLT - MISSION SURVIV. STEALTH STRIKE VS LAND THREATS (PROB)
NOTE  MSFFLT - MISSION SURVIVABILITY F-16 VS LAND THREATS (PROB)
NOTE  MSEFLT - MISSION SURVIVABILITY F-15 VS LAND THREATS (PROB)
NOTE  MLTFLT - MISSION SURVIVABILITY F-14 VS LAND THREATS (PROB)
NOTE  MSHFLT - MISSION SURVIVABILITY F/A-18 VS LAND THREATS (PROB)
NOTE  MSHVLT - MISSION SURVIVABILITY AV-8 VS LAND THREATS (PROB)
NOTE  MSIALT - MISSION SURVIVABILITY A-6 VS LAND THREATS (PROB)
NOTE  MSXFLT - MISSION SURVIVABILITY ATF VS LAND THREATS (PROB)
NOTE  MSXVLT - MISSION SURVIVABILITY VFMX VS LAND THREATS (PROB)
NOTE  MSXALT - MISSION SURVIVABILITY ATA VS LAND THREATS (PROB)
C    SHHLTM=.994                                                (A-24.1HH)
C    STALTM=.994                                                (A-24.1TA)
C    SXSLTM=.994                                                (A-24.1XS)
C    SFFLTM=.994                                                (A-24.1FF)
C    SEFLTM=.994                                                (A-24.1EF)
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C    STFLTM=.994                                                 (A-24.1TF)
C    SHFLTM=.994                                                 (A-24.1HF)
C    SHVLTM=.994                                                 (A-24.1HV)
C    SIALTM=.994                                                 (A-24.1IA)
C    SXFLTM=.994                                                 (A-24.1XF)
C    SXVLTM=.994                                                 (A-24.1XV)
C    SXALTM=.994                                                 (A-24.1XA)
NOTE  SHHLTM - SURVIVABILITY AH-64 VS LAND THREATS MULT (DIM)
NOTE  STALTM - SURVIVABILITY A-10 VS LAND THREATS MULT (DIM)
NOTE  SXSLTM - SURVIVABILITY STEALTH STRIKE VS LAND THREATS MULT (DIM)
NOTE  SFFLTM - SURVIVABILITY F-16 VS LAND THREATS MULT (DIM)
NOTE  SEFLTM - SURVIVABILITY F-15 VS LAND THREATS MULT (DIM)
NOTE  STFLTM - SURVIVABILITY F-14 VS LAND THREATS MULT (DIM)
NOTE  SHFLTM - SURVIVABILITY F/A-18 VS LAND THREATS MULT (DIM)
NOTE  SHVLTM - SURVIVABILITY AV-8 VS LAND THREATS MULT (DIM)
NOTE  SIALTM - SURVIVABILITY A-6 VS LAND THREATS MULT (DIM)
NOTE  SXFLTM - SURVIVABILITY ATF VS LAND THREATS MULT (DIM)
NOTE  SXVLTM - SURVIVABILITY VFMX VS LAND THREATS MULT (DIM)
NOTE  SXALTM - SURVIVABILITY ATA VS LAND THREATS MULT (DIM)
NOTE
NOTE      +---------------------------------------+
NOTE      |       MISSION     VS.   AIRCRAFT      |
NOTE      +---------------------------------------+
NOTE
A    SRHHHD.K=FSHHAT*EHHHD.K*MIN(AAHDAT/(1-MSHDHH.K),SRHHM*AVHH) (A-40HH)
A    SRTAHD.K=FSTAAT*ETAHD.K*MIN(AAHDAT/(1-MSHDTA.K),SRTAM*AVTA) (A-40TA)
A    SRXSHD.K=FSXSAT*EXSHD.K*MIN(AAHDAT/(1-MSHDXS.K),SRXSM*AVXS) (A-40XS)
A    SRFFHD.K=FSFFAT*EFFHD.K*MIN(AAHDAT/(1-MSHDFF.K),SRFFM*AVFF) (A-40FF)
A    SREFHD.K=FSEFAT*EEFHD.K*MIN(AAHDAT/(1-MSHDEF.K),SREFM*AVEF) (A-40EF)
A    SRTFHD.K=FSTFAT*ETFHD.K*MIN(AAHDAT/(1-MSHDTF.K),SRTFM*AVTF) (A-40TF)
A    SRHFHD.K=FSHFAT*EHFHD.K*MIN(AAHDAT/(1-MSHDHF.K),SRHFM*AVHF) (A-40HF)
A    SRHVHD.K=FSHVAT*EHVHD.K*MIN(AAHDAT/(1-MSHDHV.K),SRHVM*AVHV) (A-40HV)
A    SRIAHD.K=FSIAAT*EIAHD.K*MIN(AAHDAT/(1-MSHDIA.K),SRIAM*AVIA) (A-40IA)
A    SRXFHD.K=FSXFAT*EXFHD.K*MIN(AAHDAT/(1-MSHDXF.K),SRXFM*AVXF) (A-40XF)
A    SRXVHD.K=FSXVAT*EXVHD.K*MIN(AAHDAT/(1-MSHDXV.K),SRXVM*AVXV) (A-40XV)
A    SRXAHD.K=FSXAAT*EXAHD.K*MIN(AAHDAT/(1-MSHDXA.K),SRXAM*AVXA) (A-40XA)
NOTE SR$$HD - SORTIE RATE OF $$ VS MI-24 (AC/AC-DAY)
A    SRHHFT.K=FSHHAT*EHHFT.K*MIN(AAFTAT/(1-MSFTHH.K),SRHHM*AVHH) (A-41HH)
A    SRTAFT.K=FSTAAT*ETAFT.K*MIN(AAFTAT/(1-MSFTTA.K),SRTAM*AVTA) (A-41TA)
A    SRXSFT.K=FSXSAT*EXSFT.K*MIN(AAFTAT/(1-MSFTXS.K),SRXSM*AVXS) (A-41XS)
A    SRFFFT.K=FSFFAT*EFFFT.K*MIN(AAFTAT/(1-MSFTFF.K),SRFFM*AVFF) (A-41FF)
A    SREFFT.K=FSEFAT*EEFFT.K*MIN(AAFTAT/(1-MSFTEF.K),SREFM*AVEF) (A-41EF)
A    SRTFFT.K=FSTFAT*ETFFT.K*MIN(AAFTAT/(1-MSFTTF.K),SRTFM*AVTF) (A-41TF)
A    SRHFFT.K=FSHFAT*EHFFT.K*MIN(AAFTAT/(1-MSFTHF.K),SRHFM*AVHF) (A-41HF)
A    SRHVFT.K=FSHVAT*EHVFT.K*MIN(AAFTAT/(1-MSFTHV.K),SRHVM*AVHV) (A-41HV)
A    SRIAFT.K=FSIAAT*EIAFT.K*MIN(AAFTAT/(1-MSFTIA.K),SRIAM*AVIA) (A-41IA)
A    SRXFFT.K=FSXFAT*EXFFT.K*MIN(AAFTAT/(1-MSFTXF.K),SRXFM*AVXF) (A-41XF)
A    SRXVFT.K=FSXVAT*EXVFT.K*MIN(AAFTAT/(1-MSFTXV.K),SRXVM*AVXV) (A-41XV)
A    SRXAFT.K=FSXAAT*EXAFT.K*MIN(AAFTAT/(1-MSFTXA.K),SRXAM*AVXA) (A-41XA)
NOTE SR$$FT - SORTIE RATE OF $$ VS SU-17/SU-20/SU-22 (AC/AC-DAY)
A    SRHHFR.K=FSHHAT*EHHFR.K*MIN(AAFRAT/(1-MSFRHH.K),SRHHM*AVHH) (A-42HH)
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A    SRTAFR.K=FSTAAT*ETAFR.K*MIN(AAFRAT/(1-MSFRTA.K),SRTAM*AVTA)  (A-42TA)
A    SRXSFR.K=FSXSAT*EXSFR.K*MIN(AAFRAT/(1-MSFRXS.K),SRXSM*AVXS)  (A-42XS)
A    SRFFFR.K=FSFFAT*EFFFR.K*MIN(AAFRAT/(1-MSFRFF.K),SRFFM*AVFF)  (A-42FF)
A    SREFFR.K=FSEFAT*EEFFR.K*MIN(AAFRAT/(1-MSFREF.K),SREFM*AVEF)  (A-42EF)
A    SRTFFR.K=FSTFAT*ETFFR.K*MIN(AAFRAT/(1-MSFRTF.K),SRTFM*AVTF)  (A-42TF)
A    SRHFFR.K=FSHFAT*EHFFR.K*MIN(AAFRAT/(1-MSFRHF.K),SRHFM*AVHF)  (A-42HF)
A    SRHVFR.K=FSHVAT*EHVFR.K*MIN(AAFRAT/(1-MSFRHV.K),SRHVM*AVHV)  (A-42HV)
A    SRIAFR.K=FSIAAT*EIAFR.K*MIN(AAFRAT/(1-MSFRIA.K),SRIAM*AVIA)  (A-42IA)
A    SRXFFR.K=FSXFAT*EXFFR.K*MIN(AAFRAT/(1-MSFRXF.K),SRXFM*AVXF)  (A-42XF)
A    SRXVFR.K=FSXVAT*EXVFR.K*MIN(AAFRAT/(1-MSFRXV.K),SRXVM*AVXV)  (A-42XV)
A    SRXAFR.K=FSXAAT*EXAFR.K*MIN(AAFRAT/(1-MSFRXA.K),SRXAM*AVXA)  (A-42XA)
NOTE SR$$FR - SORTIE RATE OF $$ VS SU-19/SU-24 (AC/AC-DAY)
A    SRHHFD.K=FSHHAT*EHHFD.K*MIN(AAFDAT/(1-MSFDHH.K),SRHHM*AVHH)  (A-43HH)
A    SRTAFD.K=FSTAAT*ETAFD.K*MIN(AAFDAT/(1-MSFDTA.K),SRTAM*AVTA)  (A-43TA)
A    SRXSFD.K=FSXSAT*EXSFD.K*MIN(AAFDAT/(1-MSFDXS.K),SRXSM*AVXS)  (A-43XS)
A    SRFFFD.K=FSFFAT*EFFFD.K*MIN(AAFDAT/(1-MSFDFF.K),SRFFM*AVFF)  (A-43FF)
A    SREFFD.K=FSEFAT*EEFFD.K*MIN(AAFDAT/(1-MSFDEF.K),SREFM*AVEF)  (A-43EF)
A    SRTFFD.K=FSTFAT*ETFFD.K*MIN(AAFDAT/(1-MSFDTF.K),SRTFM*AVTF)  (A-43TF)
A    SRHFFD.K=FSHFAT*EHFFD.K*MIN(AAFDAT/(1-MSFDHF.K),SRHFM*AVHF)  (A-43HF)
A    SRHVFD.K=FSHVAT*EHVFD.K*MIN(AAFDAT/(1-MSFDHV.K),SRHVM*AVHV)  (A-43HV)
A    SRIAFD.K=FSIAAT*EIAFD.K*MIN(AAFDAT/(1-MSFDIA.K),SRIAM*AVIA)  (A-43IA)
A    SRXFFD.K=FSXFAT*EXFFD.K*MIN(AAFDAT/(1-MSFDXF.K),SRXFM*AVXF)  (A-43XF)
A    SRXVFD.K=FSXVAT*EXVFD.K*MIN(AAFDAT/(1-MSFDXV.K),SRXVM*AVXV)  (A-43XV)
A    SRXAFD.K=FSXAAT*EXAFD.K*MIN(AAFDAT/(1-MSFDXA.K),SRXAM*AVXA)  (A-43XA)
NOTE SR$$FD - SORTIE RATE OF $$ VS MIG-21 (AC/AC-DAY)
A    SRHHFH.K=FSHHAT*EHHFH.K*MIN(AAFHAT/(1-MSFHHH.K),SRHHM*AVHH)  (A-44HH)
A    SRTAFH.K=FSTAAT*ETAFH.K*MIN(AAFHAT/(1-MSFHTA.K),SRTAM*AVTA)  (A-44TA)
A    SRXSFH.K=FSXSAT*EXSFH.K*MIN(AAFHAT/(1-MSFHXS.K),SRXSM*AVXS)  (A-44XS)
A    SRFFFH.K=FSFFAT*EFFFH.K*MIN(AAFHAT/(1-MSFHFF.K),SRFFM*AVFF)  (A-44FF)
A    SREFFH.K=FSEFAT*EEFFH.K*MIN(AAFHAT/(1-MSFHEF.K),SREFM*AVEF)  (A-44EF)
A    SRTFFH.K=FSTFAT*ETFFH.K*MIN(AAFHAT/(1-MSFHTF.K),SRTFM*AVTF)  (A-44TF)
A    SRHFFH.K=FSHFAT*EHFFH.K*MIN(AAFHAT/(1-MSFHHF.K),SRHFM*AVHF)  (A-44HF)
A    SRHVFH.K=FSHVAT*EHVFH.K*MIN(AAFHAT/(1-MSFHHV.K),SRHVM*AVHV)  (A-44HV)
A    SRIAFH.K=FSIAAT*EIAFH.K*MIN(AAFHAT/(1-MSFHIA.K),SRIAM*AVIA)  (A-44IA)
A    SRXFFH.K=FSXFAT*EXFFH.K*MIN(AAFHAT/(1-MSFHXF.K),SRXFM*AVXF)  (A-44XF)
A    SRXVFH.K=FSXVAT*EXVFH.K*MIN(AAFHAT/(1-MSFHXV.K),SRXVM*AVXV)  (A-44XV)
A    SRXAFH.K=FSXAAT*EXAFH.K*MIN(AAFHAT/(1-MSFHXA.K),SRXAM*AVXA)  (A-44XA)
NOTE SR$$FH - SORTIE RATE OF $$ VS MIG-25M (AC/AC-DAY)
A    SRHHFG.K=FSHHAT*EHHFG.K*MIN(AAFGAT/(1-MSFGHH.K),SRHHM*AVHH)  (A-45HH)
A    SRTAFG.K=FSTAAT*ETAFG.K*MIN(AAFGAT/(1-MSFGTA.K),SRTAM*AVTA)  (A-45TA)
A    SRXSFG.K=FSXSAT*EXSFG.K*MIN(AAFGAT/(1-MSFGXS.K),SRXSM*AVXS)  (A-45XS)
A    SRFFFG.K=FSFFAT*EFFFG.K*MIN(AAFGAT/(1-MSFGFF.K),SRFFM*AVFF)  (A-45FF)
A    SREFFG.K=FSEFAT*EEFFG.K*MIN(AAFGAT/(1-MSFGEF.K),SREFM*AVEF)  (A-45EF)
A    SRTFFG.K=FSTFAT*ETFFG.K*MIN(AAFGAT/(1-MSFGTF.K),SRTFM*AVTF)  (A-45TF)
A    SRHFFG.K=FSHFAT*EHFFG.K*MIN(AAFGAT/(1-MSFGHF.K),SRHFM*AVHF)  (A-45HF)
A    SRHVFG.K=FSHVAT*EHVFG.K*MIN(AAFGAT/(1-MSFGHV.K),SRHVM*AVHV)  (A-45HV)
A    SRIAFG.K=FSIAAT*EIAFG.K*MIN(AAFGAT/(1-MSFGIA.K),SRIAM*AVIA)  (A-45IA)
A    SRXFFG.K=FSXFAT*EXFFG.K*MIN(AAFGAT/(1-MSFGXF.K),SRXFM*AVXF)  (A-45XF)
A    SRXVFG.K=FSXVAT*EXVFG.K*MIN(AAFGAT/(1-MSFGXV.K),SRXVM*AVXV)  (A-45XV)
A    SRXAFG.K=FSXAAT*EXAFG.K*MIN(AAFGAT/(1-MSFGXA.K),SRXAM*AVXA)  (A-45XA)
NOTE SR$$FG - SORTIE RATE OF $$ VS MIG-23/MIG-27 (AC/AC-DAY)
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A   SRHHFX.K=FSHHAT*EHHFX.K*MIN(AAFXAT/(1-MSFXHH.K),SRHHM*AVHH) (A-46HH)
A   SRTAFX.K=FSTAAT*ETAFX.K*MIN(AAFXAT/(1-MSFXTA.K),SRTAM*AVTA) (A-46TA)
A   SRXSFX.K=FSXSAT*EXSFX.K*MIN(AAFXAT/(1-MSFXXS.K),SRXSM*AVXS) (A-46XS)
A   SRFFFX.K=FSFFAT*EFFFX.K*MIN(AAFXAT/(1-MSFXFF.K),SRFFM*AVFF) (A-46FF)
A   SREFFX.K=FSEFAT*EEFFX.K*MIN(AAFXAT/(1-MSFXEF.K),SREFM*AVEF) (A-46EF)
A   SRTFFX.K=FSTFAT*ETFFX.K*MIN(AAFXAT/(1-MSFXTF.K),SRTFM*AVTF) (A-46TF)
A   SRHFFX.K=FSHFAT*EHFFX.K*MIN(AAFXAT/(1-MSFXHF.K),SRHFM*AVHF) (A-46HF)
A   SRHVFX.K=FSHVAT*EHVFX.K*MIN(AAFXAT/(1-MSFXHV.K),SRHVM*AVHV) (A-46HV)
A   SRIAFX.K=FSIAAT*EIAFX.K*MIN(AAFXAT/(1-MSFXIA.K),SRIAM*AVIA) (A-46IA)
A   SRXFFX.K=FSXFAT*EXFFX.K*MIN(AAFXAT/(1-MSFXXF.K),SRXFM*AVXF) (A-46XF)
A   SRXVFX.K=FSXVAT*EXVFX.K*MIN(AAFXAT/(1-MSFXXV.K),SRXVM*AVXV) (A-46XV)
A   SRXAFX.K=FSXAAT*EXAFX.K*MIN(AAFXAT/(1-MSFXXA.K),SRXAM*AVXA) (A-46XA)
NOTE SR$$FX - SORTIE RATE OF $$ VS MIG-25 (AC/AC-DAY)
A   SRHHFL.K=FSHHAT*EHHFL.K*MIN(AAFLAT/(1-MSFLHH.K),SRHHM*AVHH) (A-47HH)
A   SRTAFL.K=FSTAAT*ETAFL.K*MIN(AAFLAT/(1-MSFLTA.K),SRTAM*AVTA) (A-47TA)
A   SRXSFL.K=FSXSAT*EXSFL.K*MIN(AAFLAT/(1-MSFLXS.K),SRXSM*AVXS) (A-47XS)
A   SRFFFL.K=FSFFAT*EFFFL.K*MIN(AAFLAT/(1-MSFLFF.K),SRFFM*AVFF) (A-47FF)
A   SREFFL.K=FSEFAT*EEFFL.K*MIN(AAFLAT/(1-MSFLEF.K),SREFM*AVEF) (A-47EF)
A   SRTFFL.K=FSTFAT*ETFFL.K*MIN(AAFLAT/(1-MSFLTF.K),SRTFM*AVTF) (A-47TF)
A   SRHFFL.K=FSHFAT*EHFFL.K*MIN(AAFLAT/(1-MSFLHF.K),SRHFM*AVHF) (A-47HF)
A   SRHVFL.K=FSHVAT*EHVFL.K*MIN(AAFLAT/(1-MSFLHV.K),SRHVM*AVHV) (A-47HV)
A   SRIAFL.K=FSIAAT*EIAFL.K*MIN(AAFLAT/(1-MSFLIA.K),SRIAM*AVIA) (A-47IA)
A   SRXFFL.K=FSXFAT*EXFFL.K*MIN(AAFLAT/(1-MSFLXF.K),SRXFM*AVXF) (A-47XF)
A   SRXVFL.K=FSXVAT*EXVFL.K*MIN(AAFLAT/(1-MSFLXV.K),SRXVM*AVXV) (A-47XV)
A   SRXAFL.K=FSXAAT*EXAFL.K*MIN(AAFLAT/(1-MSFLXA.K),SRXAM*AVXA) (A-47XA)
NOTE SR$$FL - SORTIE RATE OF $$ VS TU-28P/TU-128 (AC/AC-DAY)
A   SRHHBK.K=FSHHAT*EHHBK.K*MIN(AABKAT/(1-MSBKHH.K),SRHHM*AVHH) (A-48HH)
A   SRTABK.K=FSTAAT*ETABK.K*MIN(AABKAT/(1-MSBKTA.K),SRTAM*AVTA) (A-48TA)
A   SRXSBK.K=FSXSAT*EXSBK.K*MIN(AABKAT/(1-MSBKXS.K),SRXSM*AVXS) (A-48XS)
A   SRFFBK.K=FSFFAT*EFFBK.K*MIN(AABKAT/(1-MSBKFF.K),SRFFM*AVFF) (A-48FF)
A   SREFBK.K=FSEFAT*EEFBK.K*MIN(AABKAT/(1-MSBKEF.K),SREFM*AVEF) (A-48EF)
A   SRTFBK.K=FSTFAT*ETFBK.K*MIN(AABKAT/(1-MSBKTF.K),SRTFM*AVTF) (A-48TF)
A   SRHFBK.K=FSHFAT*EHFBK.K*MIN(AABKAT/(1-MSBKHF.K),SRHFM*AVHF) (A-48HF)
A   SRHVBK.K=FSHVAT*EHVBK.K*MIN(AABKAT/(1-MSBKHV.K),SRHVM*AVHV) (A-48HV)
A   SRIABK.K=FSIAAT*EIABK.K*MIN(AABKAT/(1-MSBKIA.K),SRIAM*AVIA) (A-48IA)
A   SRXFBK.K=FSXFAT*EXFBK.K*MIN(AABKAT/(1-MSBKXF.K),SRXFM*AVXF) (A-48XF)
A   SRXVBK.K=FSXVAT*EXVBK.K*MIN(AABKAT/(1-MSBKXV.K),SRXVM*AVXV) (A-48XV)
A   SRXABK.K=FSXAAT*EXABK.K*MIN(AABKAT/(1-MSBKXA.K),SRXAM*AVXA) (A-48XA)
NOTE SR$$BK - SORTIE RATE OF $$ VS TU-22M (AC/AC-DAY)
A   SRHHFU.K=FSHHAT*EHHFU.K*MIN(AAFUAT/(1-MSFUHH.K),SRHHM*AVHH) (A-49HH)
A   SRTAFU.K=FSTAAT*ETAFU.K*MIN(AAFUAT/(1-MSFUTA.K),SRTAM*AVTA) (A-49TA)
A   SRXSFU.K=FSXSAT*EXSFU.K*MIN(AAFUAT/(1-MSFUXS.K),SRXSM*AVXS) (A-49XS)
A   SRFFFU.K=FSFFAT*EFFFU.K*MIN(AAFUAT/(1-MSFUFF.K),SRFFM*AVFF) (A-49FF)
A   SREFFU.K=FSEFAT*EEFFU.K*MIN(AAFUAT/(1-MSFUEF.K),SREFM*AVEF) (A-49EF)
A   SRTFFU.K=FSTFAT*ETFFU.K*MIN(AAFUAT/(1-MSFUTF.K),SRTFM*AVTF) (A-49TF)
A   SRHFFU.K=FSHFAT*EHFFU.K*MIN(AAFUAT/(1-MSFUHF.K),SRHFM*AVHF) (A-49HF)
A   SRHVFU.K=FSHVAT*EHVFU.K*MIN(AAFUAT/(1-MSFUHV.K),SRHVM*AVHV) (A-49HV)
A   SRIAFU.K=FSIAAT*EIAFU.K*MIN(AAFUAT/(1-MSFUIA.K),SRIAM*AVIA) (A-49IA)
A   SRXFFU.K=FSXFAT*EXFFU.K*MIN(AAFUAT/(1-MSFUXF.K),SRXFM*AVXF) (A-49XF)
A   SRXVFU.K=FSXVAT*EXVFU.K*MIN(AAFUAT/(1-MSFUXV.K),SRXVM*AVXV) (A-49XV)
A   SRXAFU.K=FSXAAT*EXAFU.K*MIN(AAFUAT/(1-MSFUXA.K),SRXAM*AVXA) (A-49XA)
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NOTE SR$$FU - SORTIE RATE OF $$ VS MIG-29 (AC/AC-DAY)
A    SRHHFO.K=FSHHAT*EHHFO.K*MIN(AAFOAT/(1-MSFOHH.K),SRHHM*AVHH) (A-50HH)
A    SRTAFO.K=FSTAAT*ETAFO.K*MIN(AAFOAT/(1-MSFOTA.K),SRTAM*AVTA) (A-50TA)
A    SRXSFO.K=FSXSAT*EXSFO.K*MIN(AAFOAT/(1-MSFOXS.K),SRXSM*AVXS) (A-50XS)
A    SRFFFO.K=FSFFAT*EFFFO.K*MIN(AAFOAT/(1-MSFOFF.K),SRFFM*AVFF) (A-50FF)
A    SREFFO.K=FSEFAT*EEFFO.K*MIN(AAFOAT/(1-MSFOEF.K),SREFM*AVEF) (A-50EF)
A    SRTFFO.K=FSTFAT*ETFFO.K*MIN(AAFOAT/(1-MSFOTF.K),SRTFM*AVTF) (A-50TF)
A    SRHFFO.K=FSHFAT*EHFFO.K*MIN(AAFOAT/(1-MSFOHF.K),SRHFM*AVHF) (A-50HF)
A    SRHVFO.K=FSHVAT*EHVFO.K*MIN(AAFOAT/(1-MSFOHV.K),SRHVM*AVHV) (A-50HV)
A    SRIAFO.K=FSIAAT*EIAFO.K*MIN(AAFOAT/(1-MSFOIA.K),SRIAM*AVIA) (A-50IA)
A    SRXFFO.K=FSXFAT*EXFFO.K*MIN(AAFOAT/(1-MSFOXF.K),SRXFM*AVXF) (A-50XF)
A    SRXVFO.K=FSXVAT*EXVFO.K*MIN(AAFOAT/(1-MSFOXV.K),SRXVM*AVXV) (A-50XV)
A    SRXAFO.K=FSXAAT*EXAFO.K*MIN(AAFOAT/(1-MSFOXA.K),SRXAM*AVXA) (A-50XA)
NOTE SR$$FO - SORTIE RATE OF $$ VS SU-25 (AC/AC-DAY)
A    SRHHFK.K=FSHHAT*EHHFK.K*MIN(AAFKAT/(1-MSFKHH.K),SRHHM*AVHH) (A-51HH)
A    SRTAFK.K=FSTAAT*ETAFK.K*MIN(AAFKAT/(1-MSFKTA.K),SRTAM*AVTA) (A-51TA)
A    SRXSFK.K=FSXSAT*EXSFK.K*MIN(AAFKAT/(1-MSFKXS.K),SRXSM*AVXS) (A-51XS)
A    SRFFFK.K=FSFFAT*EFFFK.K*MIN(AAFKAT/(1-MSFKFF.K),SRFFM*AVFF) (A-51FF)
A    SREFFK.K=FSEFAT*EEFFK.K*MIN(AAFKAT/(1-MSFKEF.K),SREFM*AVEF) (A-51EF)
A    SRTFFK.K=FSTFAT*ETFFK.K*MIN(AAFKAT/(1-MSFKTF.K),SRTFM*AVTF) (A-51TF)
A    SRHFFK.K=FSHFAT*EHFFK.K*MIN(AAFKAT/(1-MSFKHF.K),SRHFM*AVHF) (A-51HF)
A    SRHVFK.K=FSHVAT*EHVFK.K*MIN(AAFKAT/(1-MSFKHV.K),SRHVM*AVHV) (A-51HV)
A    SRIAFK.K=FSIAAT*EIAFK.K*MIN(AAFKAT/(1-MSFKIA.K),SRIAM*AVIA) (A-51IA)
A    SRXFFK.K=FSXFAT*EXFFK.K*MIN(AAFKAT/(1-MSFKXF.K),SRXFM*AVXF) (A-51XF)
A    SRXVFK.K=FSXVAT*EXVFK.K*MIN(AAFKAT/(1-MSFKXV.K),SRXVM*AVXV) (A-51XV)
A    SRXAFK.K=FSXAAT*EXAFK.K*MIN(AAFKAT/(1-MSFKXA.K),SRXAM*AVXA) (A-51XA)
NOTE SR$$FK - SORTIE RATE OF $$ VS SU-27 (AC/AC-DAY)
N    FSHHAT=1-FSHHST-FSHHLT                                   (A-52HH)
N    FSTAAT=1-FSTAST-FSTALT                                   (A-52TA)
N    FSXSAT=1-FSXSST-FSXSLT                                   (A-52XS)
N    FSFFAT=1-FSFFST-FSFFLT                                   (A-52FF)
N    FSEFAT=1-FSEFST-FSEFLT                                   (A-52EF)
N    FSTFAT=1-FSTFST-FSTFLT                                   (A-52TF)
N    FSHFAT=1-FSHFST-FSHFLT                                   (A-52HF)
N    FSHVAT=1-FSHVST-FSHVLT                                   (A-52HV)
N    FSIAAT=1-FSIAST-FSIALT                                   (A-52IA)
N    FSXFAT=1-FSXFST-FSXFLT                                   (A-52XF)
N    FSXVAT=1-FSXVST-FSXVLT                                   (A-52XV)
N    FSXAAT=1-FSXAST-FSXALT                                   (A-52XA)
NOTE  FS$$AT - FRACTION SORTIES $$ VS AIRCRAFT (DIM)
C    AAHHAT=.20                                            (A-40.1HH)
C    AATAAT=.20                                            (A-41.1TA)
C    AAXSAT=.20                                            (A-42.1XS)
C    AAFFAT=.20                                            (A-43.1FF)
C    AAEFAT=.20                                            (A-44.1EF)
C    AATFAT=.20                                            (A-45.1TF)
C    AAHFAT=.20                                            (A-46.1HF)
C    AAHVAT=.20                                            (A-47.1HV)
C    AAIAAT=.20                                            (A-48.1IA)
C    AAXFAT=.20                                            (A-49.1XF)
C    AAXVAT=.20                                            (A-50.1XV)
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C    AAXAAT=.20                                              (A-51.1XA)
NOTE  AA$$AT - ALLOWABLE ATTR $$ AIRCRAFT VS AIRBORNE THREATS (FRACT/DAY)
A    $$AT.K=FSHHAT*HH.K+FSTAAT*TA.K+FSXSAT*XS.K+FSFFAT*FF.K+
X      FSEFAT*EF.K+FSTFAT*TF.K+FSHFAT*HF.K+FSHVAT*HV.K+
X      FSIAAT*IA.K+FSXFAT*XF.K+FSXVAT*XV.K+FSXAAT*XA.K        (A-53$$)
NOTE  $$AT - NUMBER OF $$ AIRCRAFT VS XX AIRCRAFT (AIRCRAFT)
A    E$HD.K=FSHDAT*HD.K/XXAT.K                                (A-54$$)
NOTE  E$HD - PROB. OF ENCOUNTER BETWEEN U.S. AIRCRAFT AND HD (PROB)
A    E$FT.K=FSFTAT*FT.K/XXAT.K                                (A-55$$)
NOTE  E$FT - PROB. OF ENCOUNTER BETWEEN U.S. AIRCRAFT AND FT (PROB)
A    E$FR.K=FSFRAT*FR.K/XXAT.K                                (A-56$$)
NOTE  E$FT - PROB. OF ENCOUNTER BETWEEN U.S. AIRCRAFT AND FR (PROB)
A    E$FD.K=FSFDAT*FD.K/XXAT.K                                (A-57$$)
NOTE  E$FD - PROB. OF ENCOUNTER BETWEEN U.S. AIRCRAFT AND FD (PROB)
A    E$FH.K=FSFHAT*FH.K/XXAT.K                                (A-58$$)
NOTE  E$FH - PROB. OF ENCOUNTER BETWEEN U.S. AIRCRAFT AND FH (PROB)
A    E$FG.K=FSFGAT*FG.K/XXAT.K                                (A-59$$)
NOTE  E$FG - PROB. OF ENCOUNTER BETWEEN U.S. AIRCRAFT AND FG (PROB)
A    E$FX.K=FSFXAT*FX.K/XXAT.K                                (A-60$$)
NOTE  E$FX - PROB. OF ENCOUNTER BETWEEN U.S. AIRCRAFT AND FX (PROB)
A    E$FL.K=FSFLAT*FL.K/XXAT.K                                (A-61$$)
NOTE  E$FL - PROB. OF ENCOUNTER BETWEEN U.S. AIRCRAFT AND FL (PROB)
A    E$BK.K=FSBKAT*BK.K/XXAT.K                                (A-62$$)
NOTE  E$BK - PROB. OF ENCOUNTER BETWEEN U.S. AIRCRAFT AND BK (PROB)
A    E$FU.K=FSFUAT*FU.K/XXAT.K                                (A-63$$)
NOTE  E$FU - PROB. OF ENCOUNTER BETWEEN U.S. AIRCRAFT AND FU (PROB)
A    E$FO.K=FSFOAT*FO.K/XXAT.K                                (A-64$$)
NOTE  E$FO - PROB. OF ENCOUNTER BETWEEN U.S. AIRCRAFT AND FO (PROB)
A    E$FK.K=FSFKAT*FK.K/XXAT.K                                (A-65$$)
NOTE  E$FK - PROB. OF ENCOUNTER BETWEEN U.S. AIRCRAFT AND FK (PROB)
A    EHHHD.K=FHHHD*E$HD.K/EHHXX.K                             (A-66HH)
A    ETAHD.K=FTAHD*E$HD.K/ETAXX.K                             (A-66TA)
A    EXSHD.K=FXSHD*E$HD.K/EXSXX.K                             (A-66XS)
A    EFFHD.K=FFFHD*E$HD.K/EFFXX.K                             (A-66FF)
A    EEFHD.K=FEFHD*E$HD.K/EEFXX.K                             (A-66EF)
A    ETFHD.K=FTFHD*E$HD.K/ETFXX.K                             (A-66TF)
A    EHFHD.K=FHFHD*E$HD.K/EHFXX.K                             (A-66HF)
A    EHVHD.K=FHVHD*E$HD.K/EHVXX.K                             (A-66HV)
A    EIAHD.K=FIAHD*E$HD.K/EIAXX.K                             (A-66IA)
A    EXFHD.K=FXFHD*E$HD.K/EXFXX.K                             (A-66XF)
A    EXVHD.K=FXVHD*E$HD.K/EXVXX.K                             (A-66XV)
A    EXAHD.K=FXAHD*E$HD.K/EXAXX.K                             (A-66XA)
NOTE  E$$HD - PROB. OF ENCOUNTER BETWEEN $$ AND HD (PROB)
C    FHHHD=2                                                  (A-66.1HH)
C    FTAHD=2                                                  (A-66.1TA)
C    FXSHD=.1                                                 (A-66.1XS)
C    FFFHD=2                                                  (A-66.1FF)
C    FEFHD=2                                                  (A-66.1EF)
C    FTFHD=1                                                  (A-66.1TF)
C    FHFHD=1                                                  (A-66.1HF)
C    FHVHD=1                                                  (A-66.1HV)
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C    FIAHD=2                                                 (A-66.1IA)
C    FXFHD=2                                                 (A-66.1XF)
C    FXVHD=4                                                 (A-66.1XV)
C    FXAHD=4                                                 (A-66.1XA)
NOTE  F$$HD - WEIGHT FRACT $$ VS HD (DIM)
A    EHHFT.K=FHHFT*E$FT.K/EHHXX.K                            (A-67HH)
A    ETAFT.K=FTAFT*E$FT.K/ETAXX.K                            (A-67TA)
A    EXSFT.K=FXSFT*E$FT.K/EXSXX.K                            (A-67XS)
A    EFFFT.K=FFFFT*E$FT.K/EFFXX.K                            (A-67FF)
A    EEFFT.K=FEFFT*E$FT.K/EEFXX.K                            (A-67EF)
A    ETFFT.K=FTFFT*E$FT.K/ETFXX.K                            (A-67TF)
A    EHFFT.K=FHFFT*E$FT.K/EHFXX.K                            (A-67HF)
A    EHVFT.K=FHVFT*E$FT.K/EHVXX.K                            (A-67HV)
A    EIAFT.K=FIAFT*E$FT.K/EIAXX.K                            (A-67IA)
A    EXFFT.K=FXFFT*E$FT.K/EXFXX.K                            (A-67XF)
A    EXVFT.K=FXVFT*E$FT.K/EXVXX.K                            (A-67XV)
A    EXAFT.K=FXAFT*E$FT.K/EXAXX.K                            (A-67XA)
NOTE  E$$FT - PROB. OF ENCOUNTER BETWEEN $$ AND FT (PROB)
C    FHHFT=1                                                 (A-67.1HH)
C    FTAFT=2                                                 (A-67.1TA)
C    FXSFT=.1                                                (A-67.1XS)
C    FFFFT=1                                                 (A-67.1FF)
C    FEFFT=1                                                 (A-67.1EF)
C    FTFFT=1                                                 (A-67.1TF)
C    FHFFT=2                                                 (A-67.1HF)
C    FHVFT=2                                                 (A-67.1HV)
C    FIAFT=3                                                 (A-67.1IA)
C    FXFFT=2                                                 (A-67.1XF)
C    FXVFT=2                                                 (A-67.1XV)
C    FXAFT=.2                                                (A-67.1XA)
NOTE  F$$FT - WEIGHT FRACT $$ VS FT (DIM)
A    EHHFR.K=FHHFR*E$FR.K/EHHXX.K                            (A-68HH)
A    ETAFR.K=FTAFR*E$FR.K/ETAXX.K                            (A-68TA)
A    EXSFR.K=FXSFR*E$FR.K/EXSXX.K                            (A-68XS)
A    EFFFR.K=FFFFR*E$FR.K/EFFXX.K                            (A-68FF)
A    EEFFR.K=FEFFR*E$FR.K/EEFXX.K                            (A-68EF)
A    ETFFR.K=FTFFR*E$FR.K/ETFXX.K                            (A-68TF)
A    EHFFR.K=FHFFR*E$FR.K/EHFXX.K                            (A-68HF)
A    EHVFR.K=FHVFR*E$FR.K/EHVXX.K                            (A-68HV)
A    EIAFR.K=FIAFR*E$FR.K/EIAXX.K                            (A-68IA)
A    EXFFR.K=FXFFR*E$FR.K/EXFXX.K                            (A-68XF)
A    EXVFR.K=FXVFR*E$FR.K/EXVXX.K                            (A-68XV)
A    EXAFR.K=FXAFR*E$FR.K/EXAXX.K                            (A-68XA)
NOTE  E$$FR - PROB. OF ENCOUNTER BETWEEN $$ AND FR (PROB)
C    FHHFR=2                                                 (A-68.1HH)
C    FTAFR=3                                                 (A-68.1TA)
C    FXSFR=.1                                                (A-68.1XS)
C    FFFFR=.5                                                (A-68.1FF)
C    FEFFR=.6                                                (A-68.1EF)
C    FTFFR=.3                                                (A-68.1TF)
C    FHFFR=.5                                                (A-68.1HF)
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C    FHVFR=1                                                     (A-68.1HV)
C    FIAFR=2                                                     (A-68.1IA)
C    FXFFR=.6                                                    (A-68.1XF)
C    FXVFR=1                                                     (A-68.1XV)
C    FXAFR=.8                                                    (A-68.1XA)
NOTE   F$$FR - WEIGHT FRACTION $$ VS FR (DIM)
A    EHHFD.K=FHHFD*E$FD.K/EHHXX.K                                (A-69HH)
A    ETAFD.K=FTAFD*E$FD.K/ETAXX.K                                (A-69TA)
A    EXSFD.K=FXSFD*E$FD.K/EXSXX.K                                (A-69XS)
A    EFFFD.K=FFFFD*E$FD.K/EFFXX.K                                (A-69FF)
A    EEFFD.K=FEFFD*E$FD.K/EEFXX.K                                (A-69EF)
A    ETFFD.K=FTFFD*E$FD.K/ETFXX.K                                (A-69TF)
A    EHFFD.K=FHFFD*E$FD.K/EHFXX.K                                (A-69HF)
A    EHVFD.K=FHVFD*E$FD.K/EHVXX.K                                (A-69HV)
A    EIAFD.K=FIAFD*E$FD.K/EIAXX.K                                (A-69IA)
A    EXFFD.K=FXFFD*E$FD.K/EXFXX.K                                (A-69XF)
A    EXVFD.K=FXVFD*E$FD.K/EXVXX.K                                (A-69XV)
A    EXAFD.K=FXAFD*E$FD.K/EXAXX.K                                (A-69XA)
NOTE   E$$FD - PROB. OF ENCOUNTER BETWEEN $$ AND FD (PROB)
C    FHHFD=.5                                                    (A-69.1HH)
C    FTAFD=.5                                                    (A-69.1TA)
C    FXSFD=.2                                                    (A-69.1XS)
C    FFFFD=2                                                     (A-69.1FF)
C    FEFFD=2                                                     (A-69.1EF)
C    FTFFD=2                                                     (A-69.1TF)
C    FHFFD=2                                                     (A-69.1HF)
C    FHVFD=.5                                                    (A-69.1HV)
C    FIAFD=.5                                                    (A-69.1IA)
C    FXFFD=2                                                     (A-69.1XF)
C    FXVFD=2                                                     (A-69.1XV)
C    FXAFD=2                                                     (A-69.1XA)
NOTE   F$$HD - WEIGHT FRACTION $$ VS FD (DIM)
A    EHHFH.K=FHHFH*E$FH.K/EHHXX.K                                (A-70HH)
A    ETAFH.K=FTAFH*E$FH.K/ETAXX.K                                (A-70TA)
A    EXSFH.K=FXSFH*E$FH.K/EXSXX.K                                (A-70XS)
A    EFFFH.K=FFFFH*E$FH.K/EFFXX.K                                (A-70FF)
A    EEFFH.K=FEFFH*E$FH.K/EEFXX.K                                (A-70EF)
A    ETFFH.K=FTFFH*E$FH.K/ETFXX.K                                (A-70TF)
A    EHFFH.K=FHFFH*E$FH.K/EHFXX.K                                (A-70HF)
A    EHVFH.K=FHVFH*E$FH.K/EHVXX.K                                (A-70HV)
A    EIAFH.K=FIAFH*E$FH.K/EIAXX.K                                (A-70IA)
A    EXFFH.K=FXFFH*E$FH.K/EXFXX.K                                (A-70XF)
A    EXVFH.K=FXVFH*E$FH.K/EXVXX.K                                (A-70XV)
A    EXAFH.K=FXAFH*E$FH.K/EXAXX.K                                (A-70XA)
NOTE   E$$FH - PROB. OF ENCOUNTER BETWEEN $$ AND FH (PROB)
C    FHHFH=.3                                                    (A-70.1HH)
C    FTAFH=.8                                                    (A-70.1TA)
C    FXSFH=.1                                                    (A-70.1XS)
C    FFFFH=2                                                     (A-70.1FF)
C    FEFFH=1                                                     (A-70.1EF)
C    FTFFH=1                                                     (A-70.1TF)
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C   FHFFH=2                                                  (A-70.1HF)
C   FHVFH=.4                                                 (A-70.1HV)
C   FIAFH=.2                                                 (A-70.1IA)
C   FXFFH=2                                                  (A-70.1XF)
C   FXVFH=1                                                  (A-70.1XV)
C   FXAFH=.5                                                 (A-70.1XA)
NOTE  F$$FH - WEIGHT FRACTION $$ VS FH (DIM)
A   EHHFG.K=FHHFG*E$FG.K/EHHXX.K                             (A-71HH)
A   ETAFG.K=FTAFG*E$FG.K/ETAXX.K                             (A-71TA)
A   EXSFG.K=FXSFG*E$FG.K/EXSXX.K                             (A-71XS)
A   EFFFG.K=FFFFG*E$FG.K/EFFXX.K                             (A-71FF)
A   EEFFG.K=FEFFG*E$FG.K/EEFXX.K                             (A-71EF)
A   ETFFG.K=FTFFG*E$FG.K/ETFXX.K                             (A-71TF)
A   EHFFG.K=FHFFG*E$FG.K/EHFXX.K                             (A-71HF)
A   EHVFG.K=FHVFG*E$FG.K/EHVXX.K                             (A-71HV)
A   EIAFG.K=FIAFG*E$FG.K/EIAXX.K                             (A-71IA)
A   EXFFG.K=FXFFG*E$FG.K/EXFXX.K                             (A-71XF)
A   EXVFG.K=FXVFG*E$FG.K/EXVXX.K                             (A-71XV)
A   EXAFG.K=FXAFG*E$FG.K/EXAXX.K                             (A-71XA)
NOTE  E$$FG - PROB. OF ENCOUNTER BETWEEN $$ AND FG (PROB)
C   FHHFG=.2                                                 (A-71.1HH)
C   FTAFG=1                                                  (A-71.1TA)
C   FXSFG=.2                                                 (A-71.1XS)
C   FFFFG=3                                                  (A-71.1FF)
C   FEFFG=4                                                  (A-71.1EF)
C   FTFFG=2                                                  (A-71.1TF)
C   FHFFG=2                                                  (A-71.1HF)
C   FHVFG=.4                                                 (A-71.1HV)
C   FIAFG=.2                                                 (A-71.1IA)
C   FXFFG=3                                                  (A-71.1XF)
C   FXVFG=2                                                  (A-71.1XV)
C   FXAFG=1                                                  (A-71.1XA)
NOTE  F$$FG - WEIGHT FRACTION $$ VS FG (DIM)
A   EHHFX.K=FHHFX*E$FX.K/EHHXX.K                             (A-72HH)
A   ETAFX.K=FTAFX*E$FX.K/ETAXX.K                             (A-72TA)
A   EXSFX.K=FXSFX*E$FX.K/EXSXX.K                             (A-72XS)
A   EFFFX.K=FFFFX*E$FX.K/EFFXX.K                             (A-72FF)
A   EEFFX.K=FEFFX*E$FX.K/EEFXX.K                             (A-72EF)
A   ETFFX.K=FTFFX*E$FX.K/ETFXX.K                             (A-72TF)
A   EHFFX.K=FHFFX*E$FX.K/EHFXX.K                             (A-72HF)
A   EHVFX.K=FHVFX*E$FX.K/EHVXX.K                             (A-72HV)
A   EIAFX.K=FIAFX*E$FX.K/EIAXX.K                             (A-72IA)
A   EXFFX.K=FXFFX*E$FX.K/EXFXX.K                             (A-72XF)
A   EXVFX.K=FXVFX*E$FX.K/EXVXX.K                             (A-72XV)
A   EXAFX.K=FXAFX*E$FX.K/EXAXX.K                             (A-72XA)
NOTE  E$$FX - PROB. OF ENCOUNTER BETWEEN $$ AND FX (PROB)
C   FHHFX=.2                                                 (A-72.1HH)
C   FTAFX=.5                                                 (A-72.1TA)
C   FXSFX=.2                                                 (A-72.1XS)
C   FFFFX=2                                                  (A-72.1FF)
C   FEFFX=2                                                  (A-72.1EF)
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C    FTFFX=2                                                     (A-72.1TF)
C    FHFFX=1                                                     (A-72.1HF)
C    FHVFX=.2                                                    (A-72.1HV)
C    FIAFX=.2                                                    (A-72.1IA)
C    FXFFX=1                                                     (A-72.1XF)
C    FXVFX=.8                                                    (A-72.1XV)
C    FXAFX=.6                                                    (A-72.1XA)
NOTE  F$$FX - WEIGHT FRACTION $$ VS FX (DIM)
A    EHHFL.K=FHHFL*E$FL.K/EHHXX.K                                (A-73HH)
A    ETAFL.K=FTAFL*E$FL.K/ETAXX.K                                (A-73TA)
A    EXSFL.K=FXSFL*E$FL.K/EXSXX.K                                (A-73XS)
A    EFFFL.K=FFFFL*E$FL.K/EFFXX.K                                (A-73FF)
A    EEFFL.K=FEFFL*E$FL.K/EEFXX.K                                (A-73EF)
A    ETFFL.K=FTFFL*E$FL.K/ETFXX.K                                (A-73TF)
A    EHFFL.K=FHFFL*E$FL.K/EHFXX.K                                (A-73HF)
A    EHVFL.K=FHVFL*E$FL.K/EHVXX.K                                (A-73HV)
A    EIAFL.K=FIAFL*E$FL.K/EIAXX.K                                (A-73IA)
A    EXFFL.K=FXFFL*E$FL.K/EXFXX.K                                (A-73XF)
A    EXVFL.K=FXVFL*E$FL.K/EXVXX.K                                (A-73XV)
A    EXAFL.K=FXAFL*E$FL.K/EXAXX.K                                (A-73XA)
NOTE  E$$FL - PROB. OF ENCOUNTER BETWEEN $$ AND FL (PROB)
C    FHHFL=.2                                                    (A-73.1HH)
C    FTAFL=.2                                                    (A-73.1TA)
C    FXSFL=.3                                                    (A-73.1XS)
C    FFFFL=2                                                     (A-73.1FF)
C    FEFFL=2                                                     (A-73.1EF)
C    FTFFL=2                                                     (A-73.1TF)
C    FHFFL=2                                                     (A-73.1HF)
C    FHVFL=.1                                                    (A-73.1HV)
C    FIAFL=.1                                                    (A-73.1IA)
C    FXFFL=.2                                                    (A-73.1XF)
C    FXVFL=1                                                     (A-73.1XV)
C    FXAFL=.2                                                    (A-73.1XA)
NOTE  F$$FL - WEIGHT FRACTION $$ VS FL (DIM)
A    EHHBK.K=FHHBK*E$BK.K/EHHXX.K                                (A-74HH)
A    ETABK.K=FTABK*E$BK.K/ETAXX.K                                (A-74TA)
A    EXSBK.K=FXSBK*E$BK.K/EXSXX.K                                (A-74XS)
A    EFFBK.K=FFFBK*E$BK.K/EFFXX.K                                (A-74FF)
A    EEFBK.K=FEFBK*E$BK.K/EEFXX.K                                (A-74EF)
A    ETFBK.K=FTFBK*E$BK.K/ETFXX.K                                (A-74TF)
A    EHFBK.K=FHFBK*E$BK.K/EHFXX.K                                (A-74HF)
A    EHVBK.K=FHVBK*E$BK.K/EHVXX.K                                (A-74HV)
A    EIABK.K=FIABK*E$BK.K/EIAXX.K                                (A-74IA)
A    EXFBK.K=FXFBK*E$BK.K/EXFXX.K                                (A-74XF)
A    EXVBK.K=FXVBK*E$BK.K/EXVXX.K                                (A-74XV)
A    EXABK.K=FXABK*E$BK.K/EXAXX.K                                (A-74XA)
NOTE  E$$BK - PROB. OF ENCOUNTER BETWEEN $$ AND BK (PROB)
C    FHHBK=.1                                                    (A-74.1HH)
C    FTABK=.1                                                    (A-74.1TA)
C    FXSBK=.1                                                    (A-74.1XS)
C    FFFBK=3                                                     (A-74.1FF)
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C    FEFBK=4                                                     (A-74.1EF)
C    FTFBK=2                                                     (A-74.1TF)
C    FHFBK=2                                                     (A-74.1HF)
C    FHVBK=.5                                                    (A-74.1HV)
C    FIABK=.5                                                    (A-74.1IA)
C    FXFBK=3                                                     (A-74.1XF)
C    FXVBK=.5                                                    (A-74.1XV)
C    FXABK=2                                                     (A-74.1XA)
NOTE  F$$BK - WEIGHT FRACTION $$ VS BK (DIM)
A    EHHFU.K=FHHFU*E$FU.K/EHHXX.K                                (A-75HH)
A    ETAFU.K=FTAFU*E$FU.K/ETAXX.K                                (A-75TA)
A    EXSFU.K=FXSFU*E$FU.K/EXSXX.K                                (A-75XS)
A    EFFFU.K=FFFFU*E$FU.K/EFFXX.K                                (A-75FF)
A    EEFFU.K=FEFFU*E$FU.K/EEFXX.K                                (A-75EF)
A    ETFFU.K=FTFFU*E$FU.K/ETFXX.K                                (A-75TF)
A    EHFFU.K=FHFFU*E$FU.K/EHFXX.K.                               (A-75HF)
A    EHVFU.K=FHVFU*E$FU.K/EHVXX.K                                (A-75HV)
A    EIAFU.K=FIAFU*E$FU.K/EIAXX.K                                (A-75IA)
A    EXFFU.K=FXFFU*E$FU.K/EXFXX.K                                (A-75XF)
A    EXVFU.K=FXVFU*E$FU.K/EXVXX.K                                (A-75XV)
A    EXAFU.K=FXAFU*E$FU.K/EXAXX.K                                (A-75XA)
NOTE  E$$FU - PROB. OF ENCOUNTER BETWEEN $$ AND FU (PROB)
C    FHHFU=.1                                                    (A-75.1HH)
C    FTAFU=.3                                                    (A-75.1TA)
C    FXSFU=.1                                                    (A-75.1XS)
C    FFFFU=2                                                     (A-75.1FF)
C    FEFFU=5                                                     (A-75.1EF)
C    FTFFU=1                                                     (A-75.1TF)
C    FHFFU=3                                                     (A-75.1HF)
C    FHVFU=.5                                                    (A-75.1HV)
C    FIAFU=.3                                                    (A-75.1IA)
C    FXFFU=3                                                     (A-75.1XF)
C    FXVFU=2                                                     (A-75.1XV)
C    FXAFU=.2                                                    (A-75.1XA)
NOTE  F$$FU - WEIGHT FRACTION $$ VS FU (DIM)
A    EHHFO.K=FHHFO*E$FO.K/EHHXX.K                                (A-76HH)
A    ETAFO.K=FTAFO*E$FO.K/ETAXX.K                                (A-76TA)
A    EXSFO.K=FXSFO*E$FO.K/EXSXX.K                                (A-76XS)
A    EFFFO.K=FFFFO*E$FO.K/EFFXX.K                                (A-76FF)
A    EEFFO.K=FEFFO*E$FO.K/EEFXX.K                                (A-76EF)
A    ETFFO.K=FTFFO*E$FO.K/ETFXX.K                                (A-76TF)
A    EHFFO.K=FHFFO*E$FO.K/EHFXX.K                                (A-76HF)
A    EHVFO.K=FHVFO*E$FO.K/EHVXX.K                                (A-76HV)
A    EIAFO.K=FIAFO*E$FO.K/EIAXX.K                                (A-76IA)
A    EXFFO.K=FXFFO*E$FO.K/EXFXX.K                                (A-76XF)
A    EXVFO.K=FXVFO*E$FO.K/EXVXX.K                                (A-76XV)
A    EXAFO.K=FXAFO*E$FO.K/EXAXX.K                                (A-76XA)
NOTE  E$$FO - PROB. OF ENCOUNTER BETWEEN $$ AND FO (PROB)
C    FHHFO=2                                                     (A-76.1HH)
C    FTAFO=1                                                     (A-76.1TA)
C    FXSFO=.1                                                    (A-76.1XS)
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C   FFFFO=3                                                 (A-76.1FF)
C   FEFFO=3                                                 (A-76.1EF)
C   FTFFO=.2                                                (A-76.1TF)
C   FHFFO=.8                                                (A-76.1HF)
C   FHVFO=2                                                 (A-76.1HV)
C   FIAFO=2                                                 (A-76.1IA)
C   FXFFO=1                                                 (A-76.1XF)
C   FXVFO=2                                                 (A-76.1XV)
C   FXAFO=.6                                                (A-76.1XA)
NOTE  F$$FO - WEIGHT FRACTION $$ VS FO (DIM)
A   EHHFK.K=FHHFK*E$FK.K/EHHXX.K                            (A-77HH)
A   ETAFK.K=FTAFK*E$FK.K/ETAXX.K                            (A-77TA)
A   EXSFK.K=FXSFK*E$FK.K/EXSXX.K                            (A-77XS)
A   EFFFK.K=FFFFK*E$FK.K/EFFXX.K                            (A-77FF)
A   EEFFK.K=FEFFK*E$FK.K/EEFXX.K                            (A-77EF)
A   ETFFK.K=FTFFK*E$FK.K/ETFXX.K                            (A-77TF)
A   EHFFK.K=FHFFK*E$FK.K/EHFXX.K                            (A-77HF)
A   EHVFK.K=FHVFK*E$FK.K/EHVXX.K                            (A-77HV)
A   EIAFK.K=FIAFK*E$FK.K/EIAXX.K                            (A-77IA)
A   EXFFK.K=FXFFK*E$FK.K/EXFXX.K                            (A-77XF)
A   EXVFK.K=FXVFK*E$FK.K/EXVXX.K                            (A-77XV)
A   EXAFK.K=FXAFK*E$FK.K/EXAXX.K                            (A-77XA)
NOTE  E$$FK - PROB. OF ENCOUNTER BETWEEN $$ AND FK (PROB)
C   FHHFK=.2                                                (A-77.1HH)
C   FTAFK=.5                                                (A-77.1TA)
C   FXSFK=.3                                                (A-77.1XS)
C   FFFFK=2                                                 (A-77.1FF)
C   FEFFK=5                                                 (A-77.1EF)
C   FTFFK=4                                                 (A-77.1TF)
C   FHFFK=2                                                 (A-77.1HF)
C   FHVFK=.2                                                (A-77.1HV)
C   FIAFK=.2                                                (A-77.1IA)
C   FXFFK=2                                                 (A-77.1XF)
C   FXVFK=2                                                 (A-77.1XV)
C   FXAFK=1                                                 (A-77.1XA)
NOTE  F$$FK - WEIGHT FRACTION $$ VS FK (DIM)
A   EHHXX.K=FHHHD*E$HD.K+FHHFT*E$FT.K+FHHFR*E$FR.K+FHHFD*E$FD.K+
X     +FHHFH*E$FH.K+FHHFG*E$FG.K+FHHFX*E$FX.K+FHHFL*E$FL.K+FHHBK*E$BK.K
X     +FHHFU*E$FU.K+FHHFO*E$FO.K+FHHFK*E$FK.K               (A-78HH)
NOTE  EHHXX - VS XX (PROB)
A   ETAXX.K=FTAHD*E$HD.K+FTAFT*E$FT.K+FTAFR*E$FR.K+FTAFD*E$FD.K+
X     +FTAFH*E$FH.K+FTAFG*E$FG.K+FTAFX*E$FX.K+FTAFL*E$FL.K+FTABK*E$BK.K
X     +FTAFU*E$FU.K+FTAFO*E$FO.K+FTAFK*E$FK.K               (A-78TA)
NOTE  ETAXX - VS XX (PROB)
A   EXSXX.K=FXSHD*E$HD.K+FXSFT*E$FT.K+FXSFR*E$FR.K+FXSFD*E$FD.K+
X     +FXSFH*E$FH.K+FXSFG*E$FG.K+FXSFX*E$FX.K+FXSFL*E$FL.K+FXSBK*E$BK.K
X     +FXSFU*E$FU.K+FXSFO*E$FO.K+FXSFK*E$FK.K               (A-78XS)
NOTE  EXSXX - VS XX (PROB)
A   EFFXX.K=FFFHD*E$HD.K+FFFFT*E$FT.K+FFFFR*E$FR.K+FFFFD*E$FD.K+
X     +FFFFH*E$FH.K+FFFFG*E$FG.K+FFFFX*E$FX.K+FFFFL*E$FL.K+FFFBK*E$BK.K
X     +FFFFU*E$FU.K+FFFFO*E$FO.K+FFFFK*E$FK.K               (A-78FF)
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NOTE  EFFXX - VS XX (PROB)
A    EEFXX.K=FEFHD*E$HD.K+FEFFT*E$FT.K+FEFFR*E$FR.K+FEFFD*E$FD.K+
X      +FEFFH*E$FH.K+FEFFG*E$FG.K+FEFFX*E$FX.K+FEFFL*E$FL.K+FEFBK*E$BK.K
X      +FEFFU*E$FU.K+FEFFO*E$FO.K+FEFFK*E$FK.K                (A-78EF)
NOTE  EEFXX - VS XX (PROB)
A    ETFXX.K=FTFHD*E$HD.K+FTFFT*E$FT.K+FTFFR*E$FR.K+FTFFD*E$FD.K+
X      +FTFFH*E$FH.K+FTFFG*E$FG.K+FTFFX*E$FX.K+FTFFL*E$FL.K+FTFBK*E$BK.K
X      +FTFFU*E$FU.K+FTFFO*E$FO.K+FTFFK*E$FK.K                (A-78TF)
NOTE  ETFXX - VS XX (PROB)
A    EHFXX.K=FHFHD*E$HD.K+FHFFT*E$FT.K+FHFFR*E$FR.K+FHFFD*E$FD.K+
X      +FHFFH*E$FH.K+FHFFG*E$FG.K+FHFFX*E$FX.K+FHFFL*E$FL.K+FHFBK*E$BK.K
X      +FHFFU*E$FU.K+FHFFO*E$FO.K+FHFFK*E$FK.K                (A-78HF)
NOTE  EHFXX - VS XX (PROB)
A    EHVXX.K=FHVHD*E$HD.K+FHVFT*E$FT.K+FHVFR*E$FR.K+FHVFD*E$FD.K+
X      +FHVFH*E$FH.K+FHVFG*E$FG.K+FHVFX*E$FX.K+FHVFL*E$FL.K+FHVBK*E$BK.K
X      +FHVFU*E$FU.K+FHVFO*E$FO.K+FHVFK*E$FK.K                (A-78HV)
NOTE  EHVXX - VS XX (PROB)
A    EIAXX.K=FIAHD*E$HD.K+FIAFT*E$FT.K+FIAFR*E$FR.K+FIAFD*E$FD.K+
X      +FIAFH*E$FH.K+FIAFG*E$FG.K+FIAFX*E$FX.K+FIAFL*E$FL.K+FIABK*E$BK.K
X      +FIAFU*E$FU.K+FIAFO*E$FO.K+FIAFK*E$FK.K                (A-78IA)
NOTE  EIAXX - VS XX (PROB)
A    EXFXX.K=FXFHD*E$HD.K+FXFFT*E$FT.K+FXFFR*E$FR.K+FXFFD*E$FD.K+
X      +FXFFH*E$FH.K+FXFFG*E$FG.K+FXFFX*E$FX.K+FXFFL*E$FL.K+FXFBK*E$BK.K
X      +FXFFU*E$FU.K+FXFFO*E$FO.K+FXFFK*E$FK.K                (A-78XF)
NOTE  EXFFX - VS XX (PROB)
A    EXVXX.K=FXVHD*E$HD.K+FXVFT*E$FT.K+FXVFR*E$FR.K+FXVFD*E$FD.K+
X      +FXVFH*E$FH.K+FXVFG*E$FG.K+FXVFX*E$FX.K+FXVFL*E$FL.K+FXVBK*E$BK.K
X      +FXVFU*E$FU.K+FXVFO*E$FO.K+FXVFK*E$FK.K                (A-78XV)
NOTE  EXVXX - VS XX (PROB)
A    EXAXX.K=FXAHD*E$HD.K+FXAFT*E$FT.K+FXAFR*E$FR.K+FXAFD*E$FD.K+
X      +FXAFH*E$FH.K+FXAFG*E$FG.K+FXAFX*E$FX.K+FXAFL*E$FL.K+FXABK*E$BK.K
X      +FXAFU*E$FU.K+FXAFO*E$FO.K+FXAFK*E$FK.K                (A-78XA)
NOTE  EXAXX - VS XX (PROB)
A    MSHHHD.K=EXP(-NARHD*(1-HHARHD.K))*EXP(-NAIHD*(1-HHAIHD.K))
X       *EXP(-NCHD*(1-HHCHD.K))                              (A-79HH)
A    MSTAHD.K=EXP(-NARHD*(1-TAARHD.K))*EXP(-NAIHD*(1-TAAIHD.K))
X       *EXP(-NCHD*(1-TACHD.K))                              (A-79TA)
A    MSXSHD.K=EXP(-NARHD*(1-XSARHD.K))*EXP(-NAIHD*(1-XSAIHD.K))
X       *EXP(-NCHD*(1-XSCHD.K))                              (A-79XS)
A    MSFFHD.K=EXP(-NARHD*(1-FFARHD.K))*EXP(-NAIHD*(1-FFAIHD.K))
X       *EXP(-NCHD*(1-FFCHD.K))                              (A-79FF)
A    MSEFHD.K=EXP(-NARHD*(1-EFARHD.K))*EXP(-NAIHD*(1-EFAIHD.K))
X       *EXP(-NCHD*(1-EFCHD.K))                              (A-79EF)
A    MSTFHD.K=EXP(-NARHD*(1-TFARHD.K))*EXP(-NAIHD*(1-TFAIHD.K))
X       *EXP(-NCHD*(1-TFCHD.K))                              (A-79TF)
A    MSHFHD.K=EXP(-NARHD*(1-HFARHD.K))*EXP(-NAIHD*(1-HFAIHD.K))
X       *EXP(-NCHD*(1-HFCHD.K))                              (A-79HF)
A    MSHVHD.K=EXP(-NARHD*(1-HVARHD.K))*EXP(-NAIHD*(1-HVAIHD.K))
X       *EXP(-NCHD*(1-HVCHD.K))                              (A-79HV)
A    MSIAHD.K=EXP(-NARHD*(1-IAARHD.K))*EXP(-NAIHD*(1-IAAIHD.K))
X       *EXP(-NCHD*(1-IACHD.K))                              (A-79IA)
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A   MSXFHD.K=EXP(-NARHD*(1-XFARHD.K))*EXP(-NAIHD*(1-XFAIHD.K))
X      *EXP(-NCHD*(1-XFCHD.K))                             (A-79XF)
A   MSXVHD.K=EXP(-NARHD*(1-XVARHD.K))*EXP(-NAIHD*(1-XVAIHD.K))
X      *EXP(-NCHD*(1-XVCHD.K))                             (A-79XV)
A   MSXAHD.K=EXP(-NARHD*(1-XAARHD.K))*EXP(-NAIHD*(1-XAAIHD.K))
X      *EXP(-NCHD*(1-XACHD.K))                             (A-79XA)
NOTE  MS$$HD - MISSION SURVIVABILITY $$ AIRCRAFT VS HD (PROB)
C   NARHD=2                                                (A-79.1HD)
C   NARFT=1                                                (A-79.1FT)
C   NARFR=2                                                (A-79.1FR)
C   NARFD=2                                                (A-79.1FD)
C   NARFH=2                                                (A-79.1FH)
C   NARFG=2                                                (A-79.1FG)
C   NARFX=2                                                (A-79.1FX)
C   NARFL=4                                                (A-79.1FL)
C   NARBK=2                                                (A-79.1BK)
C   NARFU=4                                                (A-79.1FU)
C   NARFO=4                                                (A-79.1FO)
C   NARFK=4                                                (A-79.1FK)
NOTE  NARXX - NUMBER OF RADAR AAM ON XX AIRCRAFT
C   NAIHD=1                                                (A-79.2HD)
C   NAIFT=1                                                (A-79.2FT)
C   NAIFR=1                                                (A-79.2FR)
C   NAIFD=1                                                (A-79.2FD)
C   NAIFH=2                                                (A-79.2FH)
C   NAIFG=2                                                (A-79.2FG)
C   NAIFX=2                                                (A-79.2FX)
C   NAIFL=1                                                (A-79.2FL)
C   NAIBK=1                                                (A-79.2BK)
C   NAIFU=4                                                (A-79.2FU)
C   NAIFO=4                                                (A-79.2FO)
C   NAIFK=4                                                (A-79.2FK)
NOTE  NAIXX - NUMBER OF IR GUIDED AAM ON XX AIRCRAFT
C   NCHD=2                                                 (A-79.3HD)
C   NCFT=2                                                 (A-79.3FT)
C   NCFR=2                                                 (A-79.3FR)
C   NCFD=2                                                 (A-79.3FD)
C   NCFH=2                                                 (A-79.3FH)
C   NCFG=2                                                 (A-79.3FG)
C   NCFX=2                                                 (A-79.3FX)
C   NCFL=2                                                 (A-79.3FL)
C   NCBK=4                                                 (A-79.3BK)
C   NCFU=2                                                 (A-79.3FU)
C   NCFO=2                                                 (A-79.3FO)
C   NCFK=2                                                 (A-79.3FK)
NOTE  NACXX - NUMBER OF CANNON ON XX AIRCRAFT
A   MSHHFT.K=EXP(-NARFT*(1-HHARFT.K))*EXP(-NAIFT*(1-HHAIFT.K))
X      *EXP(-NCFT*(1-HHCFT.K))                             (A-80HH)
A   MSTAFT.K=EXP(-NARFT*(1-TAARFT.K))*EXP(-NAIFT*(1-TAAIFT.K))
X      *EXP(-NCFT*(1-TACFT.K))                             (A-80TA)
A   MSXSFT.K=EXP(-NARFT*(1-XSARFT.K))*EXP(-NAIFT*(1-XSAIFT.K))
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X       *EXP(-NCFT*(1-XSCFT.K))                                 (A-80XS)
A    MSFFFT.K=EXP(-NARFT*(1-FFARFT.K))*EXP(-NAIFT*(1-FFAIFT.K))
X       *EXP(-NCFT*(1-FFCFT.K))                                 (A-80FF)
A    MSEFFT.K=EXP(-NARFT*(1-EFARFT.K))*EXP(-NAIFT*(1-EFAIFT.K))
X       *EXP(-NCFT*(1-EFCFT.K))                                 (A-80EF)
A    MSTFFT.K=EXP(-NARFT*(1-TFARFT.K))*EXP(-NAIFT*(1-TFAIFT.K))
X       *EXP(-NCFT*(1-TFCFT.K))                                 (A-80TF)
A    MSHFFT.K=EXP(-NARFT*(1-HFARFT.K))*EXP(-NAIFT*(1-HFAIFT.K))
X       *EXP(-NCFT*(1-HFCFT.K))                                 (A-80HF)
A    MSHVFT.K=EXP(-NARFT*(1-HVARFT.K))*EXP(-NAIFT*(1-HVAIFT.K))
X       *EXP(-NCFT*(1-HVCFT.K))                                 (A-80HV)
A    MSIAFT.K=EXP(-NARFT*(1-IAARFT.K))*EXP(-NAIFT*(1-IAAIFT.K))
X       *EXP(-NCFT*(1-IACFT.K))                                 (A-80IA)
A    MSXFFT.K=EXP(-NARFT*(1-XFARFT.K))*EXP(-NAIFT*(1-XFAIFT.K))
X       *EXP(-NCFT*(1-XFCFT.K))                                 (A-80XF)
A    MSXVFT.K=EXP(-NARFT*(1-XVARFT.K))*EXP(-NAIFT*(1-XVAIFT.K))
X       *EXP(-NCFT*(1-XVCFT.K))                                 (A-80XV)
A    MSXAFT.K=EXP(-NARFT*(1-XAARFT.K))*EXP(-NAIFT*(1-XAAIFT.K))
X       *EXP(-NCFT*(1-XACFT.K))                                 (A-80XA)
NOTE  MS$$FT - MISSION SURVIVABILITY $$ AIRCRAFT VS FT (PROB)
A    MSHHFR.K=EXP(-NARFR*(1-HHARFR.K))*EXP(-NAIFR*(1-HHAIFR.K))
X       *EXP(-NCFR*(1-HHCFR.K))                                 (A-81HH)
A    MSTAFR.K=EXP(-NARFR*(1-TAARFR.K))*EXP(-NAIFR*(1-TAAIFR.K))
X       *EXP(-NCFR*(1-TACFR.K))                                 (A-81TA)
A    MSXSFR.K=EXP(-NARFR*(1-XSARFR.K))*EXP(-NAIFR*(1-XSAIFR.K))
X       *EXP(-NCFR*(1-XSCFR.K))                                 (A-81XS)
A    MSFFFR.K=EXP(-NARFR*(1-FFARFR.K))*EXP(-NAIFR*(1-FFAIFR.K))
X       *EXP(-NCFR*(1-FFCFR.K))                                 (A-81FF)
A    MSEFFR.K=EXP(-NARFR*(1-EFARFR.K))*EXP(-NAIFR*(1-EFAIFR.K))
X       *EXP(-NCFR*(1-EFCFR.K))                                 (A-81EF)
A    MSTFFR.K=EXP(-NARFR*(1-TFARFR.K))*EXP(-NAIFR*(1-TFAIFR.K))
X       *EXP(-NCFR*(1-TFCFR.K))                                 (A-81TF)
A    MSHFFR.K=EXP(-NARFR*(1-HFARFR.K))*EXP(-NAIFR*(1-HFAIFR.K))
X       *EXP(-NCFR*(1-HFCFR.K))                                 (A-81HF)
A    MSHVFR.K=EXP(-NARFR*(1-HVARFR.K))*EXP(-NAIFR*(1-HVAIFR.K))
X       *EXP(-NCFR*(1-HVCFR.K))                                 (A-81HV)
A    MSIAFR.K=EXP(-NARFR*(1-IAARFR.K))*EXP(-NAIFR*(1-IAAIFR.K))
X       *EXP(-NCFR*(1-IACFR.K))                                 (A-81IA)
A    MSXFFR.K=EXP(-NARFR*(1-XFARFR.K))*EXP(-NAIFR*(1-XFAIFR.K))
X       *EXP(-NCFR*(1-XFCFR.K))                                 (A-81XF)
A    MSXVFR.K=EXP(-NARFR*(1-XVARFR.K))*EXP(-NAIFR*(1-XVAIFR.K))
X       *EXP(-NCFR*(1-XVCFR.K))                                 (A-81XV)
A    MSXAFR.K=EXP(-NARFR*(1-XAARFR.K))*EXP(-NAIFR*(1-XAAIFR.K))
X       *EXP(-NCFR*(1-XACFR.K))                                 (A-81XA)
NOTE  MS$$FR - MISSION SURVIVABILITY $$ AIRCRAFT VS FR (PROB)
A    MSHHFD.K=EXP(-NARFD*(1-HHARFD.K))*EXP(-NAIFD*(1-HHAIFD.K))
X       *EXP(-NCFD*(1-HHCFD.K))                                 (A-82HH)
A    MSTAFD.K=EXP(-NARFD*(1-TAARFD.K))*EXP(-NAIFD*(1-TAAIFD.K))
X       *EXP(-NCFD*(1-TACFD.K))                                 (A-82TA)
A    MSXSFD.K=EXP(-NARFD*(1-XSARFD.K))*EXP(-NAIFD*(1-XSAIFD.K))
X       *EXP(-NCFD*(1-XSCFD.K))                                 (A-82XS)
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A   MSFFFD.K=EXP(-NARFD*(1-FFARFD.K))*EXP(-NAIFD*(1-FFAIFD.K))
X      *EXP(-NCFD*(1-FFCFD.K))                               (A-82FF)
A   MSEFFD.K=EXP(-NARFD*(1-EFARFD.K))*EXP(-NAIFD*(1-EFAIFD.K))
X      *EXP(-NCFD*(1-EFCFD.K))                               (A-82EF)
A   MSTFFD.K=EXP(-NARFD*(1-TFARFD.K))*EXP(-NAIFD*(1-TFAIFD.K))
X      *EXP(-NCFD*(1-TFCFD.K))                               (A-82TF)
A   MSHFFD.K=EXP(-NARFD*(1-HFARFD.K))*EXP(-NAIFD*(1-HFAIFD.K))
X      *EXP(-NCFD*(1-HFCFD.K))                               (A-82HF)
A   MSHVFD.K=EXP(-NARFD*(1-HVARFD.K))*EXP(-NAIFD*(1-HVAIFD.K))
X      *EXP(-NCFD*(1-HVCFD.K))                               (A-82HV)
A   MSIAFD.K=EXP(-NARFD*(1-IAARFD.K))*EXP(-NAIFD*(1-IAAIFD.K))
X      *EXP(-NCFD*(1-IACFD.K))                               (A-82IA)
A   MSXFFD.K=EXP(-NARFD*(1-XFARFD.K))*EXP(-NAIFD*(1-XFAIFD.K))
X      *EXP(-NCFD*(1-XFCFD.K))                               (A-82XF)
A   MSXVFD.K=EXP(-NARFD*(1-XVARFD.K))*EXP(-NAIFD*(1-XVAIFD.K))
X      *EXP(-NCFD*(1-XVCFD.K))                               (A-82XV)
A   MSXAFD.K=EXP(-NARFD*(1-XAARFD.K))*EXP(-NAIFD*(1-XAAIFD.K))
X      *EXP(-NCFD*(1-XACFD.K))                               (A-82XA)
NOTE  MS$$FD - MISSION SURVIVABILITY $$ AIRCRAFT VS FD (PROB)
A   MSHHFH.K=EXP(-NARFH*(1-HHARFH.K))*EXP(-NAIFH*(1-HHAIFH.K))
X      *EXP(-NCFH*(1-HHCFH.K))                               (A-83HH)
A   MSTAFH.K=EXP(-NARFH*(1-TAARFH.K))*EXP(-NAIFH*(1-TAAIFH.K))
X      *EXP(-NCFH*(1-TACFH.K))                               (A-83TA)
A   MSXSFH.K=EXP(-NARFH*(1-XSARFH.K))*EXP(-NAIFH*(1-XSAIFH.K))
X      *EXP(-NCFH*(1-XSCFH.K))                               (A-83XS)
A   MSFFFH.K=EXP(-NARFH*(1-FFARFH.K))*EXP(-NAIFH*(1-FFAIFH.K))
X      *EXP(-NCFH*(1-FFCFH.K))                               (A-83FF)
A   MSEFFH.K=EXP(-NARFH*(1-EFARFH.K))*EXP(-NAIFH*(1-EFAIFH.K))
X      *EXP(-NCFH*(1-EFCFH.K))                               (A-83EF)
A   MSTFFH.K=EXP(-NARFH*(1-TFARFH.K))*EXP(-NAIFH*(1-TFAIFH.K))
X      *EXP(-NCFH*(1-TFCFH.K))                               (A-83TF)
A   MSHFFH.K=EXP(-NARFH*(1-HFARFH.K))*EXP(-NAIFH*(1-HFAIFH.K))
X      *EXP(-NCFH*(1-HFCFH.K))                               (A-83HF)
A   MSHVFH.K=EXP(-NARFH*(1-HVARFH.K))*EXP(-NAIFH*(1-HVAIFH.K))
X      *EXP(-NCFH*(1-HVCFH.K))                               (A-83HV)
A   MSIAFH.K=EXP(-NARFH*(1-IAARFH.K))*EXP(-NAIFH*(1-IAAIFH.K))
X      *EXP(-NCFH*(1-IACFH.K))                               (A-83IA)
A   MSXFFH.K=EXP(-NARFH*(1-XFARFH.K))*EXP(-NAIFH*(1-XFAIFH.K))
X      *EXP(-NCFH*(1-XFCFH.K))                               (A-83XF)
A   MSXVFH.K=EXP(-NARFH*(1-XVARFH.K))*EXP(-NAIFH*(1-XVAIFH.K))
X      *EXP(-NCFH*(1-XVCFH.K))                               (A-83XV)
A   MSXAFH.K=EXP(-NARFH*(1-XAARFH.K))*EXP(-NAIFH*(1-XAAIFH.K))
X      *EXP(-NCFH*(1-XACFH.K))                               (A-83XA)
NOTE  MS$$FH - MISSION SURVIVABILITY $$ AIRCRAFT VS FH (PROB)
A   MSHHFG.K=EXP(-NARFG*(1-HHARFG.K))*EXP(-NAIFG*(1-HHAIFG.K))
X      *EXP(-NCFG*(1-HHCFG.K))                               (A-84HH)
A   MSTAFG.K=EXP(-NARFG*(1-TAARFG.K))*EXP(-NAIFG*(1-TAAIFG.K))
X      *EXP(-NCFG*(1-TACFG.K))                               (A-84TA)
A   MSXSFG.K=EXP(-NARFG*(1-XSARFG.K))*EXP(-NAIFG*(1-XSAIFG.K))
X      *EXP(-NCFG*(1-XSCFG.K))                               (A-84XS)
A   MSFFFG.K=EXP(-NARFG*(1-FFARFG.K))*EXP(-NAIFG*(1-FFAIFG.K))
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X      *EXP(-NCFG*(1-FFCFG.K))                              (A-84FF)
A   MSEFFG.K=EXP(-NARFG*(1-EFARFG.K))*EXP(-NAIFG*(1-EFAIFG.K))
X      *EXP(-NCFG*(1-EFCFG.K))                              (A-84EF)
A   MSTFFG.K=EXP(-NARFG*(1-TFARFG.K))*EXP(-NAIFG*(1-TFAIFG.K))
X      *EXP(-NCFG*(1-TFCFG.K))                              (A-84TF)
A   MSHFFG.K=EXP(-NARFG*(1-HFARFG.K))*EXP(-NAIFG*(1-HFAIFG.K))
X      *EXP(-NCFG*(1-HFCFG.K))                              (A-84HF)
A   MSHVFG.K=EXP(-NARFG*(1-HVARFG.K))*EXP(-NAIFG*(1-HVAIFG.K))
X      *EXP(-NCFG*(1-HVCFG.K))                              (A-84HV)
A   MSIAFG.K=EXP(-NARFG*(1-IAARFG.K))*EXP(-NAIFG*(1-IAAIFG.K))
X      *EXP(-NCFG*(1-IACFG.K))                              (A-84IA)
A   MSXFFG.K=EXP(-NARFG*(1-XFARFG.K))*EXP(-NAIFG*(1-XFAIFG.K))
X      *EXP(-NCFG*(1-XFCFG.K))                              (A-84XF)
A   MSXVFG.K=EXP(-NARFG*(1-XVARFG.K))*EXP(-NAIFG*(1-XVAIFG.K))
X      *EXP(-NCFG*(1-XVCFG.K))                              (A-84XV)
A   MSXAFG.K=EXP(-NARFG*(1-XAARFG.K))*EXP(-NAIFG*(1-XAAIFG.K))
X      *EXP(-NCFG*(1-XACFG.K))                              (A-84XA)
NOTE  MS$$FG - MISSION SURVIVABILITY $$ AIRCRAFT VS FG (PROB)
A   MSHHFX.K=EXP(-NARFX*(1-HHARFX.K))*EXP(-NAIFX*(1-HHAIFX.K))
X      *EXP(-NCFX*(1-HHCFX.K))                              (A-85HH)
A   MSTAFX.K=EXP(-NARFX*(1-TAARFX.K))*EXP(-NAIFX*(1-TAAIFX.K))
X      *EXP(-NCFX*(1-TACFX.K))                              (A-85TA)
A   MSXSFX.K=EXP(-NARFX*(1-XSARFX.K))*EXP(-NAIFX*(1-XSAIFX.K))
X      *EXP(-NCFX*(1-XSCFX.K))                              (A-85XS)
A   MSFFFX.K=EXP(-NARFX*(1-FFARFX.K))*EXP(-NAIFX*(1-FFAIFX.K))
X      *EXP(-NCFX*(1-FFCFX.K))                              (A-85FF)
A   MSEFFX.K=EXP(-NARFX*(1-EFARFX.K))*EXP(-NAIFX*(1-EFAIFX.K))
X      *EXP(-NCFX*(1-EFCFX.K))                              (A-85EF)
A   MSTFFX.K=EXP(-NARFX*(1-TFARFX.K))*EXP(-NAIFX*(1-TFAIFX.K))
X      *EXP(-NCFX*(1-TFCFX.K))                              (A-85TF)
A   MSHFFX.K=EXP(-NARFX*(1-HFARFX.K))*EXP(-NAIFX*(1-HFAIFX.K))
X      *EXP(-NCFX*(1-HFCFX.K))                              (A-85HF)
A   MSHVFX.K=EXP(-NARFX*(1-HVARFX.K))*EXP(-NAIFX*(1-HVAIFX.K))
X      *EXP(-NCFX*(1-HVCFX.K))                              (A-85HV)
A   MSIAFX.K=EXP(-NARFX*(1-IAARFX.K))*EXP(-NAIFX*(1-IAAIFX.K))
X      *EXP(-NCFX*(1-IACFX.K))                              (A-85IA)
A   MSXFFX.K=EXP(-NARFX*(1-XFARFX.K))*EXP(-NAIFX*(1-XFAIFX.K))
X      *EXP(-NCFX*(1-XFCFX.K))                              (A-85XF)
A   MSXVFX.K=EXP(-NARFX*(1-XVARFX.K))*EXP(-NAIFX*(1-XVAIFX.K))
X      *EXP(-NCFX*(1-XVCFX.K))                              (A-85XV)
A   MSXAFX.K=EXP(-NARFX*(1-XAARFX.K))*EXP(-NAIFX*(1-XAAIFX.K))
X      *EXP(-NCFX*(1-XACFX.K))                              (A-85XA)
NOTE  MS$$FX - MISSION SURVIVABILITY $$ AIRCRAFT VS FX (PROB)
A   MSHHFL.K=EXP(-NARFL*(1-HHARFL.K))*EXP(-NAIFL*(1-HHAIFL.K))
X      *EXP(-NCFL*(1-HHCFL.K))                              (A-86HH)
A   MSTAFL.K=EXP(-NARFL*(1-TAARFL.K))*EXP(-NAIFL*(1-TAAIFL.K))
X      *EXP(-NCFL*(1-TACFL.K))                              (A-86TA)
A   MSXSFL.K=EXP(-NARFL*(1-XSARFL.K))*EXP(-NAIFL*(1-XSAIFL.K))
X      *EXP(-NCFL*(1-XSCFL.K))                              (A-86XS)
A   MSFFFL.K=EXP(-NARFL*(1-FFARFL.K))*EXP(-NAIFL*(1-FFAIFL.K))
X      *EXP(-NCFL*(1-FFCFL.K))                              (A-86FF)
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A    MSEFFL.K=EXP(-NARFL*(1-EFARFL.K))*EXP(-NAIFL*(1-EFAIFL.K))
X        *EXP(-NCFL*(1-EFCFL.K))                              (A-86EF)
A    MSTFFL.K=EXP(-NARFL*(1-TFARFL.K))*EXP(-NAIFL*(1-TFAIFL.K))
X        *EXP(-NCFL*(1-TFCFL.K))                              (A-86TF)
A    MSHFFL.K=EXP(-NARFL*(1-HFARFL.K))*EXP(-NAIFL*(1-HFAIFL.K))
X        *EXP(-NCFL*(1-HFCFL.K))                              (A-86HF)
A    MSHVFL.K=EXP(-NARFL*(1-HVARFL.K))*EXP(-NAIFL*(1-HVAIFL.K))
X        *EXP(-NCFL*(1-HVCFL.K))                              (A-86HV)
A    MSIAFL.K=EXP(-NARFL*(1-IAARFL.K))*EXP(-NAIFL*(1-IAAIFL.K))
X        *EXP(-NCFL*(1-IACFL.K))                              (A-86IA)
A    MSXFFL.K=EXP(-NARFL*(1-XFARFL.K))*EXP(-NAIFL*(1-XFAIFL.K))
X        *EXP(-NCFL*(1-XFCFL.K))                              (A-86XF)
A    MSXVFL.K=EXP(-NARFL*(1-XVARFL.K))*EXP(-NAIFL*(1-XVAIFL.K))
X        *EXP(-NCFL*(1-XVCFL.K))                              (A-86XV)
A    MSXAFL.K=EXP(-NARFL*(1-XAARFL.K))*EXP(-NAIFL*(1-XAAIFL.K))
X        *EXP(-NCFL*(1-XACFL.K))                              (A-86XA)
NOTE  MS$$FL - MISSION SURVIVABILITY $$ AIRCRAFT VS FL (PROB)
A    MSHHBK.K=EXP(-NARBK*(1-HHARBK.K))*EXP(-NAIBK*(1-HHAIBK.K))
X        *EXP(-NCBK*(1-HHCBK.K))                              (A-87HH)
A    MSTABK.K=EXP(-NARBK*(1-TAARBK.K))*EXP(-NAIBK*(1-TAAIBK.K))
X        *EXP(-NCBK*(1-TACBK.K))                              (A-87TA)
A    MSXSBK.K=EXP(-NARBK*(1-XSARBK.K))*EXP(-NAIBK*(1-XSAIBK.K))
X        *EXP(-NCBK*(1-XSCBK.K))                              (A-87XS)
A    MSFFBK.K=EXP(-NARBK*(1-FFARBK.K))*EXP(-NAIBK*(1-FFAIBK.K))
X        *EXP(-NCBK*(1-FFCBK.K))                              (A-87FF)
A    MSEFBK.K=EXP(-NARBK*(1-EFARBK.K))*EXP(-NAIBK*(1-EFAIBK.K))
X        *EXP(-NCBK*(1-EFCBK.K))                              (A-87EF)
A    MSTFBK.K=EXP(-NARBK*(1-TFARBK.K))*EXP(-NAIBK*(1-TFAIBK.K))
X        *EXP(-NCBK*(1-TFCBK.K))                              (A-87TF)
A    MSHFBK.K=EXP(-NARBK*(1-HFARBK.K))*EXP(-NAIBK*(1-HFAIBK.K))
X        *EXP(-NCBK*(1-HFCBK.K))                              (A-87HF)
A    MSHVBK.K=EXP(-NARBK*(1-HVARBK.K))*EXP(-NAIBK*(1-HVAIBK.K))
X        *EXP(-NCBK*(1-HVCBK.K))                              (A-87HV)
A    MSIABK.K=EXP(-NARBK*(1-IAARBK.K))*EXP(-NAIBK*(1-IAAIBK.K))
X        *EXP(-NCBK*(1-IACBK.K))                              (A-87IA)
A    MSXFBK.K=EXP(-NARBK*(1-XFARBK.K))*EXP(-NAIBK*(1-XFAIBK.K))
X        *EXP(-NCBK*(1-XFCBK.K))                              (A-87XF)
A    MSXVBK.K=EXP(-NARBK*(1-XVARBK.K))*EXP(-NAIBK*(1-XVAIBK.K))
X        *EXP(-NCBK*(1-XVCBK.K))                              (A-87XV)
A    MSXABK.K=EXP(-NARBK*(1-XAARBK.K))*EXP(-NAIBK*(1-XAAIBK.K))
X        *EXP(-NCBK*(1-XACBK.K))                              (A-87XA)
NOTE  MS$$BK - MISSION SURVIVABILITY $$ AIRCRAFT VS BK (PROB)
A    MSHHFU.K=EXP(-NARFU*(1-HHARFU.K))*EXP(-NAIFU*(1-HHAIFU.K))
X        *EXP(-NCFU*(1-HHCFU.K))                              (A-88HH)
A    MSTAFU.K=EXP(-NARFU*(1-TAARFU.K))*EXP(-NAIFU*(1-TAAIFU.K))
X        *EXP(-NCFU*(1-TACFU.K))                              (A-88TA)
A    MSXSFU.K=EXP(-NARFU*(1-XSARFU.K))*EXP(-NAIFU*(1-XSAIFU.K))
X        *EXP(-NCFU*(1-XSCFU.K))                              (A-88XS)
A    MSFFFU.K=EXP(-NARFU*(1-FFARFU.K))*EXP(-NAIFU*(1-FFAIFU.K))
X        *EXP(-NCFU*(1-FFCFU.K))                              (A-88FF)
A    MSEFFU.K=EXP(-NARFU*(1-EFARFU.K))*EXP(-NAIFU*(1-EFAIFU.K))
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X       *EXP(-NCFU*(1-EFCFU.K))                              (A-88EF)
A    MSTFFU.K=EXP(-NARFU*(1-TFARFU.K))*EXP(-NAIFU*(1-TFAIFU.K))
X       *EXP(-NCFU*(1-TFCFU.K))                              (A-88TF)
A    MSHFFU.K=EXP(-NARFU*(1-HFARFU.K))*EXP(-NAIFU*(1-HFAIFU.K))
X       *EXP(-NCFU*(1-HFCFU.K))                              (A-88HF)
A    MSHVFU.K=EXP(-NARFU*(1-HVARFU.K))*EXP(-NAIFU*(1-HVAIFU.K))
X       *EXP(-NCFU*(1-HVCFU.K))                              (A-88HV)
A    MSIAFU.K=EXP(-NARFU*(1-IAARFU.K))*EXP(-NAIFU*(1-IAAIFU.K))
X       *EXP(-NCFU*(1-IACFU.K))                              (A-88IA)
A    MSXFFU.K=EXP(-NARFU*(1-XFARFU.K))*EXP(-NAIFU*(1-XFAIFU.K))
X       *EXP(-NCFU*(1-XFCFU.K))                              (A-88XF)
A    MSXVFU.K=EXP(-NARFU*(1-XVARFU.K))*EXP(-NAIFU*(1-XVAIFU.K))
X       *EXP(-NCFU*(1-XVCFU.K))                              (A-88XV)
A    MSXAFU.K=EXP(-NARFU*(1-XAARFU.K))*EXP(-NAIFU*(1-XAAIFU.K))
X       *EXP(-NCFU*(1-XACFU.K))                              (A-88XA)
NOTE  MS$$FU - MISSION SURVIVABILITY $$ AIRCRAFT VS FU (PROB)
A    MSHHFO.K=EXP(-NARFO*(1-HHARFO.K))*EXP(-NAIFO*(1-HHAIFO.K))
X       *EXP(-NCFO*(1-HHCFO.K))                              (A-89HH)
A    MSTAFO.K=EXP(-NARFO*(1-TAARFO.K))*EXP(-NAIFO*(1-TAAIFO.K))
X       *EXP(-NCFO*(1-TACFO.K))                              (A-89TA)
A    MSXSFO.K=EXP(-NARFO*(1-XSARFO.K))*EXP(-NAIFO*(1-XSAIFO.K))
X       *EXP(-NCFO*(1-XSCFO.K))                              (A-89XS)
A    MSFFFO.K=EXP(-NARFO*(1-FFARFO.K))*EXP(-NAIFO*(1-FFAIFO.K))
X       *EXP(-NCFO*(1-FFCFO.K))                              (A-89FF)
A    MSEFFO.K=EXP(-NARFO*(1-EFARFO.K))*EXP(-NAIFO*(1-EFAIFO.K))
X       *EXP(-NCFO*(1-EFCFO.K))                              (A-89EF)
A    MSTFFO.K=EXP(-NARFO*(1-TFARFO.K))*EXP(-NAIFO*(1-TFAIFO.K))
X       *EXP(-NCFO*(1-TFCFO.K))                              (A-89TF)
A    MSHFFO.K=EXP(-NARFO*(1-HFARFO.K))*EXP(-NAIFO*(1-HFAIFO.K))
X       *EXP(-NCFO*(1-HFCFO.K))                              (A-89HF)
A    MSHVFO.K=EXP(-NARFO*(1-HVARFO.K))*EXP(-NAIFO*(1-HVAIFO.K))
X       *EXP(-NCFO*(1-HVCFO.K))                              (A-89HV)
A    MSIAFO.K=EXP(-NARFO*(1-IAARFO.K))*EXP(-NAIFO*(1-IAAIFO.K))
X       *EXP(-NCFO*(1-IACFO.K))                              (A-89IA)
A    MSXFFO.K=EXP(-NARFO*(1-XFARFO.K))*EXP(-NAIFO*(1-XFAIFO.K))
X       *EXP(-NCFO*(1-XFCFO.K))                              (A-89XF)
A    MSXVFO.K=EXP(-NARFO*(1-XVARFO.K))*EXP(-NAIFO*(1-XVAIFO.K))
X       *EXP(-NCFO*(1-XVCFO.K))                              (A-89XV)
A    MSXAFO.K=EXP(-NARFO*(1-XAARFO.K))*EXP(-NAIFO*(1-XAAIFO.K))
X       *EXP(-NCFO*(1-XACFO.K))                              (A-89XA)
NOTE  MS$$FO - MISSION SURVIVABILITY $$ AIRCRAFT VS FO (PROB)
A    MSHHFK.K=EXP(-NARFK*(1-HHARFK.K))*EXP(-NAIFK*(1-HHAIFK.K))
X       *EXP(-NCFK*(1-HHCFK.K))                              (A-90HH)
A    MSTAFK.K=EXP(-NARFK*(1-TAARFK.K))*EXP(-NAIFK*(1-TAAIFK.K))
X       *EXP(-NCFK*(1-TACFK.K))                              (A-90TA)
A    MSXSFK.K=EXP(-NARFK*(1-XSARFK.K))*EXP(-NAIFK*(1-XSAIFK.K))
X       *EXP(-NCFK*(1-XSCFK.K))                              (A-90XS)
A    MSFFFK.K=EXP(-NARFK*(1-FFARFK.K))*EXP(-NAIFK*(1-FFAIFK.K))
X       *EXP(-NCFK*(1-FFCFK.K))                              (A-90FF)
A    MSEFFK.K=EXP(-NARFK*(1-EFARFK.K))*EXP(-NAIFK*(1-EFAIFK.K))
X       *EXP(-NCFK*(1-EFCFK.K))                              (A-90EF)
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A   MSTFFK.K=EXP(-NARFK*(1-TFARFK.K))*EXP(-NAIFK*(1-TFAIFK.K))
X      *EXP(-NCFK*(1-TFCFK.K))                              (A-90TF)
A   MSHFFK.K=EXP(-NARFK*(1-HFARFK.K))*EXP(-NAIFK*(1-HFAIFK.K))
X      *EXP(-NCFK*(1-HFCFK.K))                              (A-90HF)
A   MSHVFK.K=EXP(-NARFK*(1-HVARFK.K))*EXP(-NAIFK*(1-HVAIFK.K))
X      *EXP(-NCFK*(1-HVCFK.K))                              (A-90HV)
A   MSIAFK.K=EXP(-NARFK*(1-IAARFK.K))*EXP(-NAIFK*(1-IAAIFK.K))
X      *EXP(-NCFK*(1-IACFK.K))                              (A-90IA)
A   MSXFFK.K=EXP(-NARFK*(1-XFARFK.K))*EXP(-NAIFK*(1-XFAIFK.K))
X      *EXP(-NCFK*(1-XFCFK.K))                              (A-90XF)
A   MSXVFK.K=EXP(-NARFK*(1-XVARFK.K))*EXP(-NAIFK*(1-XVAIFK.K))
X      *EXP(-NCFK*(1-XVCFK.K))                              (A-90XV)
A   MSXAFK.K=EXP(-NARFK*(1-XAARFK.K))*EXP(-NAIFK*(1-XAAIFK.K))
X      *EXP(-NCFK*(1-XACFK.K))                              (A-90XA)
NOTE  MS$$FK - MISSION SURVIVABILITY $$ AIRCRAFT VS FK (PROB)
A   HHARHD.K=MSHH.K*SHHARM                                    (A-94HH)
A   TAARHD.K=MSTA.K*STAARM                                    (A-94TA)
A   XSARHD.K=MSXS.K*SXSARM                                    (A-94XS)
A   FFARHD.K=MSFF.K*SFFARM                                    (A-94FF)
A   EFARHD.K=MSEF.K*SEFARM                                    (A-94EF)
A   TFARHD.K=MSTF.K*STFARM                                    (A-94TF)
A   HFARHD.K=MSHF.K*SHFARM                                    (A-94HF)
A   HVARHD.K=MSHV.K*SHVARM                                    (A-94HV)
A   IAARHD.K=MSIA.K*SIAARM                                    (A-94IA)
A   XFARHD.K=MSXF.K*SXFARM                                    (A-94XF)
A   XVARHD.K=MSXV.K*SXVARM                                    (A-94XV)
A   XAARHD.K=MSXA.K*SXAARM                                    (A-94XA)
NOTE  $$ARHD - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM OF HD (PROB)
C   SHHARM=1.005                                              (A-94.1HH)
C   STAARM=1.005                                              (A-94.1TA)
C   SXSARM=1.005                                              (A-94.1XS)
C   SFFARM=1.005                                              (A-94.1FF)
C   SEFARM=1.005                                              (A-94.1EF)
C   STFARM=1.005                                              (A-94.1TF)
C   SHFARM=1.005                                              (A-94.1HF)
C   SHVARM=1.005                                              (A-94.1HV)
C   SIAARM=1.005                                              (A-94.1IA)
C   SXFARM=1.005                                              (A-94.1XF)
C   SXVARM=1.005                                              (A-94.1XV)
C   SXAARM=1.005                                              (A-94.1XA)
NOTE  SHHARM - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM MULT. (DIM)
A   HHARFT.K=MSHH.K*SHHARM                                    (A-95HH)
A   TAARFT.K=MSTA.K*STAARM                                    (A-95TA)
A   XSARFT.K=MSXS.K*SXSARM                                    (A-95XS)
A   FFARFT.K=MSFF.K*SFFARM                                    (A-95FF)
A   EFARFT.K=MSEF.K*SEFARM                                    (A-95EF)
A   TFARFT.K=MSTF.K*STFARM                                    (A-95TF)
A   HFARFT.K=MSHF.K*SHFARM                                    (A-95HF)
A   HVARFT.K=MSHV.K*SHVARM                                    (A-95HV)
A   IAARFT.K=MSIA.K*SIAARM                                    (A-95IA)
A   XFARFT.K=MSXF.K*SXFARM                                    (A-95XF)
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A    XVARFT.K=MSXV.K*SXVARM                                   (A-95XV)
A    XAARFT.K=MSXA.K*SXAARM                                   (A-95XA)
NOTE  $$ARFT - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM OF FT (PROB)
A    HHARFR.K=MSHH.K*SHHARM                                   (A-96HH)
A    TAARFR.K=MSTA.K*STAARM                                   (A-96TA)
A    XSARFR.K=MSXS.K*SXSARM                                   (A-96XS)
A    FFARFR.K=MSFF.K*SFFARM                                   (A-96FF)
A    EFARFR.K=MSEF.K*SEFARM                                   (A-96EF)
A    TFARFR.K=MSTF.K*STFARM                                   (A-96TF)
A    HFARFR.K=MSHF.K*SHFARM                                   (A-96HF)
A    HVARFR.K=MSHV.K*SHVARM                                   (A-96HV)
A    IAARFR.K=MSIA.K*SIAARM                                   (A-96IA)
A    XFARFR.K=MSXF.K*SXFARM                                   (A-96XF)
A    XVARFR.K=MSXV.K*SXVARM                                   (A-96XV)
A    XAARFR.K=MSXA.K*SXAARM                                   (A-96XA)
NOTE  $$ARFR - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM OF FR (PROB)
A    HHARFD.K=MSHH.K*SHHARM                                   (A-97HH)
A    TAARFD.K=MSTA.K*STAARM                                   (A-97TA)
A    XSARFD.K=MSXS.K*SXSARM                                   (A-97XS)
A    FFARFD.K=MSFF.K*SFFARM                                   (A-97FF)
A    EFARFD.K=MSEF.K*SEFARM                                   (A-97EF)
A    TFARFD.K=MSTF.K*STFARM                                   (A-97TF)
A    HFARFD.K=MSHF.K*SHFARM                                   (A-97HF)
A    HVARFD.K=MSHV.K*SHVARM                                   (A-97HV)
A    IAARFD.K=MSIA.K*SIAARM                                   (A-97IA)
A    XFARFD.K=MSXF.K*SXFARM                                   (A-97XF)
A    XVARFD.K=MSXV.K*SXVARM                                   (A-97XV)
A    XAARFD.K=MSXA.K*SXAARM                                   (A-97XA)
NOTE  $$ARFD - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM OF FD (PROB)
A    HHARFH.K=MSHH.K*SHHARM                                   (A-98HH)
A    TAARFH.K=MSTA.K*STAARM                                   (A-98TA)
A    XSARFH.K=MSXS.K*SXSARM                                   (A-98XS)
A    FFARFH.K=MSFF.K*SFFARM                                   (A-98FF)
A    EFARFH.K=MSEF.K*SEFARM                                   (A-98EF)
A    TFARFH.K=MSTF.K*STFARM                                   (A-98TF)
A    HFARFH.K=MSHF.K*SHFARM                                   (A-98HF)
A    HVARFH.K=MSHV.K*SHVARM                                   (A-98HV)
A    IAARFH.K=MSIA.K*SIAARM                                   (A-98IA)
A    XFARFH.K=MSXF.K*SXFARM                                   (A-98XF)
A    XVARFH.K=MSXV.K*SXVARM                                   (A-98XV)
A    XAARFH.K=MSXA.K*SXAARM                                   (A-98XA)
NOTE  $$ARFH - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM OF FH (PROB)
A    HHARFG.K=MSHH.K*SHHARM                                   (A-99HH)
A    TAARFG.K=MSTA.K*STAARM                                   (A-99TA)
A    XSARFG.K=MSXS.K*SXSARM                                   (A-99XS)
A    FFARFG.K=MSFF.K*SFFARM                                   (A-99FF)
A    EFARFG.K=MSEF.K*SEFARM                                   (A-99EF)
A    TFARFG.K=MSTF.K*STFARM                                   (A-99TF)
A    HFARFG.K=MSHF.K*SHFARM                                   (A-99HF)
A    HVARFG.K=MSHV.K*SHVARM                                   (A-99HV)
A    IAARFG.K=MSIA.K*SIAARM                                   (A-99IA)
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A    XFARFG.K=MSXF.K*SXFARM                                 (A-99XF)
A    XVARFG.K=MSXV.K*SXVARM                                 (A-99XV)
A    XAARFG.K=MSXA.K*SXAARM                                 (A-99XA)
NOTE  $$ARFG - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM OF FG (PROB)
A    HHARFX.K=MSHH.K*SHHARM                                 (A-100HH)
A    TAARFX.K=MSTA.K*STAARM                                 (A-100TA)
A    XSARFX.K=MSXS.K*SXSARM                                 (A-100XS)
A    FFARFX.K=MSFF.K*SFFARM                                 (A-100FF)
A    EFARFX.K=MSEF.K*SEFARM                                 (A-100EF)
A    TFARFX.K=MSTF.K*STFARM                                 (A-100TF)
A    HFARFX.K=MSHF.K*SHFARM                                 (A-100HF)
A    HVARFX.K=MSHV.K*SHVARM                                 (A-100HV)
A    IAARFX.K=MSIA.K*SIAARM                                 (A-100IA)
A    XFARFX.K=MSXF.K*SXFARM                                 (A-100XF)
A    XVARFX.K=MSXV.K*SXVARM                                 (A-100XV)
A    XAARFX.K=MSXA.K*SXAARM                                 (A-100XA)
NOTE  $$ARFX - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM OF FX (PROB)
A    HHARFL.K=MSHH.K*SHHARM                                 (A-101HH)
A    TAARFL.K=MSTA.K*STAARM                                 (A-101TA)
A    XSARFL.K=MSXS.K*SXSARM                                 (A-101XS)
A    FFARFL.K=MSFF.K*SFFARM                                 (A-101FF)
A    EFARFL.K=MSEF.K*SEFARM                                 (A-101EF)
A    TFARFL.K=MSTF.K*STFARM                                 (A-101TF)
A    HFARFL.K=MSHF.K*SHFARM                                 (A-101HF)
A    HVARFL.K=MSHV.K*SHVARM                                 (A-101HV)
A    IAARFL.K=MSIA.K*SIAARM                                 (A-101IA)
A    XFARFL.K=MSXF.K*SXFARM                                 (A-101XF)
A    XVARFL.K=MSXV.K*SXVARM                                 (A-101XV)
A    XAARFL.K=MSXA.K*SXAARM                                 (A-101XA)
NOTE  $$ARFL - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM OF FL (PROB)
A    HHARBK.K=MSHH.K*SHHARM                                 (A-102HH)
A    TAARBK.K=MSTA.K*STAARM                                 (A-102TA)
A    XSARBK.K=MSXS.K*SXSARM                                 (A-102XS)
A    FFARBK.K=MSFF.K*SFFARM                                 (A-102FF)
A    EFARBK.K=MSEF.K*SEFARM                                 (A-102EF)
A    TFARBK.K=MSTF.K*STFARM                                 (A-102TF)
A    HFARBK.K=MSHF.K*SHFARM                                 (A-102HF)
A    HVARBK.K=MSHV.K*SHVARM                                 (A-102HV)
A    IAARBK.K=MSIA.K*SIAARM                                 (A-102IA)
A    XFARBK.K=MSXF.K*SXFARM                                 (A-102XF)
A    XVARBK.K=MSXV.K*SXVARM                                 (A-102XV)
A    XAARBK.K=MSXA.K*SXAARM                                 (A-102XA)
NOTE  $$ARBK - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM OF BK (PROB)
A    HHARFU.K=MSHH.K*SHHARM                                 (A-103HH)
A    TAARFU.K=MSTA.K*STAARM                                 (A-103TA)
A    XSARFU.K=MSXS.K*SXSARM                                 (A-103XS)
A    FFARFU.K=MSFF.K*SFFARM                                 (A-103FF)
A    EFARFU.K=MSEF.K*SEFARM                                 (A-103EF)
A    TFARFU.K=MSTF.K*STFARM                                 (A-103TF)
A    HFARFU.K=MSHF.K*SHFARM                                 (A-103HF)
A    HVARFU.K=MSHV.K*SHVARM                                 (A-103HV)
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A    IAARFU.K=MSIA.K*SIAARM                                      (A-103IA)
A    XFARFU.K=MSXF.K*SXFARM                                      (A-103XF)
A    XVARFU.K=MSXV.K*SXVARM                                      (A-103XV)
A    XAARFU.K=MSXA.K*SXAARM                                      (A-103XA)
NOTE  $$ARFU - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM OF FU (PROB)
A    HHARFO.K=MSHH.K*SHHARM                                      (A-104HH)
A    TAARFO.K=MSTA.K*STAARM                                      (A-104TA)
A    XSARFO.K=MSXS.K*SXSARM                                      (A-104XS)
A    FFARFO.K=MSFF.K*SFFARM                                      (A-104FF)
A    EFARFO.K=MSEF.K*SEFARM                                      (A-104EF)
A    TFARFO.K=MSTF.K*STFARM                                      (A-104TF)
A    HFARFO.K=MSHF.K*SHFARM                                      (A-104HF)
A    HVARFO.K=MSHV.K*SHVARM                                      (A-104HV)
A    IAARFO.K=MSIA.K*SIAARM                                      (A-104IA)
A    XFARFO.K=MSXF.K*SXFARM                                      (A-104XF)
A    XVARFO.K=MSXV.K*SXVARM                                      (A-104XV)
A    XAARFO.K=MSXA.K*SXAARM                                      (A-104XA)
NOTE  $$ARFO - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM OF FO (PROB)
A    HHARFK.K=MSHH.K*SHHARM                                      (A-105HH)
A    TAARFK.K=MSTA.K*STAARM                                      (A-105TA)
A    XSARFK.K=MSXS.K*SXSARM                                      (A-105XS)
A    FFARFK.K=MSFF.K*SFFARM                                      (A-105FF)
A    EFARFK.K=MSEF.K*SEFARM                                      (A-105EF)
A    TFARFK.K=MSTF.K*STFARM                                      (A-105TF)
A    HFARFK.K=MSHF.K*SHFARM                                      (A-105HF)
A    HVARFK.K=MSHV.K*SHVARM                                      (A-105HV)
A    IAARFK.K=MSIA.K*SIAARM                                      (A-105IA)
A    XFARFK.K=MSXF.K*SXFARM                                      (A-105XF)
A    XVARFK.K=MSXV.K*SXVARM                                      (A-105XV)
A    XAARFK.K=MSXA.K*SXAARM                                      (A-105XA)
NOTE  $$ARFK - SURVIVABILITY OF $$ AIRCRAFT VS RADAR AAM OF FK (PROB)
A    HHAIHD.K=MSHH.K*SHHAIM                                      (A-106HH)
A    TAAIHD.K=MSTA.K*STAAIM                                      (A-106TA)
A    XSAIHD.K=MSXS.K*SXSAIM                                      (A-106XS)
A    FFAIHD.K=MSFF.K*SFFAIM                                      (A-106FF)
A    EFAIHD.K=MSEF.K*SEFAIM                                      (A-106EF)
A    TFAIHD.K=MSTF.K*STFAIM                                      (A-106TF)
A    HFAIHD.K=MSHF.K*SHFAIM                                      (A-106HF)
A    HVAIHD.K=MSHV.K*SHVAIM                                      (A-106HV)
A    IAAIHD.K=MSIA.K*SIAAIM                                      (A-106IA)
A    XFAIHD.K=MSXF.K*SXFAIM                                      (A-106XF)
A    XVAIHD.K=MSXV.K*SXVAIM                                      (A-106XV)
A    XAAIHD.K=MSXA.K*SXAAIM                                      (A-106XA)
NOTE  $$AIHD - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM OF HD (PROB)
C    SHHAIM=1.005                                                (A-106.1HH)
C    STAAIM=1.005                                                (A-106.1TA)
C    SXSAIM=1.005                                                (A-106.1XS)
C    SFFAIM=1.005                                                (A-106.1FF)
C    SEFAIM=1.005                                                (A-106.1EF)
C    STFAIM=1.005                                                (A-106.1TF)
C    SHFAIM=1.005                                                (A-106.1HF)
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C    SHVAIM=1.005                                                (A-106.1HV)
C    SIAAIM=1.005                                                (A-106.1IA)
C    SXFAIM=1.005                                                (A-106.1XF)
C    SXVAIM=1.005                                                (A-106.1XV)
C    SXAAIM=1.005                                                (A-106.1XA)
NOTE  SHHAIM - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM MULT. (DIM)
A    HHAIFT.K=MSHH.K*SHHAIM                                      (A-107HH)
A    TAAIFT.K=MSTA.K*STAAIM                                      (A-107TA)
A    XSAIFT.K=MSXS.K*SXSAIM                                      (A-107XS)
A    FFAIFT.K=MSFF.K*SFFAIM                                      (A-107FF)
A    EFAIFT.K=MSEF.K*SEFAIM                                      (A-107EF)
A    TFAIFT.K=MSTF.K*STFAIM                                      (A-107TF)
A    HFAIFT.K=MSHF.K*SHFAIM                                      (A-107HF)
A    HVAIFT.K=MSHV.K*SHVAIM                                      (A-107HV)
A    IAAIFT.K=MSIA.K*SIAAIM                                      (A-107IA)
A    XFAIFT.K=MSXF.K*SXFAIM                                      (A-107XF)
A    XVAIFT.K=MSXV.K*SXVAIM                                      (A-107XV)
A    XAAIFT.K=MSXA.K*SXAAIM                                      (A-107XA)
NOTE  $$AIFT - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM OF FT (PROB)
A    HHAIFR.K=MSHH.K*SHHAIM                                      (A-108HH)
A    TAAIFR.K=MSTA.K*STAAIM                                      (A-108TA)
A    XSAIFR.K=MSXS.K*SXSAIM                                      (A-108XS)
A    FFAIFR.K=MSFF.K*SFFAIM                                      (A-108FF)
A    EFAIFR.K=MSEF.K*SEFAIM                                      (A-108EF)
A    TFAIFR.K=MSTF.K*STFAIM                                      (A-108TF)
A    HFAIFR.K=MSHF.K*SHFAIM                                      (A-108HF)
A    HVAIFR.K=MSHV.K*SHVAIM                                      (A-108HV)
A    IAAIFR.K=MSIA.K*SIAAIM                                      (A-108IA)
A    XFAIFR.K=MSXF.K*SXFAIM                                      (A-108XF)
A    XVAIFR.K=MSXV.K*SXVAIM                                      (A-108XV)
A    XAAIFR.K=MSXA.K*SXAAIM                                      (A-108XA)
NOTE  $$AIFR - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM OF FR (PROB)
A    HHAIFD.K=MSHH.K*SHHAIM                                      (A-109HH)
A    TAAIFD.K=MSTA.K*STAAIM                                      (A-109TA)
A    XSAIFD.K=MSXS.K*SXSAIM                                      (A-109XS)
A    FFAIFD.K=MSFF.K*SFFAIM                                      (A-109FF)
A    EFAIFD.K=MSEF.K*SEFAIM                                      (A-109EF)
A    TFAIFD.K=MSTF.K*STFAIM                                      (A-109TF)
A    HFAIFD.K=MSHF.K*SHFAIM                                      (A-109HF)
A    HVAIFD.K=MSHV.K*SHVAIM                                      (A-109HV)
A    IAAIFD.K=MSIA.K*SIAAIM                                      (A-109IA)
A    XFAIFD.K=MSXF.K*SXFAIM                                      (A-109XF)
A    XVAIFD.K=MSXV.K*SXVAIM                                      (A-109XV)
A    XAAIFD.K=MSXA.K*SXAAIM                                      (A-109XA)
NOTE  $$AIFD - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM OF FD (PROB)
A    HHAIFH.K=MSHH.K*SHHAIM                                      (A-110HH)
A    TAAIFH.K=MSTA.K*STAAIM                                      (A-110TA)
A    XSAIFH.K=MSXS.K*SXSAIM                                      (A-110XS)
A    FFAIFH.K=MSFF.K*SFFAIM                                      (A-110FF)
A    EFAIFH.K=MSEF.K*SEFAIM                                      (A-110EF)
A    TFAIFH.K=MSTF.K*STFAIM                                      (A-110TF)
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A    HFAIFH.K=MSHF.K*SHFAIM                                   (A-110HF)
A    HVAIFH.K=MSHV.K*SHVAIM                                   (A-110HV)
A    IAAIFH.K=MSIA.K*SIAAIM                                   (A-110IA)
A    XFAIFH.K=MSXF.K*SXFAIM                                   (A-110XF)
A    XVAIFH.K=MSXV.K*SXVAIM                                   (A-110XV)
A    XAAIFH.K=MSXA.K*SXAAIM                                   (A-110XA)
NOTE  $$AIFH - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM OF FH (PROB)
A    HHAIFG.K=MSHH.K*SHHAIM                                   (A-111HH)
A    TAAIFG.K=MSTA.K*STAAIM                                   (A-111TA)
A    XSAIFG.K=MSXS.K*SXSAIM                                   (A-111XS)
A    FFAIFG.K=MSFF.K*SFFAIM                                   (A-111FF)
A    EFAIFG.K=MSEF.K*SEFAIM                                   (A-111EF)
A    TFAIFG.K=MSTF.K*STFAIM                                   (A-111TF)
A    HFAIFG.K=MSHF.K*SHFAIM                                   (A-111HF)
A    HVAIFG.K=MSHV.K*SHVAIM                                   (A-111HV)
A    IAAIFG.K=MSIA.K*SIAAIM                                   (A-111IA)
A    XFAIFG.K=MSXF.K*SXFAIM                                   (A-111XF)
A    XVAIFG.K=MSXV.K*SXVAIM                                   (A-111XV)
A    XAAIFG.K=MSXA.K*SXAAIM                                   (A-111XA)
NOTE  $$AIFG - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM OF FG (PROB)
A    HHAIFX.K=MSHH.K*SHHAIM                                   (A-112HH)
A    TAAIFX.K=MSTA.K*STAAIM                                   (A-112TA)
A    XSAIFX.K=MSXS.K*SXSAIM                                   (A-112XS)
A    FFAIFX.K=MSFF.K*SFFAIM                                   (A-112FF)
A    EFAIFX.K=MSEF.K*SEFAIM                                   (A-112EF)
A    TFAIFX.K=MSTF.K*STFAIM                                   (A-112TF)
A    HFAIFX.K=MSHF.K*SHFAIM                                   (A-112HF)
A    HVAIFX.K=MSHV.K*SHVAIM                                   (A-112HV)
A    IAAIFX.K=MSIA.K*SIAAIM                                   (A-112IA)
A    XFAIFX.K=MSXF.K*SXFAIM                                   (A-112XF)
A    XVAIFX.K=MSXV.K*SXVAIM                                   (A-112XV)
A    XAAIFX.K=MSXA.K*SXAAIM                                   (A-112XA)
NOTE  $$AIFX - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM OF FX (PROB)
A    HHAIFL.K=MSHH.K*SHHAIM                                   (A-113HH)
A    TAAIFL.K=MSTA.K*STAAIM                                   (A-113TA)
A    XSAIFL.K=MSXS.K*SXSAIM                                   (A-113XS)
A    FFAIFL.K=MSFF.K*SFFAIM                                   (A-113FF)
A    EFAIFL.K=MSEF.K*SEFAIM                                   (A-113EF)
A    TFAIFL.K=MSTF.K*STFAIM                                   (A-113TF)
A    HFAIFL.K=MSHF.K*SHFAIM                                   (A-113HF)
A    HVAIFL.K=MSHV.K*SHVAIM                                   (A-113HV)
A    IAAIFL.K=MSIA.K*SIAAIM                                   (A-113IA)
A    XFAIFL.K=MSXF.K*SXFAIM                                   (A-113XF)
A    XVAIFL.K=MSXV.K*SXVAIM                                   (A-113XV)
A    XAAIFL.K=MSXA.K*SXAAIM                                   (A-113XA)
NOTE  $$AIFL - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM OF FL (PROB)
A    HHAIBK.K=MSHH.K*SHHAIM                                   (A-114HH)
A    TAAIBK.K=MSTA.K*STAAIM                                   (A-114TA)
A    XSAIBK.K=MSXS.K*SXSAIM                                   (A-114XS)
A    FFAIBK.K=MSFF.K*SFFAIM                                   (A-114FF)
A    EFAIBK.K=MSEF.K*SEFAIM                                   (A-114EF)
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A    TFAIBK.K=MSTF.K*STFAIM                                           (A-114TF)
A    HFAIBK.K=MSHF.K*SHFAIM                                           (A-114HF)
A    HVAIBK.K=MSHV.K*SHVAIM                                           (A-114HV)
A    IAAIBK.K=MSIA.K*SIAAIM                                           (A-114IA)
A    XFAIBK.K=MSXF.K*SXFAIM                                           (A-114XF)
A    XVAIBK.K=MSXV.K*SXVAIM                                           (A-114XV)
A    XAAIBK.K=MSXA.K*SXAAIM                                           (A-114XA)
NOTE  $$AIBK - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM OF BK (PROB)
A    HHAIFU.K=MSHH.K*SHHAIM                                           (A-115HH)
A    TAAIFU.K=MSTA.K*STAAIM                                           (A-115TA)
A    XSAIFU.K=MSXS.K*SXSAIM                                           (A-115XS)
A    FFAIFU.K=MSFF.K*SFFAIM                                           (A-115FF)
A    EFAIFU.K=MSEF.K*SEFAIM                                           (A-115EF)
A    TFAIFU.K=MSTF.K*STFAIM                                           (A-115TF)
A    HFAIFU.K=MSHF.K*SHFAIM                                           (A-115HF)
A    HVAIFU.K=MSHV.K*SHVAIM                                           (A-115HV)
A    IAAIFU.K=MSIA.K*SIAAIM                                           (A-115IA)
A    XFAIFU.K=MSXF.K*SXFAIM                                           (A-115XF)
A    XVAIFU.K=MSXV.K*SXVAIM                                           (A-115XV)
A    XAAIFU.K=MSXA.K*SXAAIM                                           (A-115XA)
NOTE  $$AIFU - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM OF FU (PROB)
A    HHAIFO.K=MSHH.K*SHHAIM                                           (A-116HH)
A    TAAIFO.K=MSTA.K*STAAIM                                           (A-116TA)
A    XSAIFO.K=MSXS.K*SXSAIM                                           (A-116XS)
A    FFAIFO.K=MSFF.K*SFFAIM                                           (A-116FF)
A    EFAIFO.K=MSEF.K*SEFAIM                                           (A-116EF)
A    TFAIFO.K=MSTF.K*STFAIM                                           (A-116TF)
A    HFAIFO.K=MSHF.K*SHFAIM                                           (A-116HF)
A    HVAIFO.K=MSHV.K*SHVAIM                                           (A-116HV)
A    IAAIFO.K=MSIA.K*SIAAIM                                           (A-116IA)
A    XFAIFO.K=MSXF.K*SXFAIM                                           (A-116XF)
A    XVAIFO.K=MSXV.K*SXVAIM                                           (A-116XV)
A    XAAIFO.K=MSXA.K*SXAAIM                                           (A-116XA)
NOTE  $$AIFO - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM OF FO (PROB)
A    HHAIFK.K=MSHH.K*SHHAIM                                           (A-117HH)
A    TAAIFK.K=MSTA.K*STAAIM                                           (A-117TA)
A    XSAIFK.K=MSXS.K*SXSAIM                                           (A-117XS)
A    FFAIFK.K=MSFF.K*SFFAIM                                           (A-117FF)
A    EFAIFK.K=MSEF.K*SEFAIM                                           (A-117EF)
A    TFAIFK.K=MSTF.K*STFAIM                                           (A-117TF)
A    HFAIFK.K=MSHF.K*SHFAIM                                           (A-117HF)
A    HVAIFK.K=MSHV.K*SHVAIM                                           (A-117HV)
A    IAAIFK.K=MSIA.K*SIAAIM                                           (A-117IA)
A    XFAIFK.K=MSXF.K*SXFAIM                                           (A-117XF)
A    XVAIFK.K=MSXV.K*SXVAIM                                           (A-117XV)
A    XAAIFK.K=MSXA.K*SXAAIM                                           (A-117XA)
NOTE  $$AIFK - SURVIVABILITY OF $$ AIRCRAFT VS IR GUIDED AAM OF FK (PROB)
A    HHCHD.K=MSHH.K*SHHCM                                             (A-118HH)
A    TACHD.K=MSTA.K*STACM                                             (A-118TA)
A    XSCHD.K=MSXS.K*SXSCM                                             (A-118XS)
A    FFCHD.K=MSFF.K*SFFCM                                             (A-118FF)
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A    EFCHD.K=MSEF.K*SEFCM                                      (A-118EF)
A    TFCHD.K=MSTF.K*STFCM                                      (A-118TF)
A    HFCHD.K=MSHF.K*SHFCM                                      (A-118HF)
A    HVCHD.K=MSHV.K*SHVCM                                      (A-118HV)
A    IACHD.K=MSIA.K*SIACM                                      (A-118IA)
A    XFCHD.K=MSXF.K*SXFCM                                      (A-118XF)
A    XVCHD.K=MSXV.K*SXVCM                                      (A-118XV)
A    XACHD.K=MSXA.K*SXACM                                      (A-118XA)
NOTE  $$CHD - SURVIVABILITY OF $$ AIRCRAFT VS CANNON FROM HD (PROB)
C    SHHCM=1.007                                             (A-118.1HH)
C    STACM=1.007                                             (A-118.1TA)
C    SXSCM=1.007                                             (A-118.1XS)
C    SFFCM=1.007                                             (A-118.1FF)
C    SEFCM=1.007                                             (A-118.1EF)
C    STFCM=1.007                                             (A-118.1TF)
C    SHFCM=1.007                                             (A-118.1HF)
C    SHVCM=1.007                                             (A-118.1HV)
C    SIACM=1.007                                             (A-118.1IA)
C    SXFCM=1.007                                             (A-118.1XF)
C    SXVCM=1.007                                             (A-118.1XV)
C    SXACM=1.007                                             (A-118.1XA)
NOTE  SHHCM - SURVIVABILITY OF $$ AIRCRAFT VS CANNON MULTIPLIER (DIM)
A    HHCFT.K=MSHH.K*SHHCM                                      (A-119HH)
A    TACFT.K=MSTA.K*STACM                                      (A-119TA)
A    XSCFT.K=MSXS.K*SXSCM                                      (A-119XS)
A    FFCFT.K=MSFF.K*SFFCM                                      (A-119FF)
A    EFCFT.K=MSEF.K*SEFCM                                      (A-119EF)
A    TFCFT.K=MSTF.K*STFCM                                      (A-119TF)
A    HFCFT.K=MSHF.K*SHFCM                                      (A-119HF)
A    HVCFT.K=MSHV.K*SHVCM                                      (A-119HV)
A    IACFT.K=MSIA.K*SIACM                                      (A-119IA)
A    XFCFT.K=MSXF.K*SXFCM                                      (A-119XF)
A    XVCFT.K=MSXV.K*SXVCM                                      (A-119XV)
A    XACFT.K=MSXA.K*SXACM                                      (A-119XA)
NOTE  $$CFT - SURVIVABILITY OF $$ AIRCRAFT VS CANNON FROM FT (PROB)
A    HHCFR.K=MSHH.K*SHHCM                                      (A-120HH)
A    TACFR.K=MSTA.K*STACM                                      (A-120TA)
A    XSCFR.K=MSXS.K*SXSCM                                      (A-120XS)
A    FFCFR.K=MSFF.K*SFFCM                                      (A-120FF)
A    EFCFR.K=MSEF.K*SEFCM                                      (A-120EF)
A    TFCFR.K=MSTF.K*STFCM                                      (A-120TF)
A    HFCFR.K=MSHF.K*SHFCM                                      (A-120HF)
A    HVCFR.K=MSHV.K*SHVCM                                      (A-120HV)
A    IACFR.K=MSIA.K*SIACM                                      (A-120IA)
A    XFCFR.K=MSXF.K*SXFCM                                      (A-120XF)
A    XVCFR.K=MSXV.K*SXVCM                                      (A-120XV)
A    XACFR.K=MSXA.K*SXACM                                      (A-120XA)
NOTE  $$CFR - SURVIVABILITY OF $$ AIRCRAFT VS CANNON FROM FR (PROB)
A    HHCFD.K=MSHH.K*SHHCM                                      (A-121HH)
A    TACFD.K=MSTA.K*STACM                                      (A-121TA)
A    XSCFD.K=MSXS.K*SXSCM                                      (A-121XS)
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A   FFCFD.K=MSFF.K*SFFCM                                     (A-121FF)
A   EFCFD.K=MSEF.K*SEFCM                                     (A-121EF)
A   TFCFD.K=MSTF.K*STFCM                                     (A-121TF)
A   HFCFD.K=MSHF.K*SHFCM                                     (A-121HF)
A   HVCFD.K=MSHV.K*SHVCM                                     (A-121HV)
A   IACFD.K=MSIA.K*SIACM                                     (A-121IA)
A   XFCFD.K=MSXF.K*SXFCM                                     (A-121XF)
A   XVCFD.K=MSXV.K*SXVCM                                     (A-121XV)
A   XACFD.K=MSXA.K*SXACM                                     (A-121XA)
NOTE  $$CFD - SURVIVABILITY OF $$ AIRCRAFT VS CANNON FROM FD (PROB)
A   HHCFH.K=MSHH.K*SHHCM                                     (A-122HH)
A   TACFH.K=MSTA.K*STACM                                     (A-122TA)
A   XSCFH.K=MSXS.K*SXSCM                                     (A-122XS)
A   FFCFH.K=MSFF.K*SFFCM                                     (A-122FF)
A   EFCFH.K=MSEF.K*SEFCM                                     (A-122EF)
A   TFCFH.K=MSTF.K*STFCM                                     (A-122TF)
A   HFCFH.K=MSHF.K*SHFCM                                     (A-122HF)
A   HVCFH.K=MSHV.K*SHVCM                                     (A-122HV)
A   IACFH.K=MSIA.K*SIACM                                     (A-122IA)
A   XFCFH.K=MSXF.K*SXFCM                                     (A-122XF)
A   XVCFH.K=MSXV.K*SXVCM                                     (A-122XV)
A   XACFH.K=MSXA.K*SXACM                                     (A-122XA)
NOTE  $$CFH - SURVIVABILITY OF $$ AIRCRAFT VS CANNON FROM FH (PROB)
A   HHCFG.K=MSHH.K*SHHCM                                     (A-123HH)
A   TACFG.K=MSTA.K*STACM                                     (A-123TA)
A   XSCFG.K=MSXS.K*SXSCM                                     (A-123XS)
A   FFCFG.K=MSFF.K*SFFCM                                     (A-123FF)
A   EFCFG.K=MSEF.K*SEFCM                                     (A-123EF)
A   TFCFG.K=MSTF.K*STFCM                                     (A-123TF)
A   HFCFG.K=MSHF.K*SHFCM                                     (A-123HF)
A   HVCFG.K=MSHV.K*SHVCM                                     (A-123HV)
A   IACFG.K=MSIA.K*SIACM                                     (A-123IA)
A   XFCFG.K=MSXF.K*SXFCM                                     (A-123XF)
A   XVCFG.K=MSXV.K*SXVCM                                     (A-123XV)
A   XACFG.K=MSXA.K*SXACM                                     (A-123XA)
NOTE  $$CFG - SURVIVABILITY OF $$ AIRCRAFT VS CANNON FROM FG (PROB)
A   HHCFX.K=MSHH.K*SHHCM                                     (A-124HH)
A   TACFX.K=MSTA.K*STACM                                     (A-124TA)
A   XSCFX.K=MSXS.K*SXSCM                                     (A-124XS)
A   FFCFX.K=MSFF.K*SFFCM                                     (A-124FF)
A   EFCFX.K=MSEF.K*SEFCM                                     (A-124EF)
A   TFCFX.K=MSTF.K*STFCM                                     (A-124TF)
A   HFCFX.K=MSHF.K*SHFCM                                     (A-124HF)
A   HVCFX.K=MSHV.K*SHVCM                                     (A-124HV)
A   IACFX.K=MSIA.K*SIACM                                     (A-124IA)
A   XFCFX.K=MSXF.K*SXFCM                                     (A-124XF)
A   XVCFX.K=MSXV.K*SXVCM                                     (A-124XV)
A   XACFX.K=MSXA.K*SXACM                                     (A-124XA)
NOTE  $$CFX - SURVIVABILITY OF $$ AIRCRAFT VS CANNON FROM FX (PROB)
A   HHCFL.K=MSHH.K*SHHCM                                     (A-125HH)
A   TACFL.K=MSTA.K*STACM                                     (A-125TA)
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A   XSCFL.K=MSXS.K*SXSCM                                      (A-125XS)
A   FFCFL.K=MSFF.K*SFFCM                                      (A-125FF)
A   EFCFL.K=MSEF.K*SEFCM                                      (A-125EF)
A   TFCFL.K=MSTF.K*STFCM                                      (A-125TF)
A   HFCFL.K=MSHF.K*SHFCM                                      (A-125HF)
A   HVCFL.K=MSHV.K*SHVCM                                      (A-125HV)
A   IACFL.K=MSIA.K*SIACM                                      (A-125IA)
A   XFCFL.K=MSXF.K*SXFCM                                      (A-125XF)
A   XVCFL.K=MSXV.K*SXVCM                                      (A-125XV)
A   XACFL.K=MSXA.K*SXACM                                      (A-125XA)
NOTE  $$CFL - SURVIVABILITY OF $$ AIRCRAFT VS CANNON FROM FL (PROB)
A   HHCBK.K=MSHH.K*SHHCM                                      (A-126HH)
A   TACBK.K=MSTA.K*STACM                                      (A-126TA)
A   XSCBK.K=MSXS.K*SXSCM                                      (A-126XS)
A   FFCBK.K=MSFF.K*SFFCM                                      (A-126FF)
A   EFCBK.K=MSEF.K*SEFCM                                      (A-126EF)
A   TFCBK.K=MSTF.K*STFCM                                      (A-126TF)
A   HFCBK.K=MSHF.K*SHFCM                                      (A-126HF)
A   HVCBK.K=MSHV.K*SHVCM                                      (A-126HV)
A   IACBK.K=MSIA.K*SIACM                                      (A-126IA)
A   XFCBK.K=MSXF.K*SXFCM                                      (A-126XF)
A   XVCBK.K=MSXV.K*SXVCM                                      (A-126XV)
A   XACBK.K=MSXA.K*SXACM                                      (A-126XA)
NOTE  $$CBK - SURVIVABILITY OF $$ AIRCRAFT VS CANNON FROM BK (PROB)
A   HHCFU.K=MSHH.K*SHHCM                                      (A-127HH)
A   TACFU.K=MSTA.K*STACM                                      (A-127TA)
A   XSCFU.K=MSXS.K*SXSCM                                      (A-127XS)
A   FFCFU.K=MSFF.K*SFFCM                                      (A-127FF)
A   EFCFU.K=MSEF.K*SEFCM                                      (A-127EF)
A   TFCFU.K=MSTF.K*STFCM                                      (A-127TF)
A   HFCFU.K=MSHF.K*SHFCM                                      (A-127HF)
A   HVCFU.K=MSHV.K*SHVCM                                      (A-127HV)
A   IACFU.K=MSIA.K*SIACM                                      (A-127IA)
A   XFCFU.K=MSXF.K*SXFCM                                      (A-127XF)
A   XVCFU.K=MSXV.K*SXVCM                                      (A-127XV)
A   XACFU.K=MSXA.K*SXACM                                      (A-127XA)
NOTE  $$CFU - SURVIVABILITY OF $$ AIRCRAFT VS CANNON FROM FU (PROB)
A   HHCFO.K=MSHH.K*SHHCM                                      (A-128HH)
A   TACFO.K=MSTA.K*STACM                                      (A-128TA)
A   XSCFO.K=MSXS.K*SXSCM                                      (A-128XS)
A   FFCFO.K=MSFF.K*SFFCM                                      (A-128FF)
A   EFCFO.K=MSEF.K*SEFCM                                      (A-128EF)
A   TFCFO.K=MSTF.K*STFCM                                      (A-128TF)
A   HFCFO.K=MSHF.K*SHFCM                                      (A-128HF)
A   HVCFO.K=MSHV.K*SHVCM                                      (A-128HV)
A   IACFO.K=MSIA.K*SIACM                                      (A-128IA)
A   XFCFO.K=MSXF.K*SXFCM                                      (A-128XF)
A   XVCFO.K=MSXV.K*SXVCM                                      (A-128XV)
A   XACFO.K=MSXA.K*SXACM                                      (A-128XA)
NOTE  $$CFO - SURVIVABILITY OF $$ AIRCRAFT VS CANNON FROM FO (PROB)
A   HHCFK.K=MSHH.K*SHHCM                                      (A-129HH)
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A   TACFK.K=MSTA.K*STACM                                            (A-129TA)
A   XSCFK.K=MSXS.K*SXSCM                                            (A-129XS)
A   FFCFK.K=MSFF.K*SFFCM                                            (A-129FF)
A   EFCFK.K=MSEF.K*SEFCM                                            (A-129EF)
A   TFCFK.K=MSTF.K*STFCM                                            (A-129TF)
A   HFCFK.K=MSHF.K*SHFCM                                            (A-129HF)
A   HVCFK.K=MSHV.K*SHVCM                                            (A-129HV)
A   IACFK.K=MSIA.K*SIACM                                            (A-129IA)
A   XFCFK.K=MSXF.K*SXFCM                                            (A-129XF)
A   XVCFK.K=MSXV.K*SXVCM                                            (A-129XV)
A   XACFK.K=MSXA.K*SXACM                                            (A-129XA)
NOTE  $$CFK - SURVIVABILITY OF $$ AIRCRAFT VS CANNON FROM FK (PROB)
NOTE
NOTE   ****************************************************************
NOTE   **  COMBAT AIRCRAFT ATTRITION SUBMODEL FOR U.S.S.R. AIRCRAFT   **
NOTE   ****************************************************************
NOTE
L   HD.K=MAX(0,HD.J+(DT)(PRHD.JK-ARHD.JK))                          (A-1HD)
L   FT.K=MAX(0,FT.J+(DT)(PRFT.JK-ARFT.JK))                          (A-1FT)
L   FR.K=MAX(0,FR.J+(DT)(PRFR.JK-ARFR.JK))                          (A-1FR)
L   FD.K=MAX(0,FD.J+(DT)(PRFD.JK-ARFD.JK))                          (A-1FD)
L   FH.K=MAX(0,FH.J+(DT)(PRFH.JK-ARFH.JK))                          (A-1FH)
L   FG.K=MAX(0,FG.J+(DT)(PRFG.JK-ARFG.JK))                          (A-1FG)
L   FX.K=MAX(0,FX.J+(DT)(PRFX.JK-ARFX.JK))                          (A-1FX)
L   FL.K=MAX(0,FL.J+(DT)(PRFL.JK-ARFL.JK))                          (A-1FL)
L   BK.K=MAX(0,BK.J+(DT)(PRBK.JK-ARBK.JK))                          (A-1BK)
L   FU.K=MAX(0,FU.J+(DT)(PRFU.JK-ARFU.JK))                          (A-1FU)
L   FO.K=MAX(0,FO.J+(DT)(PRFO.JK-ARFO.JK))                          (A-1FO)
L   FK.K=MAX(0,FK.J+(DT)(PRFK.JK-ARFK.JK))                          (A-1FK)
N   HD=HDN                                                          (A-1.1HD)
N   FT=FTN                                                          (A-1.1FT)
N   FR=FRN                                                          (A-1.1FR)
N   FD=FDN                                                          (A-1.1FD)
N   FH=FHN                                                          (A-1.1FH)
N   FG=FGN                                                          (A-1.1FG)
N   FX=FXN                                                          (A-1.1FX)
N   FL=FLN                                                          (A-1.1FL)
N   BK=BKN                                                          (A-1.1BK)
N   FU=FUN                                                          (A-1.1FU)
N   FO=FON                                                          (A-1.1FO)
N   FK=FKN                                                          (A-1.1FK)
NOTE  HD - U.S.S.R. AIRCRAFT HIND MI-24  (AIRCRAFT)
NOTE  FT - U.S.S.R. AIRCRAFT FITTER SU-17/SU-20/SU-22 (AIRCRAFT)
NOTE  FR - U.S.S.R. AIRCRAFT FENCER SU-19/SU-24 (AIRCRAFT)
NOTE  FD - U.S.S.R. AIRCRAFT FISHBED MIG-21 (AIRCRAFT)
NOTE  FH - U.S.S.R. AIRCRAFT FOXHOUND MIG-25M (AIRCRAFT)
NOTE  FG - U.S.S.R. AIRCRAFT FLOGGER MIG-23/MIG-27 (AIRCRAFT)
NOTE  FX - U.S.S.R. AIRCRAFT FOXBAT MIG-25 (AIRCRAFT)
NOTE  FL - U.S.S.R. AIRCRAFT FIDDLER TU-28P/TU-128 (AIRCRAFT)
NOTE  BK - U.S.S.R. AIRCRAFT BACKFIRE TU-22M (AIRCRAFT)
NOTE  FU - U.S.S.R. AIRCRAFT FULCRUM MIG-29  (AIRCRAFT)
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NOTE  FO - U.S.S.R. AIRCRAFT FROGFOOT SU-25  (AIRCRAFT)
NOTE  FK - U.S.S.R. AIRCRAFT FLANKER SU-27  (AIRCRAFT)
C    HDN=750                                                 (A-1.2HD)
C    FTN=680                                                 (A-1.2FT)
C    FRN=370                                                 (A-1.2FR)
C    FDN=2100                                                (A-1.2FD)
C    FHN=70                                                  (A-1.2FH)
C    FGN=1900                                                (A-1.2FG)
C    FXN=500                                                 (A-1.2FX)
C    FLN=135                                                 (A-1.2FL)
C    BKN=130                                                 (A-1.2BK)
C    FUN=0                                                   (A-1.2FU)
C    FON=0                                                   (A-1.2FO)
C    FKN=0                                                   (A-1.2FK)
NOTE  XXN - NUMBER OF XX AIRCRAFT INITIALLY (AIRCRAFT)
R    PRHD.KL=CLIP(.5,180,TIME.K,WAR)          (PROC 15/MONTH)   (A-2HD)
R    PRFT.KL=CLIP(.05,20,TIME.K,WAR)                           (A-2FT)
R    PRFR.KL=CLIP(.1,20,TIME.K,WAR)                           (A-2FR)
R    PRFD.KL=CLIP(.1,25,TIME.K,WAR)                            (A-2FD)
R    PRFH.KL=CLIP(.1,25,TIME.K,WAR)                            (A-2FH)
R    PRFG.KL=CLIP(.4,100,TIME.K,WAR)                           (A-2FG)
R    PRFX.KL=CLIP(.03,10,TIME.K,WAR)                           (A-2FX)
R    PRFL.KL=CLIP(.03,10,TIME.K,WAR)                           (A-2FL)
R    PRBK.KL=CLIP(.05,15,TIME.K,WAR)                           (A-2BK)
R    PRFU.KL=CLIP(0,XFU.K,1985,TIME.K)                         (A-2FU)
A    XFU.K=CLIP(.2,75,TIME.K,WAR)
R    PRFO.KL=CLIP(0,XFO.K,1985,TIME.K)                         (A-2FO)
A    XFO.K=CLIP(.2,75,TIME.K,WAR)
R    PRFK.KL=CLIP(0,XFK.K,1985,TIME.K)                         (A-2FK)
A    XFK.K=CLIP(.2,75,TIME.K,WAR)
NOTE  PRXX - PROCUREMENT RATE XX AIRCRAFT (AIRCRAFT/DAY)
R    ARHD.KL=CLIP(HD.K*SRHDST.K*(1-MSHDST)+HD.K*SRHDLT.K*(1-MSHDLT)+
X      HH.K*SRHHHD.K*(1-MSHDHH.K)+TA.K*SRTAHD.K*(1-MSHDTA.K)+
X      XS.K*SRXSHD.K*(1-MSHDXS.K)+FF.K*SRFFHD.K*(1-MSHDFF.K)+
X      EF.K*SREFHD.K*(1-MSHDEF.K)+TF.K*SRTFHD.K*(1-MSHDTF.K)+
X      HF.K*SRHFHD.K*(1-MSHDHF.K)+HV.K*SRHVHD.K*(1-MSHDHV.K)+IA.K
X      *SRIAHD.K*(1-MSHDIA.K)+XF.K*SRXFHD.K*(1-MSHDXF.K)+XV.K*SRXVHD.K
X      *(1-MSHDXV.K)+XA.K*SRXAHD.K*(1-MSHDXA.K),0,TIME.K,WAR)   (A-3HD)
R    ARFT.KL=CLIP(FT.K*SRFTST.K*(1-MSFTST)+FT.K*SRFTLT.K*(1-MSFTLT)+
X      HH.K*SRHHFT.K*(1-MSFTHH.K)+TA.K*SRTAFT.K*(1-MSFTTA.K)+
X      XS.K*SRXSFT.K*(1-MSFTXS.K)+FF.K*SRFFFT.K*(1-MSFTFF.K)+
X      EF.K*SREFFT.K*(1-MSFTEF.K)+TF.K*SRTFFT.K*(1-MSFTTF.K)+
X      HF.K*SRHFFT.K*(1-MSFTHF.K)+HV.K*SRHVFT.K*(1-MSFTHV.K)+IA.K
X      *SRIAFT.K*(1-MSFTIA.K)+XF.K*SRXFFT.K*(1-MSFTXF.K)+XV.K*SRXVFT.K
X      *(1-MSFTXV.K)+XA.K*SRXAFT.K*(1-MSFTXA.K),0,TIME.K,WAR)   (A-3FT)
R    ARFR.KL=CLIP(FR.K*SRFRST.K*(1-MSFRST)+FR.K*SRFRLT.K*(1-MSFRLT)+
X      HH.K*SRHHFR.K*(1-MSFRHH.K)+TA.K*SRTAFR.K*(1-MSFRTA.K)+
X      XS.K*SRXSFR.K*(1-MSFRXS.K)+FF.K*SRFFFR.K*(1-MSFRFF.K)+
X      EF.K*SREFFR.K*(1-MSFREF.K)+TF.K*SRTFFR.K*(1-MSFRTF.K)+
X      HF.K*SRHFFR.K*(1-MSFRHF.K)+HV.K*SRHVFR.K*(1-MSFRHV.K)+IA.K
X      *SRIAFR.K*(1-MSFRIA.K)+XF.K*SRXFFR.K*(1-MSFRXF.K)+XV.K*SRXVFR.K
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X      *(1-MSFRXV.K)+XA.K*SRXAFR.K*(1-MSFRXA.K),0,TIME.K,WAR)    (A-3FR)
R    ARFD.KL=CLIP(FD.K*SRFDST.K*(1-MSFDST)+FD.K*SRFDLT.K*(1-MSFDLT)+
X      HH.K*SRHHFD.K*(1-MSFDHH.K)+TA.K*SRTAFD.K*(1-MSFDTA.K)+
X      XS.K*SRXSFD.K*(1-MSFDXS.K)+FF.K*SRFFFD.K*(1-MSFDFF.K)+
X      EF.K*SREFFD.K*(1-MSFDEF.K)+TF.K*SRTFFD.K*(1-MSFDTF.K)+
X      HF.K*SRHFFD.K*(1-MSFDHF.K)+HV.K*SRHVFD.K*(1-MSFDHV.K)+IA.K
X      *SRIAFD.K*(1-MSFDIA.K)+XF.K*SRXFFD.K*(1-MSFDXF.K)+XV.K*SRXVFD.K
X      *(1-MSFDXV.K)+XA.K*SRXAFD.K*(1-MSFDXA.K),0,TIME.K,WAR)    (A-3FD)
R    ARFH.KL=CLIP(FH.K*SRFHST.K*(1-MSFHST)+FH.K*SRFHLT.K*(1-MSFHLT)+
X      HH.K*SRHHFH.K*(1-MSFHHH.K)+TA.K*SRTAFH.K*(1-MSFHTA.K)+
X      XS.K*SRXSFH.K*(1-MSFHXS.K)+FF.K*SRFFFH.K*(1-MSFHFF.K)+
X      EF.K*SREFFH.K*(1-MSFHEF.K)+TF.K*SRTFFH.K*(1-MSFHTF.K)+
X      HF.K*SRHFFH.K*(1-MSFHHF.K)+HV.K*SRHVFH.K*(1-MSFHHV.K)+IA.K
X      *SRIAFH.K*(1-MSFHIA.K)+XF.K*SRXFFH.K*(1-MSFHXF.K)+XV.K*SRXVFH.K
X      *(1-MSFHXV.K)+XA.K*SRXAFH.K*(1-MSFHXA.K),0,TIME.K,WAR)    (A-3FH)
R    ARFG.KL=CLIP(FG.K*SRFGST.K*(1-MSFGST)+FG.K*SRFGLT.K*(1-MSFGLT)+
X      HH.K*SRHHFG.K*(1-MSFGHH.K)+TA.K*SRTAFG.K*(1-MSFGTA.K)+
X      XS.K*SRXSFG.K*(1-MSFGXS.K)+FF.K*SRFFFG.K*(1-MSFGFF.K)+
X      EF.K*SREFFG.K*(1-MSFGEF.K)+TF.K*SRTFFG.K*(1-MSFGTF.K)+
X      HF.K*SRHFFG.K*(1-MSFGHF.K)+HV.K*SRHVFG.K*(1-MSFGHV.K)+IA.K
X      *SRIAFG.K*(1-MSFGIA.K)+XF.K*SRXFFG.K*(1-MSFGXF.K)+XV.K*SRXVFG.K
X      *(1-MSFGXV.K)+XA.K*SRXAFG.K*(1-MSFGXA.K),0,TIME.K,WAR)    (A-3FG)
R    ARFX.KL=CLIP(FX.K*SRFXST.K*(1-MSFXST)+FX.K*SRFXLT.K*(1-MSFXLT)+
X      HH.K*SRHHFX.K*(1-MSFXHH.K)+TA.K*SRTAFX.K*(1-MSFXTA.K)+
X      XS.K*SRXSFX.K*(1-MSFXXS.K)+FF.K*SRFFFX.K*(1-MSFXFF.K)+
X      EF.K*SREFFX.K*(1-MSFXEF.K)+TF.K*SRTFFX.K*(1-MSFXTF.K)+
X      HF.K*SRHFFX.K*(1-MSFXHF.K)+HV.K*SRHVFX.K*(1-MSFXHV.K)+IA.K
X      *SRIAFX.K*(1-MSFXIA.K)+XF.K*SRXFFX.K*(1-MSFXXF.K)+XV.K*SRXVFX.K
X      *(1-MSFXXV.K)+XA.K*SRXAFX.K*(1-MSFXXA.K),0,TIME.K,WAR)    (A-3FX)
R    ARFL.KL=CLIP(FL.K*SRFLST.K*(1-MSFLST)+FL.K*SRFLLT.K*(1-MSFLLT)+
X      HH.K*SRHHFL.K*(1-MSFLHH.K)+TA.K*SRTAFL.K*(1-MSFLTA.K)+
X      XS.K*SRXSFL.K*(1-MSFLXS.K)+FF.K*SRFFFL.K*(1-MSFLFF.K)+
X      EF.K*SREFFL.K*(1-MSFLEF.K)+TF.K*SRTFFL.K*(1-MSFLTF.K)+
X      HF.K*SRHFFL.K*(1-MSFLHF.K)+HV.K*SRHVFL.K*(1-MSFLHV.K)+IA.K
X      *SRIAFL.K*(1-MSFLIA.K)+XF.K*SRXFFL.K*(1-MSFLXF.K)+XV.K*SRXVFL.K
X      *(1-MSFLXV.K)+XA.K*SRXAFL.K*(1-MSFLXA.K),0,TIME.K,WAR)    (A-3FL)
R    ARBK.KL=CLIP(BK.K*SRBKST.K*(1-MSBKST)+BK.K*SRBKLT.K*(1-MSBKLT)+
X      HH.K*SRHHBK.K*(1-MSBKHH.K)+TA.K*SRTABK.K*(1-MSBKTA.K)+
X      XS.K*SRXSBK.K*(1-MSBKXS.K)+FF.K*SRFFBK.K*(1-MSBKFF.K)+
X      EF.K*SREFBK.K*(1-MSBKEF.K)+TF.K*SRTFBK.K*(1-MSBKTF.K)+
X      HF.K*SRHFBK.K*(1-MSBKHF.K)+HV.K*SRHVBK.K*(1-MSBKHV.K)+IA.K
X      *SRIABK.K*(1-MSBKIA.K)+XF.K*SRXFBK.K*(1-MSBKXF.K)+XV.K*SRXVBK.K
X      *(1-MSBKXV.K)+XA.K*SRXABK.K*(1-MSBKXA.K),0,TIME.K,WAR)    (A-3BK)
R    ARFU.KL=CLIP(FU.K*SRFUST.K*(1-MSFUST)+FU.K*SRFULT.K*(1-MSFULT)+
X      HH.K*SRHHFU.K*(1-MSFUHH.K)+TA.K*SRTAFU.K*(1-MSFUTA.K)+
X      XS.K*SRXSFU.K*(1-MSFUXS.K)+FF.K*SRFFFU.K*(1-MSFUFF.K)+
X      EF.K*SREFFU.K*(1-MSFUEF.K)+TF.K*SRTFFU.K*(1-MSFUTF.K)+
X      HF.K*SRHFFU.K*(1-MSFUHF.K)+HV.K*SRHVFU.K*(1-MSFUHV.K)+IA.K
X      *SRIAFU.K*(1-MSFUIA.K)+XF.K*SRXFFU.K*(1-MSFUXF.K)+XV.K*SRXVFU.K
X      *(1-MSFUXV.K)+XA.K*SRXAFU.K*(1-MSFUXA.K),0,TIME.K,WAR)    (A-3FU)
R    ARFO.KL=CLIP(FO.K*SRFOST.K*(1-MSFOST)+FO.K*SRFOLT.K*(1-MSFOLT)+
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X      HH.K*SRHHFO.K*(1-MSFOHH.K)+TA.K*SRTAFO.K*(1-MSFOTA.K)+
X      XS.K*SRXSFO.K*(1-MSFOXS.K)+FF.K*SRFFFO.K*(1-MSFOFF.K)+
X      EF.K*SREFFO.K*(1-MSFOEF.K)+TF.K*SRTFFO.K*(1-MSFOTF.K)+
X      HF.K*SRHFFO.K*(1-MSFOHF.K)+HV.K*SRHVFO.K*(1-MSFOHV.K)+IA.K
X      *SRIAFO.K*(1-MSFOIA.K)+XF.K*SRXFFO.K*(1-MSFOXF.K)+XV.K*SRXVFO.K
X      *(1-MSFOXV.K)+XA.K*SRXAFO.K*(1-MSFOXA.K),0,TIME.K,WAR)   (A-3FO)
R    ARFK.KL=CLIP(FK.K*SRFKST.K*(1-MSFKST)+FK.K*SRFKLT.K*(1-MSFKLT)+
X      HH.K*SRHHFK.K*(1-MSFKHH.K)+TA.K*SRTAFK.K*(1-MSFKTA.K)+
X      XS.K*SRXSFK.K*(1-MSFKXS.K)+FF.K*SRFFFK.K*(1-MSFKFF.K)+
X      EF.K*SREFFK.K*(1-MSFKEF.K)+TF.K*SRTFFK.K*(1-MSFKTF.K)+
X      HF.K*SRHFFK.K*(1-MSFKHF.K)+HV.K*SRHVFK.K*(1-MSFKHV.K)+IA.K
X      *SRIAFK.K*(1-MSFKIA.K)+XF.K*SRXFFK.K*(1-MSFKXF.K)+XV.K*SRXVFK.K
X      *(1-MSFKXV.K)+XA.K*SRXAFK.K*(1-MSFKXA.K),0,TIME.K,WAR)   (A-3FK)
NOTE   ARHD - ATTRITION RATE AIRCRAFT HIND MI-24 (AC/DAY)
NOTE   ARFT - ATTRITION RATE AIRCRAFT FITTER SU-17/SU-20/SU-22 (AC/DAY)
NOTE   ARFR - ATTRITION RATE AIRCRAFT FENCER SU-19/SU-24 (AC/DAY)
NOTE   ARFD - ATTRITION RATE AIRCRAFT FLOGGER D MIG-27 (AC/DAY)
NOTE   ARFH - ATTRITION RATE AIRCRAFT FOXHOUND MIG-25M (AC/DAY)
NOTE   ARFG - ATTRITION RATE FLOGGER MIG-23/MIG-27 (AC/DAY)
NOTE   ARFX - ATTRITION RATE AIRCRAFT FOXBAT M-25 (AC/DAY)
NOTE   ARFL - ATTRITION RATE AIRCRAFT FIDDLER TU-28P/TU-128 (AC/DAY)
NOTE   ARBK - ATTRITION RATE AIRCRAFT BACKFIRE TU-22M (AC/DAY)
NOTE   ARFU - ATTRITION RATE AIRCRAFT FULCRUM MIG-29 (AC/DAY)
NOTE   ARFO - ATTRITION RATE AIRCRAFT FROGFOOT SU-25 (AC/DAY)
NOTE   ARFK - ATTRITION RATE AIRCRAFT FLANKER SU-27 (AC/DAY)
L    CLHD.K=CLHD.J+(DT)(ARHD.JK)                              (A-4HD)
L    CLFT.K=CLFT.J+(DT)(ARFT.JK)                              (A-4FT)
L    CLFR.K=CLFR.J+(DT)(ARFR.JK)                              (A-4FR)
L    CLFD.K=CLFD.J+(DT)(ARFD.JK)                              (A-4FD)
L    CLFH.K=CLFH.J+(DT)(ARFH.JK)                              (A-4FH)
L    CLFG.K=CLFG.J+(DT)(ARFG.JK)                              (A-4FG)
L    CLFX.K=CLFX.J+(DT)(ARFX.JK)                              (A-4FX)
L    CLFL.K=CLFL.J+(DT)(ARFL.JK)                              (A-4FL)
L    CLBK.K=CLBK.J+(DT)(ARBK.JK)                              (A-4BK)
L    CLFU.K=CLFU.J+(DT)(ARFU.JK)                              (A-4FU)
L    CLFO.K=CLFO.J+(DT)(ARFO.JK)                              (A-4FO)
L    CLFK.K=CLFK.J+(DT)(ARFK.JK)                              (A-4FK)
N    CLHD=.01                                                 (A-4.1HD)
N    CLFT=.01                                                 (A-4.1FT)
N    CLFR=.01                                                 (A-4.1FR)
N    CLFD=.01                                                 (A-4.1FD)
N    CLFH=.01                                                 (A-4.1FH)
N    CLFG=.01                                                 (A-4.1FG)
N    CLFX=.01                                                 (A-4.1FX)
N    CLFL=.01                                                 (A-4.1FL)
N    CLBK=.01                                                 (A-4.1BK)
N    CLFU=.01                                                 (A-4.1FU)
N    CLFO=.01                                                 (A-4.1FO)
N    CLFK=.01                                                 (A-4.1FK)
NOTE   CLXX - CUMULATIVE LOSSES OF XX AIRCRAFT (AC)
A    CLXX.K=CLHD.K+CLFT.K+CLFR.K+CLFD.K+CLFH.K+CLFG.K+CLFX.K
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X      +CLFL.K+CLBK.K+CLFU.K+CLFO.K+CLFK.K                       (A-5XX)
NOTE  CLXX - TOTAL CUMULATIVE LOSSES OF U.S.S.R AIRCRAFT (AC)
NOTE
NOTE       +---------------------------------------+
NOTE       |      MISSION  VS. SEA  TARGETS        |
NOTE       +---------------------------------------+
NOTE
A    SRHDST.K=FSHDST*MIN(AAHDST/(1-MSHDST),SRHDM*AVHD)           (A-6HD)
A    SRFTST.K=FSFTST*MIN(AAFTST/(1-MSFTST),SRFTM*AVFT)           (A-6FT)
A    SRFRST.K=FSFRST*MIN(AAFRST/(1-MSFRST),SRFRM*AVFR)           (A-6FR)
A    SRFDST.K=FSFDST*MIN(AAFDST/(1-MSFDST),SRFDM*AVFD)           (A-6FD)
A    SRFHST.K=FSFHST*MIN(AAFHST/(1-MSFHST),SRFHM*AVFH)           (A-6FH)
A    SRFGST.K=FSFGST*MIN(AAFGST/(1-MSFGST),SRFGM*AVFG)           (A-6FG)
A    SRFXST.K=FSFXST*MIN(AAFXST/(1-MSFXST),SRFXM*AVFX)           (A-6FX)
A    SRFLST.K=FSFLST*MIN(AAFLST/(1-MSFLST),SRFLM*AVFL)           (A-6FL)
A    SRBKST.K=FSBKST*MIN(AABKST/(1-MSBKST),SRBKM*AVBK)           (A-6BK)
A    SRFUST.K=FSFUST*MIN(AAFUST/(1-MSFUST),SRFUM*AVFU)           (A-6FU)
A    SRFOST.K=FSFOST*MIN(AAFOST/(1-MSFOST),SRFOM*AVFO)           (A-6FO)
A    SRFKST.K=FSFKST*MIN(AAFKST/(1-MSFKST),SRFKM*AVFK)           (A-6FK)
NOTE  SRHDST - SORTIE RATE MI-24 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRFTST - SORTIE RATE SU-17/SU-20/SU-22 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRFRST - SORTIE RATE SU-19/SU-24 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRFDST - SORTIE RATE MIG-27 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRFHST - SORTIE RATE MIG-25M VS SEA TARGETS (AC/AC-DAY)
NOTE  SRFGST - SORTIE RATE MIG-23/MIG-27 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRFXST - SORTIE RATE MIG-25 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRFLST - SORTIE RATE TU-28P/TU-128 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRBKST - SORTIE RATE TU-22M VS SEA TARGETS (AC/AC-DAY)
NOTE  SRFUST - SORTIE RATE MIG-29 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRFOST - SORTIE RATE SU-25 VS SEA TARGETS (AC/AC-DAY)
NOTE  SRFKST - SORTIE RATE SU-27 VS SEA TARGETS (AC/AC-DAY)
C    SRHDM=4                                                     (A-6.1HD)
C    SRFTM=4                                                     (A-6.1FT)
C    SRFRM=4                                                     (A-6.1FR)
C    SRFDM=4                                                     (A-6.1FD)
C    SRFHM=4                                                     (A-6.1FH)
C    SRFGM=4                                                     (A-6.1FG)
C    SRFXM=4                                                     (A-6.1FX)
C    SRFLM=4                                                     (A-6.1FL)
C    SRBKM=4                                                     (A-6.1BK)
C    SRFUM=4                                                     (A-6.1FU)
C    SRFOM=4                                                     (A-6.1FO)
C    SRFKM=4                                                     (A-6.1FK)
NOTE  SRXXM - SORTIE RATE XX MAXIMUM (AC/AC-DAY)
C    AVHD=.5                                                     (A-6.2HD)
C    AVFT=.5                                                     (A-6.2FT)
C    AVFR=.5                                                     (A-6.2FR)
C    AVFD=.5                                                     (A-6.2FD)
C    AVFH=.5                                                     (A-6.2FH)
C    AVFG=.5                                                     (A-6.2FG)
C    AVFX=.5                                                     (A-6.2FX)
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C    AVFL=.5                                                   (A-6.2FL)
C    AVBK=.5                                                   (A-6.2BK)
C    AVFU=.5                                                   (A-6.2FU)
C    AVFO=.5                                                   (A-6.2FO)
C    AVFK=.5                                                   (A-6.2FK)
NOTE  AVXX - AVAILABILITY OF XX AIRCRAFT (PROB)
C    FSHDST=0                                                  (A-6.3HD)
C    FSFTST=.2                                                 (A-6.3FT)
C    FSFRST=.3                                                 (A-6.3FR)
C    FSFDST=.3                                                 (A-6.3FD)
C    FSFHST=0                                                  (A-6.3FH)
C    FSFGST=.2                                                 (A-6.3FG)
C    FSFXST=0                                                  (A-6.3FX)
C    FSFLST=.4                                                 (A-6.3FL)
C    FSBKST=.2                                                 (A-6.3BK)
C    FSFUST=.5                                                 (A-6.3FU)
C    FSFOST=.3                                                 (A-6.3FO)
C    FSFKST=.2                                                 (A-6.3FK)
NOTE  FSXXST - FRACT SORTIE XX VS SEA TARGETS (DIM)
C    AAHDST=.10                                                (A-6.4HD)
C    AAFTST=.10                                                (A-6.4FT)
C    AAFRST=.10                                                (A-6.4FR)
C    AAFDST=.10                                                (A-6.4FD)
C    AAFHST=.10                                                (A-6.4FH)
C    AAFGST=.10                                                (A-6.4FG)
C    AAFXST=.10                                                (A-6.4FX)
C    AAFLST=.10                                                (A-6.4FL)
C    AABKST=.10                                                (A-6.4BK)
C    AAFUST=.10                                                (A-6.4FU)
C    AAFOST=.10                                                (A-6.4FO)
C    AAFKST=.10                                                (A-6.4FK)
NOTE  AAXXST - ALLOWABLE ATTRITION XX VS SEA THREATS (FRACT/DAY)
C    MSHDST=.959                                               (A-6.5HD)
C    MSFTST=.957                                               (A-6.5FT)
C    MSFRST=.969                                               (A-6.5FR)
C    MSFDST=.952                                               (A-6.5FD)
C    MSFHST=.95                                                (A-6.5FH)
C    MSFGST=.955                                               (A-6.5FG)
C    MSFXST=.95                                                (A-6.5FX)
C    MSFLST=.95                                                (A-6.5FL)
C    MSBKST=.971                                               (A-6.5BK)
C    MSFUST=.964                                               (A-6.5FU)
C    MSFOST=.959                                               (A-6.5FO)
C    MSFKST=.974                                               (A-6.5FK)
NOTE  MSXXST - MISSION SURVIVABILITY XX AIRCRAFT VS SEA THREATS
NOTE
NOTE          +---------------------------------------+
NOTE          |     MISSION  VS.  LAND  TARGETS       |
NOTE          +---------------------------------------+
NOTE
A    SRHDLT.K=FSHDLT*MIN(AAHDLT/(1-MSHDLT),SRHDM*AVHD)         (A-23HD)
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A   SRFTLT.K=FSFTLT*MIN(AAFTLT/(1-MSFTLT),SRFTM*AVFT)        (A-23FT)
A   SRFRLT.K=FSFRLT*MIN(AAFRLT/(1-MSFRLT),SRFRM*AVFR)        (A-23FR)
A   SRFDLT.K=FSFDLT*MIN(AAFDLT/(1-MSFDLT),SRFDM*AVFD)        (A-23FD)
A   SRFHLT.K=FSFHLT*MIN(AAFHLT/(1-MSFHLT),SRFHM*AVFH)        (A-23FH)
A   SRFGLT.K=FSFGLT*MIN(AAFGLT/(1-MSFGLT),SRFGM*AVFG)        (A-23FG)
A   SRFXLT.K=FSFXLT*MIN(AAFXLT/(1-MSFXLT),SRFXM*AVFX)        (A-23FX)
A   SRFLLT.K=FSFLLT*MIN(AAFLLT/(1-MSFLLT),SRFLM*AVFL)        (A-23FL)
A   SRBKLT.K=FSBKLT*MIN(AABKLT/(1-MSBKLT),SRBKM*AVBK)        (A-23BK)
A   SRFULT.K=FSFULT*MIN(AAFULT/(1-MSFULT),SRFUM*AVFU)        (A-23FU)
A   SRFOLT.K=FSFOLT*MIN(AAFOLT/(1-MSFOLT),SRFOM*AVFO)        (A-23FO)
A   SRFKLT.K=FSFKLT*MIN(AAFKLT/(1-MSFKLT),SRFKM*AVFK)        (A-23FK)
NOTE  SRHDLT - SORTIE RATE MI-24 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRFTLT - SORTIE RATE SU-17/SU-20/SU-22 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRFRLT - SORTIE RATE SU-19/SU-24 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRFDLT - SORTIE RATE MIG-27 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRFHLT - SORTIE RATE MIG-25M VS LAND TARGETS (AC/AC-DAY)
NOTE  SRFGLT - SORTIE RATE MIG-23/MIG-27 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRFXLT - SORTIE RATE MIG-25 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRFLLT - SORTIE RATE TU-28P/TU-128 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRBKLT - SORTIE RATE TU-22M VS LAND TARGETS (AC/AC-DAY)
NOTE  SRFULT - SORTIE RATE MIG-29 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRFOLT - SORTIE RATE SU-25 VS LAND TARGETS (AC/AC-DAY)
NOTE  SRFKLT - SORTIE RATE SU-27 VS LAND TARGETS (AC/AC-DAY)
C   FSHDLT=.9                                                 (A-23.1HD)
C   FSFTLT=.7                                                 (A-23.1FT)
C   FSFRLT=.6                                                 (A-23.1FR)
C   FSFDLT=0                                                  (A-23.1FD)
C   FSFHLT=.2                                                 (A-23.1FH)
C   FSFGLT=.4                                                 (A-23.1FG)
C   FSFXLT=.2                                                 (A-23.1FX)
C   FSFLLT=.4                                                 (A-23.1FL)
C   FSBKLT=.75                                                (A-23.1BK)
C   FSFULT=0                                                  (A-23.1FU)
C   FSFOLT=.5                                                 (A-23.1FO)
C   FSFKLT=.3                                                 (A-23.1FK)
NOTE  FSXXLT - FRACTION SORTIE XX VS LAND TARGETS (DIM)
C   AAHDLT=.10                                                (A-23.2HD)
C   AAFTLT=.10                                                (A-23.2FT)
C   AAFRLT=.10                                                (A-23.2FR)
C   AAFDLT=.10                                                (A-23.2FD)
C   AAFHLT=.10                                                (A-23.2FH)
C   AAFGLT=.10                                                (A-23.2FG)
C   AAFXLT=.10                                                (A-23.2FX)
C   AAFLLT=.10                                                (A-23.2FL)
C   AABKLT=.10                                                (A-23.2BK)
C   AAFULT=.10                                                (A-23.2FU)
C   AAFOLT=.10                                                (A-23.2FO)
C   AAFKLT=.10                                                (A-23.2FK)
NOTE  AAXXLT - ALLOWABLE ATTRITION RATE XX VS LAND THREATS (FRACT/DAY)
C   MSHDLT=.959                                               (A-23.3HD)
C   MSFTLT=.957                                               (A-23.3FT)
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C    MSFRLT=.969                                                (A-23.3FR)
C    MSFDLT=.952                                                (A-23.3FD)
C    MSFHLT=.95                                                 (A-23.3FH)
C    MSFGLT=.955                                                (A-23.3FG)
C    MSFXLT=.95                                                 (A-23.3FX)
C    MSFLLT=.95                                                 (A-23.3FL)
C    MSBKLT=.971                                                (A-23.3BK)
C    MSFULT=.964                                                (A-23.3FU)
C    MSFOLT=.959                                                (A-23.3FO)
C    MSFKLT=.974                                                (A-23.3FK)
NOTE  MSXXLT - MISSION SURVIVABILITY XX AIRCRAFT VS LAND THREATS (PROB)
NOTE
NOTE          +------------------------------------+
NOTE          |      MISSION   VS.  AIRCRAFT       |
NOTE          +------------------------------------+
NOTE
A    SRHDHH.K=FSHDAT*EHDHH.K*MIN(AAHHAT/(1-MSHHHD.K),SRHDM*AVHD)   (A-40HD)
A    SRFTHH.K=FSFTAT*EFTHH.K*MIN(AAHHAT/(1-MSHHFT.K),SRFTM*AVFT)   (A-40FT)
A    SRFRHH.K=FSFRAT*EFRHH.K*MIN(AAHHAT/(1-MSHHFR.K),SRFRM*AVFR)   (A-40FR)
A    SRFDHH.K=FSFDAT*EFDHH.K*MIN(AAHHAT/(1-MSHHFD.K),SRFDM*AVFD)   (A-40FD)
A    SRFHHH.K=FSFHAT*EFHHH.K*MIN(AAHHAT/(1-MSHHFH.K),SRFHM*AVFH)   (A-40FH)
A    SRFGHH.K=FSFGAT*EFGHH.K*MIN(AAHHAT/(1-MSHHFG.K),SRFGM*AVFG)   (A-40FG)
A    SRFXHH.K=FSFXAT*EFXHH.K*MIN(AAHHAT/(1-MSHHFX.K),SRFXM*AVFX)   (A-40FX)
A    SRFLHH.K=FSFLAT*EFLHH.K*MIN(AAHHAT/(1-MSHHFL.K),SRFLM*AVFL)   (A-40FL)
A    SRBKHH.K=FSBKAT*EBKHH.K*MIN(AAHHAT/(1-MSHHBK.K),SRBKM*AVBK)   (A-40BK)
A    SRFUHH.K=FSFUAT*EFUHH.K*MIN(AAHHAT/(1-MSHHFU.K),SRFUM*AVFU)   (A-40FU)
A    SRFOHH.K=FSFOAT*EFOHH.K*MIN(AAHHAT/(1-MSHHFO.K),SRFOM*AVFO)   (A-40FO)
A    SRFKHH.K=FSFKAT*EFKHH.K*MIN(AAHHAT/(1-MSHHFK.K),SRFKM*AVFK)   (A-40FK)
NOTE  SRXXHH - SORTIE RATE XX VS AH-64 (AC/AC-DAY)
A    SRHDTA.K=FSHDAT*EHDTA.K*MIN(AATAAT/(1-MSTAHD.K),SRHDM*AVHD)   (A-41HD)
A    SRFTTA.K=FSFTAT*EFTTA.K*MIN(AATAAT/(1-MSTAFT.K),SRFTM*AVFT)   (A-41FT)
A    SRFRTA.K=FSFRAT*EFRTA.K*MIN(AATAAT/(1-MSTAFR.K),SRFRM*AVFR)   (A-41FR)
A    SRFDTA.K=FSFDAT*EFDTA.K*MIN(AATAAT/(1-MSTAFD.K),SRFDM*AVFD)   (A-41FD)
A    SRFHTA.K=FSFHAT*EFHTA.K*MIN(AATAAT/(1-MSTAFH.K),SRFHM*AVFH)   (A-41FH)
A    SRFGTA.K=FSFGAT*EFGTA.K*MIN(AATAAT/(1-MSTAFG.K),SRFGM*AVFG)   (A-41FG)
A    SRFXTA.K=FSFXAT*EFXTA.K*MIN(AATAAT/(1-MSTAFX.K),SRFXM*AVFX)   (A-41FX)
A    SRFLTA.K=FSFLAT*EFLTA.K*MIN(AATAAT/(1-MSTAFL.K),SRFLM*AVFL)   (A-41FL)
A    SRBKTA.K=FSBKAT*EBKTA.K*MIN(AATAAT/(1-MSTABK.K),SRBKM*AVBK)   (A-41BK)
A    SRFUTA.K=FSFUAT*EFUTA.K*MIN(AATAAT/(1-MSTAFU.K),SRFUM*AVFU)   (A-41FU)
A    SRFOTA.K=FSFOAT*EFOTA.K*MIN(AATAAT/(1-MSTAFO.K),SRFOM*AVFO)   (A-41FO)
A    SRFKTA.K=FSFKAT*EFKTA.K*MIN(AATAAT/(1-MSTAFK.K),SRFKM*AVFK)   (A-41FK)
NOTE  SRXXTA - SORTIE RATE XX VS A-10 (AC/AC-DAY)
A    SRHDXS.K=FSHDAT*EHDXS.K*MIN(AAXSAT/(1-MSXSHD.K),SRHDM*AVHD)   (A-42HD)
A    SRFTXS.K=FSFTAT*EFTXS.K*MIN(AAXSAT/(1-MSXSFT.K),SRFTM*AVFT)   (A-42FT)
A    SRFRXS.K=FSFRAT*EFRXS.K*MIN(AAXSAT/(1-MSXSFR.K),SRFRM*AVFR)   (A-42FR)
A    SRFDXS.K=FSFDAT*EFDXS.K*MIN(AAXSAT/(1-MSXSFD.K),SRFDM*AVFD)   (A-42FD)
A    SRFHXS.K=FSFHAT*EFHXS.K*MIN(AAXSAT/(1-MSXSFH.K),SRFHM*AVFH)   (A-42FH)
A    SRFGXS.K=FSFGAT*EFGXS.K*MIN(AAXSAT/(1-MSXSFG.K),SRFGM*AVFG)   (A-42FG)
A    SRFXXS.K=FSFXAT*EFXXS.K*MIN(AAXSAT/(1-MSXSFX.K),SRFXM*AVFX)   (A-42FX)
A    SRFLXS.K=FSFLAT*EFLXS.K*MIN(AAXSAT/(1-MSXSFL.K),SRFLM*AVFL)   (A-42FL)
A    SRBKXS.K=FSBKAT*EBKXS.K*MIN(AAXSAT/(1-MSXSBK.K),SRBKM*AVBK)   (A-42BK)
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A   SRFUXS.K=FSFUAT*EFUXS.K*MIN(AAXSAT/(1-MSXSFU.K),SRFUM*AVFU)  (A-42FU)
A   SRFOXS.K=FSFOAT*EFOXS.K*MIN(AAXSAT/(1-MSXSFO.K),SRFOM*AVFO)  (A-42FO)
A   SRFKXS.K=FSFKAT*EFKXS.K*MIN(AAXSAT/(1-MSXSFK.K),SRFKM*AVFK)  (A-42FK)
NOTE  SRXXXS - SORTIE RATE XX VS STEALTH STRIKE (AC/AC-DAY)
A   SRHDFF.K=FSHDAT*EHDFF.K*MIN(AAFFAT/(1-MSFFHD.K),SRHDM*AVHD)  (A-43HD)
A   SRFTFF.K=FSFTAT*EFTFF.K*MIN(AAFFAT/(1-MSFFFT.K),SRFTM*AVFT)  (A-43FT)
A   SRFRFF.K=FSFRAT*EFRFF.K*MIN(AAFFAT/(1-MSFFFR.K),SRFRM*AVFR)  (A-43FR)
A   SRFDFF.K=FSFDAT*EFDFF.K*MIN(AAFFAT/(1-MSFFFD.K),SRFDM*AVFD)  (A-43FD)
A   SRFHFF.K=FSFHAT*EFHFF.K*MIN(AAFFAT/(1-MSFFFH.K),SRFHM*AVFH)  (A-43FH)
A   SRFGFF.K=FSFGAT*EFGFF.K*MIN(AAFFAT/(1-MSFFFG.K),SRFGM*AVFG)  (A-43FG)
A   SRFXFF.K=FSFXAT*EFXFF.K*MIN(AAFFAT/(1-MSFFFX.K),SRFXM*AVFX)  (A-43FX)
A   SRFLFF.K=FSFLAT*EFLFF.K*MIN(AAFFAT/(1-MSFFFL.K),SRFLM*AVFL)  (A-43FL)
A   SRBKFF.K=FSBKAT*EBKFF.K*MIN(AAFFAT/(1-MSFFBK.K),SRBKM*AVBK)  (A-43BK)
A   SRFUFF.K=FSFUAT*EFUFF.K*MIN(AAFFAT/(1-MSFFFU.K),SRFUM*AVFU)  (A-43FU)
A   SRFOFF.K=FSFOAT*EFOFF.K*MIN(AAFFAT/(1-MSFFFO.K),SRFOM*AVFO)  (A-43FO)
A   SRFKFF.K=FSFKAT*EFKFF.K*MIN(AAFFAT/(1-MSFFFK.K),SRFKM*AVFK)  (A-43FK)
NOTE  SRXXFF - SORTIE RATE XX VS F-16 (AC/AC-DAY)
A   SRHDEF.K=FSHDAT*EHDEF.K*MIN(AAEFAT/(1-MSEFHD.K),SRHDM*AVHD)  (A-44HD)
A   SRFTEF.K=FSFTAT*EFTEF.K*MIN(AAEFAT/(1-MSEFFT.K),SRFTM*AVFT)  (A-44FT)
A   SRFREF.K=FSFRAT*EFREF.K*MIN(AAEFAT/(1-MSEFFR.K),SRFRM*AVFR)  (A-44FR)
A   SRFDEF.K=FSFDAT*EFDEF.K*MIN(AAEFAT/(1-MSEFFD.K),SRFDM*AVFD)  (A-44FD)
A   SRFHEF.K=FSFHAT*EFHEF.K*MIN(AAEFAT/(1-MSEFFH.K),SRFHM*AVFH)  (A-44FH)
A   SRFGEF.K=FSFGAT*EFGEF.K*MIN(AAEFAT/(1-MSEFFG.K),SRFGM*AVFG)  (A-44FG)
A   SRFXEF.K=FSFXAT*EFXEF.K*MIN(AAEFAT/(1-MSEFFX.K),SRFXM*AVFX)  (A-44FX)
A   SRFLEF.K=FSFLAT*EFLEF.K*MIN(AAEFAT/(1-MSEFFL.K),SRFLM*AVFL)  (A-44FL)
A   SRBKEF.K=FSBKAT*EBKEF.K*MIN(AAEFAT/(1-MSEFBK.K),SRFKM*AVBK)  (A-44BK)
A   SRFUEF.K=FSFUAT*EFUEF.K*MIN(AAEFAT/(1-MSEFFU.K),SRFUM*AVFU)  (A-44FU)
A   SRFOEF.K=FSFOAT*EFOEF.K*MIN(AAEFAT/(1-MSEFFO.K),SRFOM*AVFO)  (A-44FO)
A   SRFKEF.K=FSFKAT*EFKEF.K*MIN(AAEFAT/(1-MSEFFK.K),SRFKM*AVFK)  (A-44FK)
NOTE  SRXXEF - SORTIE RATE XX VS F-15 (AC/AC-DAY)
A   SRHDTF.K=FSHDAT*EHDTF.K*MIN(AATFAT/(1-MSTFHD.K),SRHDM*AVHD)  (A-45HD)
A   SRFTTF.K=FSFTAT*EFTTF.K*MIN(AATFAT/(1-MSTFFT.K),SRFTM*AVFT)  (A-45FT)
A   SRFRTF.K=FSFRAT*EFRTF.K*MIN(AATFAT/(1-MSTFFR.K),SRFRM*AVFR)  (A-45FR)
A   SRFDTF.K=FSFDAT*EFDTF.K*MIN(AATFAT/(1-MSTFFD.K),SRFDM*AVFD)  (A-45FD)
A   SRFHTF.K=FSFHAT*EFHTF.K*MIN(AATFAT/(1-MSTFFH.K),SRFHM*AVFH)  (A-45FH)
A   SRFGTF.K=FSFGAT*EFGTF.K*MIN(AATFAT/(1-MSTFFG.K),SRFGM*AVFG)  (A-45FG)
A   SRFXTF.K=FSFXAT*EFXTF.K*MIN(AATFAT/(1-MSTFFX.K),SRFXM*AVFX)  (A-45FX)
A   SRFLTF.K=FSFLAT*EFLTF.K*MIN(AATFAT/(1-MSTFFL.K),SRFLM*AVFL)  (A-45FL)
A   SRBKTF.K=FSBKAT*EBKTF.K*MIN(AATFAT/(1-MSTFBK.K),SRFKM*AVBK)  (A-45BK)
A   SRFUTF.K=FSFUAT*EFUTF.K*MIN(AATFAT/(1-MSTFFU.K),SRFUM*AVFU)  (A-45FU)
A   SRFOTF.K=FSFOAT*EFOTF.K*MIN(AATFAT/(1-MSTFFO.K),SRFOM*AVFO)  (A-45FO)
A   SRFKTF.K=FSFKAT*EFKTF.K*MIN(AATFAT/(1-MSTFFK.K),SRFKM*AVFK)  (A-45FK)
NOTE  SRXXTF - SORTIE RATE XX VS F-14 (AC/AC-DAY)
A   SRHDHF.K=FSHDAT*EHDHF.K*MIN(AAHFAT/(1-MSHFHD.K),SRHDM*AVHD)  (A-46HD)
A   SRFTHF.K=FSFTAT*EFTHF.K*MIN(AAHFAT/(1-MSHFFT.K),SRFTM*AVFT)  (A-46FT)
A   SRFRHF.K=FSFRAT*EFRHF.K*MIN(AAHFAT/(1-MSHFFR.K),SRFRM*AVFR)  (A-46FR)
A   SRFDHF.K=FSFDAT*EFDHF.K*MIN(AAHFAT/(1-MSHFFD.K),SRFDM*AVFD)  (A-46FD)
A   SRFHHF.K=FSFHAT*EFHHF.K*MIN(AAHFAT/(1-MSHFFH.K),SRFHM*AVFH)  (A-46FH)
A   SRFGHF.K=FSFGAT*EFGHF.K*MIN(AAHFAT/(1-MSHFFG.K),SRFGM*AVFG)  (A-46FG)
A   SRFXHF.K=FSFXAT*EFXHF.K*MIN(AAHFAT/(1-MSHFFX.K),SRFXM*AVFX)  (A-46FX)
A   SRFLHF.K=FSFLAT*EFLHF.K*MIN(AAHFAT/(1-MSHFFL.K),SRFLM*AVFL)  (A-46FL)
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A    SRBKHF.K=FSBKAT*EBKHF.K*MIN(AAHFAT/(1-MSHFBK.K),SRBKM*AVBK)   (A-46BK)
A    SRFUHF.K=FSFUAT*EFUHF.K*MIN(AAHFAT/(1-MSHFFU.K),SRFUM*AVFU)   (A-46FU)
A    SRFOHF.K=FSFOAT*EFOHF.K*MIN(AAHFAT/(1-MSHFFO.K),SRFOM*AVFO)   (A-46FO)
A    SRFKHF.K=FSFKAT*EFKHF.K*MIN(AAHFAT/(1-MSHFFK.K),SRFKM*AVFK)   (A-46FK)
NOTE   SRXXHF - SORTIE RATE XX VS F/A-18 (AC/AC-DAY)
A    SRHDHV.K=FSHDAT*EHDHV.K*MIN(AAHVAT/(1-MSHVHD.K),SRHDM*AVHD)   (A-47HD)
A    SRFTHV.K=FSFTAT*EFTHV.K*MIN(AAHVAT/(1-MSHVFT.K),SRFTM*AVFT)   (A-47FT)
A    SRFRHV.K=FSFRAT*EFRHV.K*MIN(AAHVAT/(1-MSHVFR.K),SRFRM*AVFR)   (A-47FR)
A    SRFDHV.K=FSFDAT*EFDHV.K*MIN(AAHVAT/(1-MSHVFD.K),SRFDM*AVFD)   (A-47FD)
A    SRFHHV.K=FSFHAT*EFHHV.K*MIN(AAHVAT/(1-MSHVFH.K),SRFHM*AVFH)   (A-47FH)
A    SRFGHV.K=FSFGAT*EFGHV.K*MIN(AAHVAT/(1-MSHVFG.K),SRFGM*AVFG)   (A-47FG)
A    SRFXHV.K=FSFXAT*EFXHV.K*MIN(AAHVAT/(1-MSHVFX.K),SRFXM*AVFX)   (A-47FX)
A    SRFLHV.K=FSFLAT*EFLHV.K*MIN(AAHVAT/(1-MSHVFL.K),SRFLM*AVFL)   (A-47FL)
A    SRBKHV.K=FSBKAT*EBKHV.K*MIN(AAHVAT/(1-MSHVBK.K),SRBKM*AVBK)   (A-47BK)
A    SRFUHV.K=FSFUAT*EFUHV.K*MIN(AAHVAT/(1-MSHVFU.K),SRFUM*AVFU)   (A-47FU)
A    SRFOHV.K=FSFOAT*EFOHV.K*MIN(AAHVAT/(1-MSHVFO.K),SRFOM*AVFO)   (A-47FO)
A    SRFKHV.K=FSFKAT*EFKHV.K*MIN(AAHVAT/(1-MSHVFK.K),SRFKM*AVFK)   (A-47FK)
NOTE   SRXXHV - SORTIE RATE XX VS AV-8 (AC/AC-DAY)
A    SRHDIA.K=FSHDAT*EHDIA.K*MIN(AAIAAT/(1-MSIAHD.K),SRHDM*AVHD)   (A-48HD)
A    SRFTIA.K=FSFTAT*EFTIA.K*MIN(AAIAAT/(1-MSIAFT.K),SRFTM*AVFT)   (A-48FT)
A    SRFRIA.K=FSFRAT*EFRIA.K*MIN(AAIAAT/(1-MSIAFR.K),SRFRM*AVFR)   (A-48FR)
A    SRFDIA.K=FSFDAT*EFDIA.K*MIN(AAIAAT/(1-MSIAFD.K),SRFDM*AVFD)   (A-48FD)
A    SRFHIA.K=FSFHAT*EFHIA.K*MIN(AAIAAT/(1-MSIAFH.K),SRFHM*AVFH)   (A-48FH)
A    SRFGIA.K=FSFGAT*EFGIA.K*MIN(AAIAAT/(1-MSIAFG.K),SRFGM*AVFG)   (A-48FG)
A    SRFXIA.K=FSFXAT*EFXIA.K*MIN(AAIAAT/(1-MSIAFX.K),SRFXM*AVFX)   (A-48FX)
A    SRFLIA.K=FSFLAT*EFLIA.K*MIN(AAIAAT/(1-MSIAFL.K),SRFLM*AVFL)   (A-48FL)
A    SRBKIA.K=FSBKAT*EBKIA.K*MIN(AAIAAT/(1-MSIABK.K),SRBKM*AVBK)   (A-48BK)
A    SRFUIA.K=FSFUAT*EFUIA.K*MIN(AAIAAT/(1-MSIAFU.K),SRFUM*AVFU)   (A-48FU)
A    SRFOIA.K=FSFOAT*EFOIA.K*MIN(AAIAAT/(1-MSIAFO.K),SRFOM*AVFO)   (A-48FO)
A    SRFKIA.K=FSFKAT*EFKIA.K*MIN(AAIAAT/(1-MSIAFK.K),SRFKM*AVFK)   (A-48FK)
NOTE   SRXXIA - SORTIE RATE XX VS A-6 (AC/AC-DAY)
A    SRHDXF.K=FSHDAT*EHDXF.K*MIN(AAXFAT/(1-MSXFHD.K),SRHDM*AVHD)   (A-49HD)
A    SRFTXF.K=FSFTAT*EFTXF.K*MIN(AAXFAT/(1-MSXFFT.K),SRFTM*AVFT)   (A-49FT)
A    SRFRXF.K=FSFRAT*EFRXF.K*MIN(AAXFAT/(1-MSXFFR.K),SRFRM*AVFR)   (A-49FR)
A    SRFDXF.K=FSFDAT*EFDXF.K*MIN(AAXFAT/(1-MSXFFD.K),SRFDM*AVFD)   (A-49FD)
A    SRFHXF.K=FSFHAT*EFHXF.K*MIN(AAXFAT/(1-MSXFFH.K),SRFHM*AVFH)   (A-49FH)
A    SRFGXF.K=FSFGAT*EFGXF.K*MIN(AAXFAT/(1-MSXFFG.K),SRFGM*AVFG)   (A-49FG)
A    SRFXXF.K=FSFXAT*EFXXF.K*MIN(AAXFAT/(1-MSXFFX.K),SRFXM*AVFX)   (A-49FX)
A    SRFLXF.K=FSFLAT*EFLXF.K*MIN(AAXFAT/(1-MSXFFL.K),SRFLM*AVFL)   (A-49FL)
A    SRBKXF.K=FSBKAT*EBKXF.K*MIN(AAXFAT/(1-MSXFBK.K),SRBKM*AVBK)   (A-49BK)
A    SRFUXF.K=FSFUAT*EFUXF.K*MIN(AAXFAT/(1-MSXFFU.K),SRFUM*AVFU)   (A-49FU)
A    SRFOXF.K=FSFOAT*EFOXF.K*MIN(AAXFAT/(1-MSXFFO.K),SRFOM*AVFO)   (A-49FO)
A    SRFKXF.K=FSFKAT*EFKXF.K*MIN(AAXFAT/(1-MSXFFK.K),SRFKM*AVFK)   (A-49FK)
NOTE   SRXXXF - SORTIE RATE XX VS ATF (AC/AC-DAY)
A    SRHDXV.K=FSHDAT*EHDXV.K*MIN(AAXVAT/(1-MSXVHD.K),SRHDM*AVHD)   (A-50HD)
A    SRFTXV.K=FSFTAT*EFTXV.K*MIN(AAXVAT/(1-MSXVFT.K),SRFTM*AVFT)   (A-50FT)
A    SRFRXV.K=FSFRAT*EFRXV.K*MIN(AAXVAT/(1-MSXVFR.K),SRFRM*AVFR)   (A-50FR)
A    SRFDXV.K=FSFDAT*EFDXV.K*MIN(AAXVAT/(1-MSXVFD.K),SRFDM*AVFD)   (A-50FD)
A    SRFHXV.K=FSFHAT*EFHXV.K*MIN(AAXVAT/(1-MSXVFH.K),SRFHM*AVFH)   (A-50FH)
A    SRFGXV.K=FSFGAT*EFGXV.K*MIN(AAXVAT/(1-MSXVFG.K),SRFGM*AVFG)   (A-50FG)
A    SRFXXV.K=FSFXAT*EFXXV.K*MIN(AAXVAT/(1-MSXVFX.K),SRFXM*AVFX)   (A-50FX)
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A   SRFLXV.K=FSFLAT*EFLXV.K*MIN(AAXVAT/(1-MSXVFL.K),SRFLM*AVFL)  (A-50FL)
A   SRBKXV.K=FSBKAT*EBKXV.K*MIN(AAXVAT/(1-MSXVBK.K),SRBKM*AVBK)  (A-50BK)
A   SRFUXV.K=FSFUAT*EFUXV.K*MIN(AAXVAT/(1-MSXVFU.K),SRFUM*AVFU)  (A-50FU)
A   SRFOXV.K=FSFOAT*EFOXV.K*MIN(AAXVAT/(1-MSXVFO.K),SRFOM*AVFO)  (A-50FO)
A   SRFKXV.K=FSFKAT*EFKXV.K*MIN(AAXVAT/(1-MSXVFK.K),SRFKM*AVFK)  (A-50FK)
NOTE  SRXXXV - SORTIE RATE XX VS VFMX (AC/AC-DAY)
A   SRHDXA.K=FSHDAT*EHDXA.K*MIN(AAXAAT/(1-MSXAHD.K),SRHDM*AVHD)  (A-51HD)
A   SRFTXA.K=FSFTAT*EFTXA.K*MIN(AAXAAT/(1-MSXAFT.K),SRFTM*AVFT)  (A-51FT)
A   SRFRXA.K=FSFRAT*EFRXA.K*MIN(AAXAAT/(1-MSXAFR.K),SRFRM*AVFR)  (A-51FR)
A   SRFDXA.K=FSFDAT*EFDXA.K*MIN(AAXAAT/(1-MSXAFD.K),SRFDM*AVFD)  (A-51FD)
A   SRFHXA.K=FSFHAT*EFHXA.K*MIN(AAXAAT/(1-MSXAFH.K),SRFHM*AVFH)  (A-51FH)
A   SRFGXA.K=FSFGAT*EFGXA.K*MIN(AAXAAT/(1-MSXAFG.K),SRFGM*AVFG)  (A-51FG)
A   SRFXXA.K=FSFXAT*EFXXA.K*MIN(AAXAAT/(1-MSXAFX.K),SRFXM*AVFX)  (A-51FX)
A   SRFLXA.K=FSFLAT*EFLXA.K*MIN(AAXAAT/(1-MSXAFL.K),SRFLM*AVFL)  (A-51FL)
A   SRBKXA.K=FSBKAT*EBKXA.K*MIN(AAXAAT/(1-MSXABK.K),SRBKM*AVBK)  (A-51BK)
A   SRFUXA.K=FSFUAT*EFUXA.K*MIN(AAXAAT/(1-MSXAFU.K),SRFUM*AVFU)  (A-51FU)
A   SRFOXA.K=FSFOAT*EFOXA.K*MIN(AAXAAT/(1-MSXAFO.K),SRFOM*AVFO)  (A-51FO)
A   SRFKXA.K=FSFKAT*EFKXA.K*MIN(AAXAAT/(1-MSXAFK.K),SRFKM*AVFK)  (A-51FK)
NOTE  SRXXVF - SORTIE RATE XX VS ATA (AC/AC-DAY)
N   FSHDAT=1-FSHDST-FSHDLT                                    (A-52HD)
N   FSFTAT=1-FSFTST-FSFTLT                                    (A-52FT)
N   FSFRAT=1-FSFRST-FSFRLT                                    (A-52FR)
N   FSFDAT=1-FSFDST-FSFDLT                                    (A-52FD)
N   FSFHAT=1-FSFHST-FSFHLT                                    (A-52FH)
N   FSFGAT=1-FSFGST-FSFGLT                                    (A-52FG)
N   FSFXAT=1-FSFXST-FSFXLT                                    (A-52FX)
N   FSFLAT=1-FSFLST-FSFLLT                                    (A-52FL)
N   FSBKAT=1-FSBKST-FSBKLT                                    (A-52BK)
N   FSFUAT=1-FSFUST-FSFULT                                    (A-52FU)
N   FSFOAT=1-FSFOST-FSFOLT                                    (A-52FO)
N   FSFKAT=1-FSFKST-FSFKLT                                    (A-52FK)
NOTE FSXXAT - FRACTION SORTIE XX AIRCRAFT VS U.S. AIRCRAFT (DIM)
C   AAHDAT=.20                                              (A-40.1HD)
C   AAFTAT=.20                                              (A-41.1FT)
C   AAFRAT=.20                                              (A-42.1FR)
C   AAFDAT=.20                                              (A-43.1FD)
C   AAFHAT=.20                                              (A-44.1FH)
C   AAFGAT=.20                                              (A-45.1FG)
C   AAFXAT=.20                                              (A-46.1FX)
C   AAFLAT=.20                                              (A-47.1FL)
C   AABKAT=.20                                              (A-48.1BK)
C   AAFUAT=.20                                              (A-49.1FU)
C   AAFOAT=.20                                              (A-50.1FO)
C   AAFKAT=.20                                              (A-51.1FK)
NOTE  AAXXAT- ALLOWABLE ATTR. RATE OF XX VS AIRBORNE THREATS (FRACT/DAY)
A   XXAT.K=FSHDAT*HD.K+FSFTAT*FT.K+FSFRAT*FR.K+FSFDAT*FD.K+
X     FSFHAT*FH.K+FSFGAT*FG.K+FSFXAT*FX.K+FSFLAT*FL.K+
X     FSBKAT*BK.K+FSFUAT*FU.K+FSFOAT*FO.K+FSFKAT*FK.K         (A-53XX)
NOTE  XXAT - NUMBER OF XX AIRCRAFT VS $$ AIRCRAFT (AIRCRAFT)
A   EXHH.K=FSHHAT*HH.K/$$AT.K                                (A-54XX)
NOTE  EXHH - PROB. OF ENCOUNTER BETWEEN U.S.S.R. AIRCRAFT AND HH (PROB)
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A    EXTA.K=FSTAAT*TA.K/$$AT.K                                 (A-55XX)
NOTE  EXTA - PROB. OF ENCOUNTER BETWEEN U.S.S.R. AIRCRAFT AND TA (PROB)
A    EXXS.K=FSXSAT*XS.K/$$AT.K                                 (A-56XX)
NOTE  EXXS - PROB. OF ENCOUNTER BETWEEN U.S.S.R. AIRCRAFT AND XS (PROB)
A    EXFF.K=FSFFAT*FF.K/$$AT.K                                 (A-57XX)
NOTE  EXFF - PROB. OF ENCOUNTER BETWEEN U.S.S.R. AIRCRAFT AND FF (PROB)
A    EXEF.K=FSEFAT*EF.K/$$AT.K                                 (A-58XX)
NOTE  EXEF - PROB. OF ENCOUNTER BETWEEN U.S.S.R. AIRCRAFT AND EF (PROB)
A    EXTF.K=FSTFAT*TF.K/$$AT.K                                 (A-59XX)
NOTE  EXTF - PROB. OF ENCOUNTER BETWEEN U.S.S.R. AIRCRAFT AND TF (PROB)
A    EXHF.K=FSHFAT*HF.K/$$AT.K                                 (A-60XX)
NOTE  EXHF - PROB. OF ENCOUNTER BETWEEN U.S.S.R. AIRCRAFT AND HF (PROB)
A    EXHV.K=FSHVAT*HV.K/$$AT.K                                 (A-61XX)
NOTE  EXHV - PROB. OF ENCOUNTER BETWEEN U.S.S.R. AIRCRAFT AND HV (PROB)
A    EXIA.K=FSIAAT*IA.K/$$AT.K                                 (A-62XX)
NOTE  EXIA - PROB. OF ENCOUNTER BETWEEN U.S.S.R. AIRCRAFT AND IA (PROB)
A    EXXF.K=FSXFAT*XF.K/$$AT.K                                 (A-63XX)
NOTE  EXXF - PROB. OF ENCOUNTER BETWEEN U.S.S.R. AIRCRAFT AND ATF (PROB)
A    EXXV.K=FSXVAT*XV.K/$$AT.K                                 (A-64XX)
NOTE  EXXV - PROB. OF ENCOUNTER BETWEEN U.S.S.R. AIRCRAFT AND VFMX (PROB)
A    EXXA.K=FSXAAT*XA.K/$$AT.K                                 (A-65XX)
NOTE  EXXA - PROB. OF ENCOUNTER BETWEEN U.S.S.R. AIRCRAFT AND ATA (PROB)
A    EHDHH.K=FHDHH*EXHH.K/EHD$$.K                              (A-66HD)
A    EFTHH.K=FFTHH*EXHH.K/EFT$$.K                              (A-66FT)
A    EFRHH.K=FFRHH*EXHH.K/EFR$$.K                              (A-66FR)
A    EFDHH.K=FFDHH*EXHH.K/EFD$$.K                              (A-66FD)
A    EFHHH.K=FFHHH*EXHH.K/EFH$$.K                              (A-66FH)
A    EFGHH.K=FFGHH*EXHH.K/EFG$$.K                              (A-66FG)
A    EFXHH.K=FFXHH*EXHH.K/EFX$$.K                              (A-66FX)
A    EFLHH.K=FFLHH*EXHH.K/EFL$$.K                              (A-66FL)
A    EBKHH.K=FBKHH*EXHH.K/EBK$$.K                              (A-66BK)
A    EFUHH.K=FFUHH*EXHH.K/EFU$$.K                              (A-66FU)
A    EFOHH.K=FFOHH*EXHH.K/EFO$$.K                              (A-66FO)
A    EFKHH.K=FFKHH*EXHH.K/EFK$$.K                              (A-66FK)
NOTE  EXXHH - PROB. OF ENCOUNTER BETWEEN XX AND HH (PROB)
C    FHDHH=.8                                                  (A-66.1HH)
C    FFTHH=2                                                   (A-66.1FT)
C    FFRHH=2                                                   (A-66.1FR)
C    FFDHH=1                                                   (A-66.1FD)
C    FFHHH=.5                                                  (A-66.1FH)
C    FFGHH=1                                                   (A-66.1FG)
C    FFXHH=.3                                                  (A-66.1FX)
C    FFLHH=.4                                                  (A-66.1FL)
C    FBKHH=.1                                                  (A-66.1BK)
C    FFUHH=.5                                                  (A-66.1FU)
C    FFOHH=1                                                   (A-66.1FO)
C    FFKHH=.5                                                  (A-66.1FK)
NOTE  FXXHH - WEIGHT FRACT XX VS HH (DIM)
A    EHDTA.K=FHDTA*EXTA.K/EHD$$.K                              (A-67HD)
A    EFTTA.K=FFTTA*EXTA.K/EFT$$.K                              (A-67FT)
A    EFRTA.K=FFRTA*EXTA.K/EFR$$.K                              (A-67FR)
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A    EFDTA.K=FFDTA*EXTA.K/EFD$$.K                              (A-67FD)
A    EFHTA.K=FFHTA*EXTA.K/EFH$$.K                              (A-67FH)
A    EFGTA.K=FFGTA*EXTA.K/EFG$$.K                              (A-67FG)
A    EFXTA.K=FFXTA*EXTA.K/EFX$$.K                              (A-67FX)
A    EFLTA.K=FFLTA*EXTA.K/EFL$$.K                              (A-67FL)
A    EBKTA.K=FBKTA*EXTA.K/EBK$$.K                              (A-67BK)
A    EFUTA.K=FFUTA*EXTA.K/EFU$$.K                              (A-67FU)
A    EFOTA.K=FFOTA*EXTA.K/EFC$$.K                              (A-67FO)
A    EFKTA.K=FFKTA*EXTA.K/EFK$$.K                              (A-67FK)
NOTE  EXXTA - PROB. OF ENCOUNTER BETWEEN XX AND TA (PROB)
C    FHDTA=1                                                   (A-67.1HD)
C    FFTTA=3                                                   (A-67.1FT)
C    FFRTA=3                                                   (A-67.1FR)
C    FFDTA=.8                                                  (A-67.1FD)
C    FFHTA=.2                                                  (A-67.1FH)
C    FFGTA=.6                                                  (A-67.1FG)
C    FFXTA=.2                                                  (A-67.1FX)
C    FFLTA=.5                                                  (A-67.1FL)
C    FBKTA=.1                                                  (A-67.1BK)
C    FFUTA=1                                                   (A-67.1FU)
C    FFOTA=3                                                   (A-67.1FO)
C    FFKTA=1                                                   (A-67.1FK)
NOTE  FXXTA - WEIGHT FRACT XX VS TA (DIM)
A    EHDXS.K=FHDXS*EXXS.K/EHD$$.K                              (A-68HD)
A    EFTXS.K=FFTXS*EXXS.K/EFT$$.K                              (A-68FT)
A    EFRXS.K=FFRXS*EXXS.K/EFR$$.K                              (A-68FR)
A    EFDXS.K=FFDXS*EXXS.K/EFD$$.K                              (A-68FD)
A    EFHXS.K=FFHXS*EXXS.K/EFH$$.K                              (A-68FH)
A    EFGXS.K=FFGXS*EXXS.K/EFG$$.K                              (A-68FG)
A    EFXXS.K=FFXXS*EXXS.K/EFX$$.K                              (A-68FX)
A    EFLXS.K=FFLXS*EXXS.K/EFL$$.K                              (A-68FL)
A    EBKXS.K=FBKXS*EXXS.K/EBK$$.K                              (A-68BK)
A    EFUXS.K=FFUXS*EXXS.K/EFU$$.K                              (A-68FU)
A    EFOXS.K=FFOXS*EXXS.K/EFO$$.K                              (A-68FO)
A    EFKXS.K=FFKXS*EXXS.K/EFK$$.K                              (A-68FK)
NOTE  EXXXS - PROB. OF ENCOUNTER BETWEEN XX AND XS (PROB)
C    FHDXS=.1                                                  (A-68.1HD)
C    FFTXS=.1                                                  (A-68.1FT)
C    FFRXS=.1                                                  (A-68.1FR)
C    FFDXS=.2                                                  (A-68.1FD)
C    FFHXS=1                                                   (A-68.1FH)
C    FFGXS=2                                                   (A-68.1FG)
C    FFXXS=1                                                   (A-68.1FX)
C    FFLXS=.5                                                  (A-68.1FL)
C    FBKXS=.1                                                  (A-68.1BK)
C    FFUXS=3                                                   (A-68.1FU)
C    FFOXS=.5                                                  (A-68.1FO)
C    FFKXS=4                                                   (A-68.1FK)
NOTE  FXXXS - WEIGHT FRACT XX VS XS (DIM)
A    EHDFF.K=FHDFF*EXFF.K/EHD$$.K                              (A-69HD)
A    EFTFF.K=FFTFF*EXFF.K/EFT$$.K                              (A-69FT)
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A    EFRFF.K=FFRFF*EXFF.K/EFR$$.K                             (A-69FR)
A    EFDFF.K=FFDFF*EXFF.K/EFD$$.K                             (A-69FD)
A    EFHFF.K=FFHFF*EXFF.K/EFH$$.K                             (A-69FH)
A    EFGFF.K=FFGFF*EXFF.K/EFG$$.K                             (A-69FG)
A    EFXFF.K=FFXFF*EXFF.K/EFX$$.K                             (A-69FX)
A    EFLFF.K=FFLFF*EXFF.K/EFL$$.K                             (A-69FL)
A    EBKFF.K=FBKFF*EXFF.K/EBK$$.K                             (A-69BK)
A    EFUFF.K=FFUFF*EXFF.K/EFU$$.K                             (A-69FU)
A    EFOFF.K=FFOFF*EXFF.K/EFO$$.K                             (A-69FO)
A    EFKFF.K=FFKFF*EXFF.K/EFK$$.K                             (A-69FK)
NOTE  EXXFF - PROB. OF ENCOUNTER BETWEEN XX AND FF (PROB)
C    FHDFF=.5                                                 (A-69.1HD)
C    FFTFF=.2                                                 (A-69.1FT)
C    FFRFF=.2                                                 (A-69.1FR)
C    FFDFF=1                                                  (A-69.1FD)
C    FFHFF=1                                                  (A-69.1FH)
C    FFGFF=2                                                  (A-69.1FG)
C    FFXFF=1                                                  (A-69.1FX)
C    FFLFF=2                                                  (A-69.1FL)
C    FBKFF=.2                                                 (A-69.1BK)
C    FFUFF=2                                                  (A-69.1FU)
C    FFOFF=.5                                                 (A-69.1FO)
C    FFKFF=1.5                                                (A-69.1FK)
NOTE  FXXFF - WEIGHT FRACT XX VS FF (DIM)
A    EHDEF.K=FHDEF*EXEF.K/EHD$$.K                             (A-70HD)
A    EFTEF.K=FFTEF*EXEF.K/EFT$$.K                             (A-70FT)
A    EFREF.K=FFREF*EXEF.K/EFR$$.K                             (A-70FR)
A    EFDEF.K=FFDEF*EXEF.K/EFD$$.K                             (A-70FD)
A    EFHEF.K=FFHEF*EXEF.K/EFH$$.K                             (A-70FH)
A    EFGEF.K=FFGEF*EXEF.K/EFG$$.K                             (A-70FG)
A    EFXEF.K=FFXEF*EXEF.K/EFX$$.K                             (A-70FX)
A    EFLEF.K=FFLEF*EXEF.K/EFL$$.K                             (A-70FL)
A    EBKEF.K=FBKEF*EXEF.K/EBK$$.K                             (A-70BK)
A    EFUEF.K=FFUEF*EXEF.K/EFU$$.K                             (A-70FU)
A    EFOEF.K=FFOEF*EXEF.K/EFO$$.K                             (A-70FO)
A    EFKEF.K=FFKEF*EXEF.K/EFK$$.K                             (A-70FK)
NOTE  EXXEF - PROB. OF ENCOUNTER BETWEEN XX AND EF (PROB)
C    FHDEF=.4                                                 (A-70.1HD)
C    FFTEF=.4                                                 (A-70.1FT)
C    FFREF=.4                                                 (A-70.1FR)
C    FFDEF=2                                                  (A-70.1FD)
C    FFHEF=1                                                  (A-70.1FH)
C    FFGEF=3                                                  (A-70.1FG)
C    FFXEF=1                                                  (A-70.1FX)
C    FFLEF=2                                                  (A-70.1FL)
C    FBKEF=.4                                                 (A-70.1BK)
C    FFUEF=2                                                  (A-70.1FU)
C    FFOEF=.5                                                 (A-70.1FO)
C    FFKEF=2                                                  (A-70.1FK)
NOTE  FXXEF - WEIGHT FRACT XX VS EF (DIM)
A    EHDTF.K=FHDTF*EXTF.K/EHD$$.K                             (A-71HD)
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A    EFTTF.K=FFTTF*EXTF.K/EFT$$.K                             (A-71FT)
A    EFRTF.K=FFRTF*EXTF.K/EFR$$.K                             (A-71FR)
A    EFDTF.K=FFDTF*EXTF.K/EFD$$.K                             (A-71FD)
A    EFHTF.K=FFHTF*EXTF.K/EFH$$.K                             (A-71FH)
A    EFGTF.K=FFGTF*EXTF.K/EFG$$.K                             (A-71FG)
A    EFXTF.K=FFXTF*EXTF.K/EFX$$.K                             (A-71FX)
A    EFLTF.K=FFLTF*EXTF.K/EFL$$.K                             (A-71FL)
A    EBKTF.K=FBKTF*EXTF.K/EBK$$.K                             (A-71BK)
A    EFUTF.K=FFUTF*EXTF.K/EFU$$.K                             (A-71FU)
A    EFOTF.K=FFOTF*EXTF.K/EFO$$.K                             (A-71FO)
A    EFKTF.K=FFKTF*EXTF.K/EFK$$.K                             (A-71FK)
NOTE  EXXTF - PROB. OF ENCOUNTER BETWEEN XX AND TF (PROB)
C    FHDTF=.1                                                 (A-71.1HD)
C    FFTTF=.2                                                 (A-71.1FT)
C    FFRTF=.2                                                 (A-71.1FR)
C    FFDTF=2                                                  (A-71.1FD)
C    FFHTF=2                                                  (A-71.1FH)
C    FFGTF=2                                                  (A-71.1FG)
C    FFXTF=2                                                  (A-71.1FX)
C    FFLTF=1                                                  (A-71.1FL)
C    FBKTF=.1                                                 (A-71.1BK)
C    FFUTF=2                                                  (A-71.1FU)
C    FFOTF=.3                                                 (A-71.1FO)
C    FFKTF=1                                                  (A-71.1FK)
NOTE  FXXTF - WEIGHT FRACT XX VS TF (DIM)
A    EHDHF.K=FHDHF*EXHF.K/EHD$$.K                             (A-72HD)
A    EFTHF.K=FFTHF*EXHF.K/EFT$$.K                             (A-72FT)
A    EFRHF.K=FFRHF*EXHF.K/EFR$$.K                             (A-72FR)
A    EFDHF.K=FFDHF*EXHF.K/EFD$$.K                             (A-72FD)
A    EFHHF.K=FFHHF*EXHF.K/EFH$$.K                             (A-72FH)
A    EFGHF.K=FFGHF*EXHF.K/EFG$$.K                             (A-72FG)
A    EFXHF.K=FFXHF*EXHF.K/EFX$$.K                             (A-72FX)
A    EFLHF.K=FFLHF*EXHF.K/EFL$$.K                             (A-72FL)
A    EBKHF.K=FBKHF*EXHF.K/EBK$$.K                             (A-72BK)
A    EFUHF.K=FFUHF*EXHF.K/EFU$$.K                             (A-72FU)
A    EFOHF.K=FFOHF*EXHF.K/EFO$$.K                             (A-72FO)
A    EFKHF.K=FFKHF*EXHF.K/EFK$$.K                             (A-72FK)
NOTE  EXXHF - PROB. OF ENCOUNTER BETWEEN XX AND HF (PROB)
C    FHDHF=.5                                                 (A-72.1HD)
C    FFTHF=.2                                                 (A-72.1FT)
C    FFRHF=.1                                                 (A-72.1FR)
C    FFDHF=3                                                  (A-72.1FD)
C    FFHHF=3                                                  (A-72.1FH)
C    FFGHF=3                                                  (A-72.1FG)
C    FFXHF=3                                                  (A-72.1FX)
C    FFLHF=3                                                  (A-72.1FL)
C    FBKHF=.2                                                 (A-72.1BK)
C    FFUHF=3                                                  (A-72.1FU)
C    FFOHF=.2                                                 (A-72.1FO)
C    FFKHF=3                                                  (A-72.1FK)
NOTE  FXXHF - WEIGHT FRACT XX VS HF (DIM)
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A   EHDHV.K=FHDHV*EXHV.K/EHD$$.K                             (A-73HD)
A   EFTHV.K=FFTHV*EXHV.K/EFT$$.K                             (A-73FT)
A   EFRHV.K=FFRHV*EXHV.K/EFR$$.K                             (A-73FR)
A   EFDHV.K=FFDHV*EXHV.K/EFD$$.K                             (A-73FD)
A   EFHHV.K=FFHHV*EXHV.K/EFH$$.K                             (A-73FH)
A   EFGHV.K=FFGHV*EXHV.K/EFG$$.K                             (A-73FG)
A   EFXHV.K=FFXHV*EXHV.K/EFX$$.K                             (A-73FX)
A   EFLHV.K=FFLHV*EXHV.K/EFL$$.K                             (A-73FL)
A   EBKHV.K=FBKHV*EXHV.K/EBK$$.K                             (A-73BK)
A   EFUHV.K=FFUHV*EXHV.K/EFU$$.K                             (A-73FU)
A   EFOHV.K=FFOHV*EXHV.K/EFO$$.K                             (A-73FO)
A   EFKHV.K=FFKHV*EXHV.K/EFK$$.K                             (A-73FK)
NOTE  EXXHV - PROB. OF ENCOUNTER BETWEEN XX AND HV (PROB)
C   FHDHV=.5                                                 (A-73.1HD)
C   FFTHV=1                                                  (A-73.1FT)
C   FFRHV=1                                                  (A-73.1FR)
C   FFDHV=.5                                                 (A-73.1FD)
C   FFHHV=.1                                                 (A-73.1FH)
C   FFGHV=.2                                                 (A-73.1FG)
C   FFXHV=.1                                                 (A-73.1FX)
C   FFLHV=.3                                                 (A-73.1FL)
C   FBKHV=.1                                                 (A-73.1BK)
C   FFUHV=2                                                  (A-73.1FU)
C   FFOHV=1                                                  (A-73.1FO)
C   FFKHV=.1                                                 (A-73.1FK)
NOTE  FXXHV - WEIGHT FRACT XX VS HV (DIM)
A   EHDIA.K=FHDIA*EXIA.K/EHD$$.K                             (A-74HD)
A   EFTIA.K=FFTIA*EXIA.K/EFT$$.K                             (A-74FT)
A   EFRIA.K=FFRIA*EXIA.K/EFR$$.K                             (A-74FR)
A   EFDIA.K=FFDIA*EXIA.K/EFD$$.K                             (A-74FD)
A   EFHIA.K=FFHIA*EXIA.K/EFH$$.K                             (A-74FH)
A   EFGIA.K=FFGIA*EXIA.K/EFG$$.K                             (A-74FG)
A   EFXIA.K=FFXIA*EXIA.K/EFX$$.K                             (A-74FX)
A   EFLIA.K=FFLIA*EXIA.K/EFL$$.K                             (A-74FL)
A   EBKIA.K=FBKIA*EXIA.K/EBK$$.K                             (A-74BK)
A   EFUIA.K=FFUIA*EXIA.K/EFU$$.K                             (A-74FU)
A   EFOIA.K=FFOIA*EXIA.K/EFO$$.K                             (A-74FO)
A   EFKIA.K=FFKIA*EXIA.K/EFK$$.K                             (A-74FK)
NOTE  EXXIA - PROB. OF ENCOUNTER BETWEEN XX AND IA (PROB)
C   FHDIA=.2                                                 (A-74.1HD)
C   FFTIA=1                                                  (A-74.1FT)
C   FFRIA=1                                                  (A-74.1FR)
C   FFDIA=.5                                                 (A-74.1FD)
C   FFHIA=2                                                  (A-74.1FH)
C   FFGIA=.5                                                 (A-74.1FG)
C   FFXIA=.2                                                 (A-74.1FX)
C   FFLIA=.1                                                 (A-74.1FL)
C   FBKIA=.1                                                 (A-74.1BK)
C   FFUIA=.3                                                 (A-74.1FU)
C   FFOIA=1                                                  (A-74.1FO)
C   FFKIA=.2                                                 (A-74.1FK)
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NOTE  FXXIA - WEIGHT FRACT XX VS IA (DIM)
A   EHDXF.K=FHDXF*EXXF.K/EHD$$.K                          (A-75HD)
A   EFTXF.K=FFTXF*EXXF.K/EFT$$.K                          (A-75FT)
A   EFRXF.K=FFRXF*EXXF.K/EFR$$.K                          (A-75FR)
A   EFDXF.K=FFDXF*EXXF.K/EFD$$.K                          (A-75FD)
A   EFHXF.K=FFHXF*EXXF.K/EFH$$.K                          (A-75FH)
A   EFGXF.K=FFGXF*EXXF.K/EFG$$.K                          (A-75FG)
A   EFXXF.K=FFXXF*EXXF.K/EFX$$.K                          (A-75FX)
A   EFLXF.K=FFLXF*EXXF.K/EFL$$.K                          (A-75FL)
A   EBKXF.K=FBKXF*EXXF.K/EBK$$.K                          (A-75BK)
A   EFUXF.K=FFUXF*EXXF.K/EFU$$.K                          (A-75FU)
A   EFOXF.K=FFOXF*EXXF.K/EFO$$.K                          (A-75FO)
A   EFKXF.K=FFKXF*EXXF.K/EFK$$.K                          (A-75FK)
NOTE  EXXXF - PROB. OF ENCOUNTER BETWEEN XX AND XF (PROB)
C   FHDXF=2                                               (A-75.1HD)
C   FFTXF=1                                               (A-75.1FT)
C   FFRXF=1                                               (A-75.1FR)
C   FFDXF=1                                               (A-75.1FD)
C   FFHXF=.5                                              (A-75.1FH)
C   FFGXF=.5                                              (A-75.1FG)
C   FFXXF=.5                                              (A-75.1FX)
C   FFLXF=.1                                              (A-75.1FL)
C   FBKXF=.1                                              (A-75.1BK)
C   FFUXF=.5                                              (A-75.1FU)
C   FFOXF=.1                                              (A-75.1FO)
C   FFKXF=1                                               (A-75.1FK)
NOTE  FXXXF - WEIGHT FRACT XX VS XF (DIM)
A   EHDXV.K=FHDXV*EXXV.K/EHD$$.K                          (A-76HD)
A   EFTXV.K=FFTXV*EXXV.K/EFT$$.K                          (A-76FT)
A   EFRXV.K=FFRXV*EXXV.K/EFR$$.K                          (A-76FR)
A   EFDXV.K=FFDXV*EXXV.K/EFD$$.K                          (A-76FD)
A   EFHXV.K=FFHXV*EXXV.K/EFH$$.K                          (A-76FH)
A   EFGXV.K=FFGXV*EXXV.K/EFG$$.K                          (A-76FG)
A   EFXXV.K=FFXXV*EXXV.K/EFX$$.K                          (A-76FX)
A   EFLXV.K=FFLXV*EXXV.K/EFL$$.K                          (A-76FL)
A   EBKXV.K=FBKXV*EXXV.K/EBK$$.K                          (A-76BK)
A   EFUXV.K=FFUXV*EXXV.K/EFU$$.K                          (A-76FU)
A   EFOXV.K=FFOXV*EXXV.K/EFO$$.K                          (A-76FO)
A   EFKXV.K=FFKXV*EXXV.K/EFK$$.K                          (A-76FK)
NOTE  EXXXV - PROB. OF ENCOUNTER BETWEEN XX AND XV (PROB)
C   FHDXV=2                                               (A-76.1HD)
C   FFTXV=2                                               (A-76.1FT)
C   FFRXV=2                                               (A-76.1FR)
C   FFDXV=1                                               (A-76.1FD)
C   FFHXV=.5                                              (A-76.1FH)
C   FFGXV=1                                               (A-76.1FG)
C   FFXXV=.2                                              (A-76.1FX)
C   FFLXV=.3                                              (A-76.1FL)
C   FBKXV=.1                                              (A-76.1BK)
C   FFUXV=1                                               (A-76.1FU)
C   FFOXV=.5                                              (A-76.1FO)
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C    FFKXV=.4                                                    (A-76.1FK)
NOTE  FXXXV - WEIGHT FRACT XX VS XV (DIM)
A    EHDXA.K=FHDXA*EXXA.K/EHD$$.K                                (A-77HD)
A    EFTXA.K=FFTXA*EXXA.K/EFT$$.K                                (A-77FT)
A    EFRXA.K=FFRXA*EXXA.K/EFR$$.K                                (A-77FR)
A    EFDXA.K=FFDXA*EXXA.K/EFD$$.K                                (A-77FD)
A    EFHXA.K=FFHXA*EXXA.K/EFH$$.K                                (A-77FH)
A    EFGXA.K=FFGXA*EXXA.K/EFG$$.K                                (A-77FG)
A    EFXXA.K=FFXXA*EXXA.K/EFX$$.K                                (A-77FX)
A    EFLXA.K=FFLXA*EXXA.K/EFL$$.K                                (A-77FL)
A    EBKXA.K=FBKXA*EXXA.K/EBK$$.K                                (A-77BK)
A    EFUXA.K=FFUXA*EXXA.K/EFU$$.K                                (A-77FU)
A    EFOXA.K=FFOXA*EXXA.K/EFO$$.K                                (A-77FO)
A    EFKXA.K=FFKXA*EXXA.K/EFK$$.K                                (A-77FK)
NOTE  EXXXA - PROB. OF ENCOUNTER BETWEEN XX AND XA (PROB)
C    FHDXA=1                                                     (A-77.1HD)
C    FFTXA=.5                                                    (A-77.1FT)
C    FFRXA=.5                                                    (A-77.1FR)
C    FFDXA=.5                                                    (A-77.1FD)
C    FFHXA=1                                                     (A-77.1FH)
C    FFGXA=.5                                                    (A-77.1FG)
C    FFXXA=.2                                                    (A-77.1FX)
C    FFLXA=1                                                     (A-77.1FL)
C    FBKXA=.1                                                    (A-77.1BK)
C    FFUXA=1                                                     (A-77.1FU)
C    FFOXA=2                                                     (A-77.1FO)
C    FFKXA=.5                                                    (A-77.1FK)
NOTE  FXXXA - WEIGHT FRACT XX VS XA (DIM)
A    EHD$$.K=FHDHH*EXHH.K+FHDTA*EXTA.K+FHDXS*EXXS.K+FHDFF*EXFF.K+
X      +FHDEF*EXEF.K+FHDTF*EXTF.K+FHDHF*EXHF.K+FHDHV*EXHV.K+FHDIA*EXIA.K
X      +FHDXF*EXXF.K+FHDXV*EXXV.K+FHDXA*EXXA.K                   (A-78HD)
NOTE  EHD$$ - VS $$ (PROB)
A    EFT$$.K=FFTHH*EXHH.K+FFTTA*EXTA.K+FFTXS*EXXS.K+FFTFF*EXFF.K+
X      +FFTEF*EXEF.K+FFTTF*EXTF.K+FFTHF*EXHF.K+FFTHV*EXHV.K+FFTIA*EXIA.K
X      +FFTXF*EXXF.K+FFTXV*EXXV.K+FFTXA*EXXA.K                   (A-78FT)
NOTE  EFT$$ - VS $$ (PROB)
A    EFR$$.K=FFRHH*EXHH.K+FFRTA*EXTA.K+FFRXS*EXXS.K+FFRFF*EXFF.K+
X      +FFREF*EXEF.K+FFRTF*EXTF.K+FFRHF*EXHF.K+FFRHV*EXHV.K+FFRIA*EXIA.K
X      +FFRXF*EXXF.K+FFRXV*EXXV.K+FFRXA*EXXA.K                   (A-78FR)
NOTE  EFR$$ - VS $$ (PROB)
A    EFD$$.K=FFDHH*EXHH.K+FFDTA*EXTA.K+FFDXS*EXXS.K+FFDFF*EXFF.K+
X      +FFDEF*EXEF.K+FFDTF*EXTF.K+FFDHF*EXHF.K+FFDHV*EXHV.K+FFDIA*EXIA.K
X      +FFDXF*EXXF.K+FFDXV*EXXV.K+FFDXA*EXXA.K                   (A-78FD)
NOTE  EFD$$ - VS $$ (PROB)
A    EFH$$.K=FFHHH*EXHH.K+FFHTA*EXTA.K+FFHXS*EXXS.K+FFHFF*EXFF.K+
X      +FFHEF*EXEF.K+FFHTF*EXTF.K+FFHHF*EXHF.K+FFHHV*EXHV.K+FFHIA*EXIA.K
X      +FFHXF*EXXF.K+FFHXV*EXXV.K+FFHXA*EXXA.K                   (A-78FH)
NOTE  EFH$$ - VS $$ (PROB)
A    EFG$$.K=FFGHH*EXHH.K+FFGTA*EXTA.K+FFGXS*EXXS.K+FFGFF*EXFF.K+
X      +FFGEF*EXEF.K+FFGTF*EXTF.K+FFGHF*EXHF.K+FFGHV*EXHV.K+FFGIA*EXIA.K
X      +FFGXF*EXXF.K+FFGXV*EXXV.K+FFGXA*EXXA.K                   (A-78FG)
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NOTE  EFG$$ - VS $$ (PROB)
A   EFX$$.K=FFXHH*EXHH.K+FFXTA*EXTA.K+FFXXS*EXXS.K+FFXFF*EXFF.K+
X     +FFXEF*EXEF.K+FFXTF*EXTF.K+FFXHF*EXHF.K+FFXHV*EXHV.K+FFXIA*EXIA.K
X     +FFXXF*EXXF.K+FFXXV*EXXV.K+FFXXA*EXXA.K                  (A-78FX)
NOTE  EFX$$ - VS $$ (PROB)
A   EFL$$.K=FFLHH*EXHH.K+FFLTA*EXTA.K+FFLXS*EXXS.K+FFLFF*EXFF.K+
X     +FFLEF*EXEF.K+FFLTF*EXTF.K+FFLHF*EXHF.K+FFLHV*EXHV.K+FFLIA*EXIA.K
X     +FFLXF*EXXF.K+FFLXV*EXXV.K+FFLXA*EXXA.K                  (A-78FL)
NOTE  EFL$$ - VS $$ (PROB)
A   EBK$$.K=FBKHH*EXHH.K+FBKTA*EXTA.K+FBKXS*EXXS.K+FBKFF*EXFF.K+
X     +FBKEF*EXEF.K+FBKTF*EXTF.K+FBKHF*EXHF.K+FBKHV*EXHV.K+FBKIA*EXIA.K
X     +FBKXF*EXXF.K+FBKXV*EXXV.K+FBKXA*EXXA.K                  (A-78BK)
NOTE  EBK$$ - VS $$ (PROB)
A   EFU$$.K=FFUHH*EXHH.K+FFUTA*EXTA.K+FFUXS*EXXS.K+FFUFF*EXFF.K+
X     +FFUEF*EXEF.K+FFUTF*EXTF.K+FFUHF*EXHF.K+FFUHV*EXHV.K+FFUIA*EXIA.K
X     +FFUXF*EXXF.K+FFUXV*EXXV.K+FFUXA*EXXA.K                  (A-78FU)
NOTE  EFU$$ - VS $$ (PROB)
A   EFO$$.K=FFOHH*EXHH.K+FFOTA*EXTA.K+FFOXS*EXXS.K+FFOFF*EXFF.K+
X     +FFOEF*EXEF.K+FFOTF*EXTF.K+FFOHF*EXHF.K+FFOHV*EXHV.K+FFOIA*EXIA.K
X     +FFOXF*EXXF.K+FFOXV*EXXV.K+FFOXA*EXXA.K                  (A-78FO)
NOTE  EFO$$ - VS $$ (PROB)
A   EFK$$.K=FFKHH*EXHH.K+FFKTA*EXTA.K+FFKXS*EXXS.K+FFKFF*EXFF.K+
X     +FFKEF*EXEF.K+FFKTF*EXTF.K+FFKHF*EXHF.K+FFKHV*EXHV.K+FFKIA*EXIA.K
X     +FFKXF*EXXF.K+FFKXV*EXXV.K+FFKXA*EXXA.K                  (A-78FK)
NOTE  EFK$$ - VS $$ (PROB)
A   MSHDHH.K=.974                                               (A-79HD)
A   MSFTHH.K=.97                                                (A-79FT)
A   MSFRHH.K=.974                                               (A-79FR)
A   MSFDHH.K=.974                                               (A-79FD)
A   MSFHHH.K=.985                                               (A-79FH)
A   MSFGHH.K=.99                                                (A-79FG)
A   MSFXHH.K=.974                                               (A-79FX)
A   MSFLHH.K=.97                                                (A-79FL)
A   MSBKHH.K=.97                                                (A-79BK)
A   MSFUHH.K=.985                                               (A-79FU)
A   MSFOHH.K=.98                                                (A-79FO)
A   MSFKHH.K=.99                                                (A-79FK)
NOTE  MSXXHH - MISSION SURVIVABILITY XX VS HH (PROB)
A   MSHDTA.K=.97                                                (A-80HD)
A   MSFTTA.K=.966                                               (A-80FT)
A   MSFRTA.K=.97                                                (A-80FR)
A   MSFDTA.K=.97                                                (A-80FD)
A   MSFHTA.K=.978                                               (A-80FH)
A   MSFGTA.K=.982                                               (A-80FG)
A   MSFXTA.K=.97                                                (A-80FX)
A   MSFLTA.K=.966                                               (A-80FL)
A   MSBKTA.K=.966                                               (A-80BK)
A   MSFUTA.K=.978                                               (A-80FU)
A   MSFOTA.K=.974                                               (A-80FO)
A   MSFKTA.K=.986                                               (A-80FK)
NOTE  MSXXTA - MISSION SURVIVABILITY XX VS TA (PROB)
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A   MSHDXS.K=.97                                             (A-81HD)
A   MSFTXS.K=.966                                            (A-81FT)
A   MSFRXS.K=.97                                             (A-81FR)
A   MSFDXS.K=.97                                             (A-81FD)
A   MSFHXS.K=.978                                            (A-81FH)
A   MSFGXS.K=.982                                            (A-81FG)
A   MSFXXS.K=.97                                             (A-81FX)
A   MSFLXS.K=.966                                            (A-81FL)
A   MSBKXS.K=.966                                            (A-81BK)
A   MSFUXS.K=.978                                            (A-81FU)
A   MSFOXS.K=.974                                            (A-81FO)
A   MSFKXS.K=.986                                            (A-81FK)
NOTE  MSXXXS - MISSION SURVIVABILITY XX VS XS (PROB)
A   MSHDFF.K=.96                                             (A-82HD)
A   MSFTFF.K=.958                                            (A-82FT)
A   MSFRFF.K=.958                                            (A-82FR)
A   MSFDFF.K=.958                                            (A-82FD)
A   MSFHFF.K=.964                                            (A-82FH)
A   MSFGFF.K=.966                                            (A-82FG)
A   MSFXFF.K=.96                                             (A-82FX)
A   MSFLFF.K=.958                                            (A-82FL)
A   MSBKFF.K=.958                                            (A-82BK)
A   MSFUFF.K=.964                                            (A-82FU)
A   MSFOFF.K=.962                                            (A-82FO)
A   MSFKFF.K=.968                                            (A-82FK)
NOTE  MSXXFF - MISSION SURVIVABILITY XX VS FF (PROB)
A   MSHDEF.K=.958                                            (A-83HD)
A   MSFTEF.K=.957                                            (A-83FT)
A   MSFREF.K=.958                                            (A-83FR)
A   MSFDEF.K=.958                                            (A-83FD)
A   MSFHEF.K=.962                                            (A-83FH)
A   MSFGEF.K=.963                                            (A-83FG)
A   MSFXEF.K=.958                                            (A-83FX)
A   MSFLEF.K=.957                                            (A-83FL)
A   MSBKEF.K=.957                                            (A-83BK)
A   MSFUEF.K=.962                                            (A-83FU)
A   MSFOEF.K=.96                                             (A-83FO)
A   MSFKEF.K=.965                                            (A-83FK)
NOTE  MSXXEF - MISSION SURVIVABILITY XX VS EF (PROB)
A   MSHDTF.K=.963                                            (A-84HD)
A   MSFTTF.K=.96                                             (A-84FT)
A   MSFRTF.K=.963                                            (A-84FR)
A   MSFDTF.K=.963                                            (A-84FD)
A   MSFHTF.K=.968                                            (A-84FH)
A   MSFGTF.K=.97                                             (A-84FG)
A   MSFXTF.K=.963                                            (A-84FX)
A   MSFLTF.K=.96                                             (A-84FL)
A   MSBKTF.K=.96                                             (A-84BK)
A   MSFUTF.K=.968                                            (A-84FU)
A   MSFOTF.K=.965                                            (A-84FO)
A   MSFKTF.K=.973                                            (A-84FK)
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NOTE  MSXXTF - MISSION SURVIVABILITY XX VS TF (PROB)
A   MSHDHF.K=.961                                            (A-85HD)
A   MSFTHF.K=.959                                            (A-85FT)
A   MSFRHF.K=.961                                            (A-85FR)
A   MSFDHF.K=.961                                            (A-85FD)
A   MSFHHF.K=.966                                            (A-85FH)
A   MSFGHF.K=.968                                            (A-85FG)
A   MSFXHF.K=.961                                            (A-85FX)
A   MSFLHF.K=.959                                            (A-85FL)
A   MSBKHF.K=.959                                            (A-85BK)
A   MSFUHF.K=.966                                            (A-85FU)
A   MSFOHF.K=.963                                            (A-85FO)
A   MSFKHF.K=.97                                             (A-85FK)
NOTE  MSXXHF - MISSION SURVIVABILITY XX VS HF (PROB)
A   MSHDHV.K=.961                                            (A-86HD)
A   MSFTHV.K=.97                                             (A-86FT)
A   MSFRHV.K=.974                                            (A-86FR)
A   MSFDHV.K=.974                                            (A-86FD)
A   MSFHHV.K=.985                                            (A-86FH)
A   MSFGHV.K=.99                                             (A-86FG)
A   MSFXHV.K=.974                                            (A-86FX)
A   MSFLHV.K=.97                                             (A-86FL)
A   MSBKHV.K=.97                                             (A-86BK)
A   MSFUHV.K=.985                                            (A-86FU)
A   MSFOHV.K=.98                                             (A-86FO)
A   MSFKHV.K=.99                                             (A-86FK)
NOTE  MSXXHV - MISSION SURVIVABILITY XX VS HV (PROB)
A   MSHDIA.K=.974                                            (A-87HD)
A   MSFTIA.K=.97                                             (A-87FT)
A   MSFRIA.K=.974                                            (A-87FR)
A   MSFDIA.K=.974                                            (A-87FD)
A   MSFHIA.K=.985                                            (A-87FH)
A   MSFGIA.K=.99                                             (A-87FG)
A   MSFXIA.K=.974                                            (A-87FX)
A   MSFLIA.K=.97                                             (A-87FL)
A   MSBKIA.K=.97                                             (A-87BK)
A   MSFUIA.K=.985                                            (A-87FU)
A   MSFOIA.K=.98                                             (A-87FO)
A   MSFKIA.K=.99                                             (A-87FK)
NOTE  MSXXIA - MISSION SURVIVABILITY XX VS IA (PROB)
A   MSHDXF.K=.96                                             (A-88HD)
A   MSFTXF.K=.958                                            (A-88FT)
A   MSFRXF.K=.96                                             (A-88FR)
A   MSFDXF.K=.96                                             (A-88FD)
A   MSFHXF.K=.964                                            (A-88FH)
A   MSFGXF.K=.966                                            (A-88FG)
A   MSFXXF.K=.96                                             (A-88FX)
A   MSFLXF.K=.958                                            (A-88FL)
A   MSBKXF.K=.958                                            (A-88BK)
A   MSFUXF.K=.964                                            (A-88FU)
A   MSFOXF.K=.962                                            (A-88FO)
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A    MSFKXF.K=.968                                              (A-88FK)
NOTE  MSXXXF - MISSION SURVIVABILITY XX VS HF (PROB)
A    MSHDXV.K=.963                                              (A-89HD)
A    MSFTXV.K=.96                                               (A-89FT)
A    MSFRXV.K=.963                                              (A-89FR)
A    MSFDXV.K=.963                                              (A-89FD)
A    MSFHXV.K=.968                                              (A-89FH)
A    MSFGXV.K=.97                                               (A-89FG)
A    MSFXXV.K=.963                                              (A-89FX)
A    MSFLXV.K=.96                                               (A-89FL)
A    MSBKXV.K=.96                                               (A-89BK)
A    MSFUXV.K=.968                                              (A-89FU)
A    MSFOXV.K=.965                                              (A-89FO)
A    MSFKXV.K=.973                                              (A-89FK)
NOTE  MSXXXV - MISSION SURVIVABILITY XX VS XV (PROB)
A    MSHDXA.K=.967                                              (A-90HD)
A    MSFTXA.K=.963                                              (A-90FT)
A    MSFRXA.K=.967                                              (A-90FR)
A    MSFDXA.K=.967                                              (A-90FD)
A    MSFHXA.K=.973                                              (A-90FH)
A    MSFGXA.K=.977                                              (A-90FG)
A    MSFXXA.K=.967                                              (A-90FX)
A    MSFLXA.K=.963                                              (A-90FL)
A    MSBKXA.K=.963                                              (A-90BK)
A    MSFUXA.K=.973                                              (A-90FU)
A    MSFOXA.K=.97                                               (A-90FO)
A    MSFKXA.K=.963                                              (A-90FK)
NOTE  MSXXXA - MISSION SURVIVABILITY XX VS XA (PROB)
NOTE  *****************************************************************
NOTE  ****************    MEASURES  OF EFFECTIVENESS   ****************
NOTE  *****************************************************************
NOTE
NOTE                  U.S. COMBAT EFFECTIVENESS
NOTE             +-------------------------------+
NOTE
NOTE
A    TDBHH.K=CLIP(HH.K*SRHHLT.K*TDPSHH,0,TIME.K,WAR)            (A-214HH)
A    TDBTA.K=CLIP(TA.K*SRTALT.K*TDPSTA,0,TIME.K,WAR)            (A-214TA)
A    TDBXS.K=CLIP(XS.K*SRXSLT.K*TDPSXS,0,TIME.K,WAR)            (A-214XS)
A    TDBFF.K=CLIP(FF.K*SRFFLT.K*TDPSFF,0,TIME.K,WAR)            (A-214FF)
A    TDBEF.K=CLIP(EF.K*SREFLT.K*TDPSEF,0,TIME.K,WAR)            (A-214EF)
A    TDBTF.K=CLIP(TF.K*SRTFLT.K*TDPSTF,0,TIME.K,WAR)            (A-214TF)
A    TDBHF.K=CLIP(HF.K*SRHFLT.K*TDPSHF,0,TIME.K,WAR)            (A-214HF)
A    TDBHV.K=CLIP(HV.K*SRHVLT.K*TDPSHV,0,TIME.K,WAR)            (A-214HV)
A    TDBIA.K=CLIP(IA.K*SRIALT.K*TDPSIA,0,TIME.K,WAR)            (A-214IA)
A    TDBXF.K=CLIP(XF.K*SRXFLT.K*TDPSXF,0,TIME.K,WAR)            (A-214XF)
A    TDBXV.K=CLIP(XV.K*SRXVLT.K*TDPSXV,0,TIME.K,WAR)            (A-214XV)
A    TDBXA.K=CLIP(XA.K*SRXALT.K*TDPSXA,0,TIME.K,WAR)            (A-214XA)
NOTE  TDB$$ - TARGETS DESTROYED BY $$ (TANK EQUIV TARGETS)
C    TDPSHH=2                                                   (A-214.1HH)
C    TDPSTA=6                                                   (A-214.1TA)
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C    TDPSXS=8                                                    (A-214.1XS)
C    TDPSFF=1                                                    (A-214.1FF)
C    TDPSEF=1.5                                                  (A-214.1EF)
C    TDPSTF=1                                                    (A-214.1TF)
C    TDPSHF=2                                                    (A-214.1HF)
C    TDPSHV=2                                                    (A-214.1HV)
C    TDPSIA=1.5                                                  (A-214.1IA)
C    TDPSXF=1                                                    (A-214.1XF)
C    TDPSXV=1.5                                                  (A-214.1XV)
C    TDPSXA=6                                                    (A-214.1XA)
NOTE  TDPS$$ - TARGETS DESTROYED PER SORTIE $$ (TANK EQUIV TARGETS)
L    CTDBHH.K=CTDBHH.J+(DT)(TDBHH.J)                             (A-215HH)
L    CTDBTA.K=CTDBTA.J+(DT)(TDBTA.J)                             (A-215TA)
L    CTDBXS.K=CTDBXS.J+(DT)(TDBXS.J)                             (A-215XS)
L    CTDBFF.K=CTDBFF.J+(DT)(TDBFF.J)                             (A-215FF)
L    CTDBEF.K=CTDBEF.J+(DT)(TDBEF.J)                             (A-215EF)
L    CTDBTF.K=CTDBTF.J+(DT)(TDBTF.J)                             (A-215TF)
L    CTDBHF.K=CTDBHF.J+(DT)(TDBHF.J)                             (A-215HF)
L    CTDBHV.K=CTDBHV.J+(DT)(TDBHV.J)                             (A-215HV)
L    CTDBIA.K=CTDBIA.J+(DT)(TDBIA.J)                             (A-215IA)
L    CTDBXF.K=CTDBXF.J+(DT)(TDBXF.J)                             (A-215XF)
L    CTDBXV.K=CTDBXV.J+(DT)(TDBXV.J)                             (A-215XV)
L    CTDBXA.K=CTDBXA.J+(DT)(TDBXA.J)                             (A-215XA)
N    CTDBHH=0                                                    (A-215.1HH)
N    CTDBTA=0                                                    (A-215.1TA)
N    CTDBXS=0                                                    (A-215.1XS)
N    CTDBFF=0                                                    (A-215.1FF)
N    CTDBEF=0                                                    (A-215.1EF)
N    CTDBTF=0                                                    (A-215.1TF)
N    CTDBHF=0                                                    (A-215.1HF)
N    CTDBHV=0                                                    (A-215.1HV)
N    CTDBIA=0                                                    (A-215.1IA)
N    CTDBXF=0                                                    (A-215.1XF)
N    CTDBXV=0                                                    (A-215.1XV)
N    CTDBXA=0                                                    (A-215.1XA)
NOTE  CTDB$$ - CUMULATIVE TARGETS DESTROYED BY $$ (TANK EQUIV TARGETS)
A    CTDB$$.K=CTDBHH.K+CTDBTA.K+CTDBXS.K+CTDBFF.K+CTDBEF.K+CTDBTF.K+
X       CTDBHF.K+CTDBHV.K+CTDBIA.K+CTDBXF.K+CTDBXV.K+CTDBXA.K  (A-216$$)
NOTE  CTDB$$ - TOTAL CUMMULATIVE TARGETS DESTROYED BY U.S. AIRCRAFT
NOTE             (TANK EQUIV TARGETS)
A    TDP$$L.K=CTDB$$.K/CL$$.K                                     (A-217$$)
NOTE  TDP$$L - TARGETS DESTROYED PER $$ LOST (TARGETS/AC)
A    KP$$L.K=CLXX.K/CL$$.K                                        (A-218$$)
NOTE  KP$$L - KILLS PER $$ LOST (AC/AC)
NOTE
NOTE          +-----------------------------------+
NOTE              U.S.S.R  COMBAT EFFECTIVENESS
NOTE          +-----------------------------------+
NOTE
A    TDBHD.K=CLIP(HD.K*SRHDLT.K*TDPSHD,0,TIME.K,WAR)              (A-214HD)
A    TDBFT.K=CLIP(FT.K*SRFTLT.K*TDPSFT,0,TIME.K,WAR)              (A-214FT)
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A    TDBFR.K=CLIP(FR.K*SRFRLT.K*TDPSFR,0,TIME.K,WAR)             (A-214FR)
A    TDBFD.K=CLIP(FD.K*SRFDLT.K*TDPSFD,0,TIME.K,WAR)             (A-214FD)
A    TDBFH.K=CLIP(FH.K*SRFHLT.K*TDPSFH,0,TIME.K,WAR)             (A-214FH)
A    TDBFG.K=CLIP(FG.K*SRFGLT.K*TDPSFG,0,TIME.K,WAR)             (A-214FG)
A    TDBFX.K=CLIP(FX.K*SRFXLT.K*TDPSFX,0,TIME.K,WAR)             (A-214FX)
A    TDBFL.K=CLIP(FL.K*SRFLLT.K*TDPSFL,0,TIME.K,WAR)             (A-214FL)
A    TDBBK.K=CLIP(BK.K*SRBKLT.K*TDPSBK,0,TIME.K,WAR)             (A-214BK)
A    TDBFU.K=CLIP(FU.K*SRFULT.K*TDPSFU,0,TIME.K,WAR)             (A-214FU)
A    TDBFO.K=CLIP(FO.K*SRFOLT.K*TDPSFO,0,TIME.K,WAR)             (A-214FO)
A    TDBFK.K=CLIP(FK.K*SRFKLT.K*TDPSFK,0,TIME.K,WAR)             (A-214FK)
NOTE  TDB$$ - TARGETS DESTROYED BY XX (TANK EQUIV TARGETS)
C    TDPSHD=.5                                                   (A-214.1HD)
C    TDPSFT=1                                                    (A-214.1FT)
C    TDPSFR=2                                                    (A-214.1FR)
C    TDPSFD=.5                                                   (A-214.1FD)
C    TDPSFH=.5                                                   (A-214.1FH)
C    TDPSFG=.5                                                   (A-214.1FG)
C    TDPSFX=.5                                                   (A-214.1FX)
C    TDPSFL=.5                                                   (A-214.1FL)
C    TDPSBK=6                                                    (A-214.1BK)
C    TDPSFU=.5                                                   (A-214.1FU)
C    TDPSFO=1                                                    (A-214.1FO)
C    TDPSFK=3                                                    (A-214.1FK)
NOTE  TDPS$$ - TARGETS DESTROYED PER SORTIE $$ (TANK EQUIV TARGETS)
L    CTDBHD.K=CTDBHD.J+(DT)(TDBHD.J)                             (A-215HD)
L    CTDBFT.K=CTDBFT.J+(DT)(TDBFT.J)                             (A-215FT)
L    CTDBFR.K=CTDBFR.J+(DT)(TDBFR.J)                             (A-215FR)
L    CTDBFD.K=CTDBFD.J+(DT)(TDBFD.J)                             (A-215FD)
L    CTDBFH.K=CTDBFH.J+(DT)(TDBFH.J)                             (A-215FH)
L    CTDBFG.K=CTDBFG.J+(DT)(TDBFG.J)                             (A-215FG)
L    CTDBFX.K=CTDBFX.J+(DT)(TDBFX.J)                             (A-215FX)
L    CTDBFL.K=CTDBFL.J+(DT)(TDBFL.J)                             (A-215FL)
L    CTDBBK.K=CTDBBK.J+(DT)(TDBBK.J)                             (A-215BK)
L    CTDBFU.K=CTDBFU.J+(DT)(TDBFU.J)                             (A-215FU)
L    CTDBFO.K=CTDBFO.J+(DT)(TDBFO.J)                             (A-215FO)
L    CTDBFK.K=CTDBFK.J+(DT)(TDBFK.J)                             (A-215FK)
N    CTDBHD=0                                                    (A-215.1HD)
N    CTDBFT=0                                                    (A-215.1FT)
N    CTDBFR=0                                                    (A-215.1FR)
N    CTDBFD=0                                                    (A-215.1FD)
N    CTDBFH=0                                                    (A-215.1FH)
N    CTDBFG=0                                                    (A-215.1FG)
N    CTDBFX=0                                                    (A-215.1FX)
N    CTDBFL=0                                                    (A-215.1FL)
N    CTDBBK=0                                                    (A-215.1FU)
N    CTDBFU=0                                                    (A-215.1BK)
N    CTDBFO=0                                                    (A-215.1FO)
N    CTDBFK=0                                                    (A-215.1FK)
NOTE  CTDB$$ - CUMMULATIVE TARGETS DESTROYED BY XX (TANKS EQUIV TARGETS)
A    CTDBXX.K=CTDBHD.K+CTDBFT.K+CTDBFR.K+CTDBFD.K+CTDBFH.K+CTDBFG.K+
X       CTDBFX.K+CTDBFL.K+CTDBBK.K+CTDBFU.K+CTDBFO.K+CTDBFK.K  (A-216XX)
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NOTE  CTDBXX - TOTAL CUMMULATIVE TARGETS DESTROYED BY U.S.S.R. AIRCRAFT
NOTE           (TANK EQUIV TARGETS)
A   TDPXXL.K=CTDBXX.K/CLXX.K                                  (A-217XX)
NOTE  TDPXXL - TARGETS DESTROYED PER XX LOST (TARGETS/AC)
A   KPXXL.K=CL$$.K/CLXX.K                                     (A-218XX)
NOTE  KPXXL - KILLS PER XX LOST (AC/AC)
NOTE  ****************************************************************
N   TIME=1980
C   WAR=2000
NOTE  *****************************************************************
A   USSRAR.K=DLINF3(USSRA.K,TRXXCE)                           (A-219XX)
NOTE  USSRAR - USSR AIRPOWER RECOGNIZED (DIM)
C   TRXXCE=3                                                  (A-219.1XX)
NOTE  TRXXCE - TIME TO RECOGNIZE SOVIET COMBAT EFFECTIVENESS (YR)
L   USSRA.K=USSRA.J+(DT)(USSRCV.J-USSRA.J)                    (A-220XX)
N   USSRA=0                                                   (A-220.1XX)
NOTE  USSRA - U.S.S.R. AIRPOWER
A   USSRCV.K=HDCV.K+FTCV.K+FRCV.K+FDCV.K+FHCV.K+FGCV.K+FXCV.K+FLCV.K
X     +BKCV.K+FUCV.K+FOCV.K+FKCV.K                            (A-221XX)
NOTE  USSRCV - U.S.S.R. COMBAT VALUE
A   HDCV.K=(HD.K*FSHDAT-((PRHH.JK*FSHHAT*EHHHD.K+PRTA.JK*FSTAAT*ETAHD.K
X     +PRXS.JK*FSXSAT*EXSHD.K+PRFF.JK*FSFFAT*EFFHD.K
X     +PREF.JK*FSEFAT*EEFHD.K+PRTF.JK*FSTFAT*ETFHD.K
X     +PRHF.JK*FSHFAT*EHFHD.K+PRHV.JK*FSHVAT*EHVHD.K
X     +PRIA.JK*FSIAAT*EIAHD.K+PRXF.JK*FSXFAT*EXFHD.K
X     +PRXV.JK*FSXVAT*EXVHD.K+PRXA.JK*FSXAAT*EXAHD.K)/(TCF.K*FHD$$.K)))
X     *SQRT(FHD$$.K)+(HD.K*SQRT(SRHDLT.K*(1-MSHDLT))*TDPSHD)  (A-222HD)
NOTE  HDCV - COMBAT VALUE OF HD
A   FTCV.K=(FT.K*FSFTAT-((PRHH.JK*FSHHAT*EHHFT.K+PRTA.JK*FSTAAT*ETAFT.K
X     +PRXS.JK*FSXSAT*EXSFT.K+PRFF.JK*FSFFAT*EFFFT.K
X     +PREF.JK*FSEFAT*EEFFT.K+PRTF.JK*FSTFAT*ETFFT.K
X     +PRHF.JK*FSHFAT*EHFFT.K+PRHV.JK*FSHVAT*EHVFT.K
X     +PRIA.JK*FSIAAT*EIAFT.K+PRXF.JK*FSXFAT*EXFFT.K
X     +PRXV.JK*FSXVAT*EXVFT.K+PRXA.JK*FSXAAT*EXAFT.K)/(TCF.K*FFT$$.K)))
X     *SQRT(FFT$$.K)+(FT.K*SQRT(SRFTLT.K*(1-MSFTLT))*TDPSFT)  (A-222FT)
NOTE  FTCV - COMBAT VALUE OF FT
A   FRCV.K=(FR.K*FSFRAT-((PRHH.JK*FSHHAT*EHHFR.K+PRTA.JK*FSTAAT*ETAFR.K
X     +PRXS.JK*FSXSAT*EXSFR.K+PRFF.JK*FSFFAT*EFFFR.K
X     +PREF.JK*FSEFAT*EEFFR.K+PRTF.JK*FSTFAT*ETFFR.K
X     +PRHF.JK*FSHFAT*EHFFR.K+PRHV.JK*FSHVAT*EHVFR.K
X     +PRIA.JK*FSIAAT*EIAFR.K+PRXF.JK*FSXFAT*EXFFR.K
X     +PRXV.JK*FSXVAT*EXVFR.K+PRXA.JK*FSXAAT*EXAFR.K)/(TCF.K*FFR$$.K)))
X     *SQRT(FFR$$.K)+(FR.K*SQRT(SRFRLT.K*(1-MSFRLT))*TDPSFR)  (A-222FR)
NOTE  FRCV - COMBAT VALUE OF FR
A   FDCV.K=(FD.K*FSFDAT-((PRHH.JK*FSHHAT*EHHFD.K+PRTA.JK*FSTAAT*ETAFD.K
X     +PRXS.JK*FSXSAT*EXSFD.K+PRFF.JK*FSFFAT*EFFFD.K
X     +PREF.JK*FSEFAT*EEFFD.K+PRTF.JK*FSTFAT*ETFFD.K
X     +PRHF.JK*FSHFAT*EHFFD.K+PRHV.JK*FSHVAT*EHVFD.K
X     +PRIA.JK*FSIAAT*EIAFD.K+PRXF.JK*FSXFAT*EXFFD.K
X     +PRXV.JK*FSXVAT*EXVFD.K+PRXA.JK*FSXAAT*EXAFD.K)/(TCF.K*FFD$$.K)))
X     *SQRT(FFD$$.K)+(FD.K*SQRT(SRFDLT.K*(1-MSFDLT))*TDPSFD)  (A-222FD)
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NOTE  FDCV - COMBAT VALUE OF FD
A   FHCV.K=(FH.K*FSFHAT-((PRHH.JK*FSHHAT*EHHFH.K+PRTA.JK*FSTAAT*ETAFH.K
X     +PRXS.JK*FSXSAT*EXSFH.K+PRFF.JK*FSFFAT*EFFFH.K
X     +PREF.JK*FSEFAT*EEFFH.K+PRTF.JK*FSTFAT*ETFFH.K
X     +PRHF.JK*FSHFAT*EHFFH.K+PRHV.JK*FSHVAT*EHVFH.K
X     +PRIA.JK*FSIAAT*EIAFH.K+PRXF.JK*FSXFAT*EXFFH.K
X     +PRXV.JK*FSXVAT*EXVFH.K+PRXA.JK*FSXAAT*EXAFH.K)/(TCF.K*FFH$$.K)))
X     *SQRT(FFH$$.K)+(FH.K*SQRT(SRFHLT.K*(1-MSFHLT))*TDPSFH)  (A-222FH)
NOTE  FHCV - COMBAT VALUE OF FH
A   FGCV.K=(FG.K*FSFGAT-((PRHH.JK*FSHHAT*EHHFG.K+PRTA.JK*FSTAAT*ETAFG.K
X     +PRXS.JK*FSXSAT*EXSFG.K+PRFF.JK*FSFFAT*EFFFG.K
X     +PREF.JK*FSEFAT*EEFFG.K+PRTF.JK*FSTFAT*ETFFG.K
X     +PRHF.JK*FSHFAT*EHFFG.K+PRHV.JK*FSHVAT*EHVFG.K
X     +PRIA.JK*FSIAAT*EIAFG.K+PRXF.JK*FSXFAT*EXFFG.K
X     +PRXV.JK*FSXVAT*EXVFG.K+PRXA.JK*FSXAAT*EXAFG.K)/(TCF.K*FFG$$.K)))
X     *SQRT(FFG$$.K)+(FG.K*SQRT(SRFGLT.K*(1-MSFGLT))*TDPSFG)  (A-222FG)
NOTE  FGCV - COMBAT VALUE OF FG
A   FXCV.K=(FX.K*FSFXAT-((PRHH.JK*FSHHAT*EHHFX.K+PRTA.JK*FSTAAT*ETAFX.K
X     +PRXS.JK*FSXSAT*EXSFX.K+PRFF.JK*FSFFAT*EFFFX.K
X     +PREF.JK*FSEFAT*EEFFX.K+PRTF.JK*FSTFAT*ETFFX.K
X     +PRHF.JK*FSHFAT*EHFFX.K+PRHV.JK*FSHVAT*EHVFX.K
X     +PRIA.JK*FSIAAT*EIAFX.K+PRXF.JK*FSXFAT*EXFFX.K
X     +PRXV.JK*FSXVAT*EXVFX.K+PRXA.JK*FSXAAT*EXAFX.K)/(TCF.K*FFX$$.K)))
X     *SQRT(FFX$$.K)+(FX.K*SQRT(SRFXLT.K*(1-MSFXLT))*TDPSFX)  (A-222FX)
NOTE  FXCV - COMBAT VALUE OF FX
A   FLCV.K=(FL.K*FSFLAT-((PRHH.JK*FSHHAT*EHHFL.K+PRTA.JK*FSTAAT*ETAFL.K
X     +PRXS.JK*FSXSAT*EXSFL.K+PRFF.JK*FSFFAT*EFFFL.K
X     +PREF.JK*FSEFAT*EEFFL.K+PRTF.JK*FSTFAT*ETFFL.K
X     +PRHF.JK*FSHFAT*EHFFL.K+PRHV.JK*FSHVAT*EHVFL.K
X     +PRIA.JK*FSIAAT*EIAFL.K+PRXF.JK*FSXFAT*EXFFL.K
X     +PRXV.JK*FSXVAT*EXVFL.K+PRXA.JK*FSXAAT*EXAFL.K)/(TCF.K*FFL$$.K)))
X     *SQRT(FFL$$.K)+(FL.K*SQRT(SRFLLT.K*(1-MSFLLT))*TDPSFL)  (A-222FL)
NOTE  FLCV - COMBAT VALUE OF FL
A   BKCV.K=(BK.K*FSBKAT-((PRHH.JK*FSHHAT*EHHBK.K+PRTA.JK*FSTAAT*ETABK.K
X     +PRXS.JK*FSXSAT*EXSBK.K+PRFF.JK*FSFFAT*EFFBK.K
X     +PREF.JK*FSEFAT*EEFBK.K+PRTF.JK*FSTFAT*ETFBK.K
X     +PRHF.JK*FSHFAT*EHFBK.K+PRHV.JK*FSHVAT*EHVBK.K
X     +PRIA.JK*FSIAAT*EIABK.K+PRXF.JK*FSXFAT*EXFBK.K
X     +PRXV.JK*FSXVAT*EXVBK.K+PRXA.JK*FSXAAT*EXABK.K)/(TCF.K*FBK$$.K)))
X     *SQRT(FBK$$.K)+(BK.K*SQRT(SRBKLT.K*(1-MSBKLT))*TDPSBK)  (A-222BK)
NOTE  BKCV - COMBAT VALUE OF BK
A   FUCV.K=(FU.K*FSFUAT-((PRHH.JK*FSHHAT*EHHFU.K+PRTA.JK*FSTAAT*ETAFU.K
X     +PRXS.JK*FSXSAT*EXSFU.K+PRFF.JK*FSFFAT*EFFFU.K
X     +PREF.JK*FSEFAT*EEFFU.K+PRTF.JK*FSTFAT*ETFFU.K
X     +PRHF.JK*FSHFAT*EHFFU.K+PRHV.JK*FSHVAT*EHVFU.K
X     +PRIA.JK*FSIAAT*EIAFU.K+PRXF.JK*FSXFAT*EXFFU.K
X     +PRXV.JK*FSXVAT*EXVFU.K+PRXA.JK*FSXAAT*EXAFU.K)/(TCF.K*FFU$$.K)))
X     *SQRT(FFU$$.K)+(FU.K*SQRT(SRFULT.K*(1-MSFULT))*TDPSFU)  (A-222FU)
NOTE  FUCV - COMBAT VALUE OF FU
A   FOCV.K=(FO.K*FSFOAT-((PRHH.JK*FSHHAT*EHHFO.K+PRTA.JK*FSTAAT*ETAFO.K
X     +PRXS.JK*FSXSAT*EXSFO.K+PRFF.JK*FSFFAT*EFFFO.K
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X      +PREF.JK*FSEFAT*EEFFO.K+PRTF.JK*FSTFAT*ETFFO.K
X      +PRHF.JK*FSHFAT*EHFFO.K+PRHV.JK*FSHVAT*EHVFO.K
X      +PRIA.JK*FSIAAT*EIAFO.K+PRXF.JK*FSXFAT*EXFFO.K
X      +PRXV.JK*FSXVAT*EXVFO.K+PRXA.JK*FSXAAT*EXAFO.K)/(TCF.K*FFO$$.K)))
X      *SQRT(FFO$$.K)+(FO.K*SQRT(SRFOLT.K*(1-MSFOLT))*TDPSFO)  (A-222FO)
NOTE   FOCV - COMBAT VALUE OF FO
A    FKCV.K=(FK.K*FSFKAT-((PRHH.JK*FSHHAT*EHHFK.K+PRTA.JK*FSTAAT*ETAFK.K
X      +PRXS.JK*FSXSAT*EXSFK.K+PRFF.JK*FSFFAT*EFFFK.K
X      +PREF.JK*FSEFAT*EEFFK.K+PRTF.JK*FSTFAT*ETFFK.K
X      +PRHF.JK*FSHFAT*EHFFK.K+PRHV.JK*FSHVAT*EHVFK.K
X      +PRIA.JK*FSIAAT*EIAFK.K+PRXF.JK*FSXFAT*EXFFK.K
X      +PRXV.JK*FSXVAT*EXVFK.K+PRXA.JK*FSXAAT*EXAFK.K)/(TCF.K*FFK$$.K)))
X      *SQRT(FFK$$.K)+(FK.K*SQRT(SRFKLT.K*(1-MSFKLT))*TDPSFK)  (A-222FK)
NOTE   FKCV - COMBAT VALUE OF FK
A    FHD$$.K=SRHDHH.K*(1-MSHHHD.K)+SRHDTA.K*(1-MSTAHD.K)+SRHDXS.K*
X      (1-MSXSHD.K)+SRHDFF.K*(1-MSFFHD.K)+SRHDEF.K*(1-MSEFHD.K)
X      +SRHDTF.K*(1-MSTFHD.K)+SRHDHF.K*(1-MSHFHD.K)+SRHDHV.K*(1-MSHVHD.K)
X      +SRHDIA.K*(1-MSIAHD.K)+SRHDXF.K*(1-MSXFHD.K)+SRHDXV.K*(1-MSXVHD.K)
X      +SRHDXA.K*(1-MSXAHD.K)                                  (A-223HD)
NOTE   FHD$$ - EFFECTIVENESS OF HD VS U.S. AIRCRAFT
A    FFT$$.K=SRFTHH.K*(1-MSHHFT.K)+SRFTTA.K*(1-MSTAFT.K)+SRFTXS.K*
X      (1-MSXSFT.K)+SRFTFF.K*(1-MSFFFT.K)+SRFTEF.K*(1-MSEFFT.K)
X      +SRFTTF.K*(1-MSTFFT.K)+SRFTHF.K*(1-MSHFFT.K)+SRFTHV.K*(1-MSHVFT.K)
X      +SRFTIA.K*(1-MSIAFT.K)+SRFTXF.K*(1-MSXFFT.K)+SRFTXV.K*(1-MSXVFT.K)
X      +SRFTXA.K*(1-MSXAFT.K)                                  (A-223FT)
NOTE   FFT$$ - EFFECTIVENESS OF FT VS U.S. AIRCRAFT
A    FFR$$.K=SRFRHH.K*(1-MSHHFR.K)+SRFRTA.K*(1-MSTAFR.K)+SRFRXS.K*
X      (1-MSXSFR.K)+SRFRFF.K*(1-MSFFFR.K)+SRFREF.K*(1-MSEFFR.K)
X      +SRFRTF.K*(1-MSTFFR.K)+SRFRHF.K*(1-MSHFFR.K)+SRFRHV.K*(1-MSHVFR.K)
X      +SRFRIA.K*(1-MSIAFR.K)+SRFRXF.K*(1-MSXFFR.K)+SRFRXV.K*(1-MSXVFR.K)
X      +SRFRXA.K*(1-MSXAFR.K)                                  (A-223FR)
NOTE   FFR$$ - EFFECTIVENESS OF FR VS U.S. AIRCRAFT
A    FFD$$.K=SRFDHH.K*(1-MSHHFD.K)+SRFDTA.K*(1-MSTAFD.K)+SRFDXS.K*
X      (1-MSXSFD.K)+SRFDFF.K*(1-MSFFFD.K)+SRFDEF.K*(1-MSEFFD.K)
X      +SRFDTF.K*(1-MSTFFD.K)+SRFDHF.K*(1-MSHFFD.K)+SRFDHV.K*(1-MSHVFD.K)
X      +SRFDIA.K*(1-MSIAFD.K)+SRFDXF.K*(1-MSXFFD.K)+SRFDXV.K*(1-MSXVFD.K)
X      +SRFDXA.K*(1-MSXAFD.K)                                  (A-223FD)
NOTE   FFD$$ - EFFECTIVENESS OF FD VS U.S. AIRCRAFT
A    FFH$$.K=SRFHHH.K*(1-MSHHFH.K)+SRFHTA.K*(1-MSTAFH.K)+SRFHXS.K*
X      (1-MSXSFH.K)+SRFHFF.K*(1-MSFFFH.K)+SRFHEF.K*(1-MSEFFH.K)
X      +SRFHTF.K*(1-MSTFFH.K)+SRFHHF.K*(1-MSHFFH.K)+SRFHHV.K*(1-MSHVFH.K)
X      +SRFHIA.K*(1-MSIAFH.K)+SRFHXF.K*(1-MSXFFH.K)+SRFHXV.K*(1-MSXVFH.K)
X      +SRFHXA.K*(1-MSXAFH.K)                                  (A-223FH)
NOTE   FFH$$ - EFFECTIVENESS OF FH VS U.S. AIRCRAFT
A    FFG$$.K=SRFGHH.K*(1-MSHHFG.K)+SRFGTA.K*(1-MSTAFG.K)+SRFGXS.K*
X      (1-MSXSFG.K)+SRFGFF.K*(1-MSFFFG.K)+SRFGEF.K*(1-MSEFFG.K)
X      +SRFGTF.K*(1-MSTFFG.K)+SRFGHF.K*(1-MSHFFG.K)+SRFGHV.K*(1-MSHVFG.K)
X      +SRFGIA.K*(1-MSIAFG.K)+SRFGXF.K*(1-MSXFFG.K)+SRFGXV.K*(1-MSXVFG.K)
X      +SRFGXA.K*(1-MSXAFG.K)                                  (A-223FG)
NOTE   FFG$$ - EFFECTIVENESS OF FG VS U.S. AIRCRAFT
A    FFX$$.K=SRFXHH.K*(1-MSHHFX.K)+SRFXTA.K*(1-MSTAFX.K)+SRFXXS.K*
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X      (1-MSXSFX.K)+SRFXFF.K*(1-MSFFFX.K)+SRFXEF.K*(1-MSEFFX.K)
X      +SRFXTF.K*(1-MSTFFX.K)+SRFXHF.K*(1-MSHFFX.K)+SRFXHV.K*(1-MSHVFX.K)
X      +SRFXIA.K*(1-MSIAFX.K)+SRFXXF.K*(1-MSXFFX.K)+SRFXXV.K*(1-MSXVFX.K)
X      +SRFXXA.K*(1-MSXAFX.K)                                (A-223FX)
NOTE  FFX$$ - EFFECTIVENESS OF FX VS U.S. AIRCRAFT
A    FFL$$.K=SRFLHH.K*(1-MSHHFL.K)+SRFLTA.K*(1-MSTAFL.K)+SRFLXS.K*
X      (1-MSXSFL.K)+SRFLFF.K*(1-MSFFFL.K)+SRFLEF.K*(1-MSEFFL.K)
X      +SRFLTF.K*(1-MSTFFL.K)+SRFLHF.K*(1-MSHFFL.K)+SRFLHV.K*(1-MSHVFL.K)
X      +SRFLIA.K*(1-MSIAFL.K)+SRFLXF.K*(1-MSXFFL.K)+SRFLXV.K*(1-MSXVFL.K)
X      +SRFLXA.K*(1-MSXAFL.K)                                (A-223FL)
NOTE  FFL$$ - EFFECTIVENESS OF FL VS U.S. AIRCRAFT
A    FBK$$.K=SRBKHH.K*(1-MSHHBK.K)+SRBKTA.K*(1-MSTABK.K)+SRBKXS.K*
X      (1-MSXSBK.K)+SRBKFF.K*(1-MSFFBK.K)+SRBKEF.K*(1-MSEFBK.K)
X      +SRBKTF.K*(1-MSTFBK.K)+SRBKHF.K*(1-MSHFBK.K)+SRBKHV.K*(1-MSHVBK.K)
X      +SRBKIA.K*(1-MSIABK.K)+SRBKXF.K*(1-MSXFBK.K)+SRBKXV.K*(1-MSXVBK.K)
X      +SRBKXA.K*(1-MSXABK.K)                                (A-223BK)
NOTE  FBK$$ - EFFECTIVENESS OF BK VS U.S. AIRCRAFT
A    FFU$$.K=SRFUHH.K*(1-MSHHFU.K)+SRFUTA.K*(1-MSTAFU.K)+SRFUXS.K*
X      (1-MSXSFU.K)+SRFUFF.K*(1-MSFFFU.K)+SRFUEF.K*(1-MSEFFU.K)
X      +SRFUTF.K*(1-MSTFFU.K)+SRFUHF.K*(1-MSHFFU.K)+SRFUHV.K*(1-MSHVFU.K)
X      +SRFUIA.K*(1-MSIAFU.K)+SRFUXF.K*(1-MSXFFU.K)+SRFUXV.K*(1-MSXVFU.K)
X      +SRFUXA.K*(1-MSXAFU.K)                                (A-223FU)
NOTE  FFU$$ - EFFECTIVENESS OF FU VS U.S. AIRCRAFT
A    FFO$$.K=SRFOHH.K*(1-MSHHFO.K)+SRFOTA.K*(1-MSTAFO.K)+SRFOXS.K*
X      (1-MSXSFO.K)+SRFOFF.K*(1-MSFFFO.K)+SRFOEF.K*(1-MSEFFO.K)
X      +SRFOTF.K*(1-MSTFFO.K)+SRFOHF.K*(1-MSHFFO.K)+SRFOHV.K*(1-MSHVFO.K)
X      +SRFOIA.K*(1-MSIAFO.K)+SRFOXF.K*(1-MSXFFO.K)+SRFOXV.K*(1-MSXVFO.K)
X      +SRFOXA.K*(1-MSXAFO.K)                                (A-223FO)
NOTE  FFO$$ - EFFECTIVENESS OF FO VS U.S. AIRCRAFT
A    FFK$$.K=SRFKHH.K*(1-MSHHFK.K)+SRFKTA.K*(1-MSTAFK.K)+SRFKXS.K*
X      (1-MSXSFK.K)+SRFKFF.K*(1-MSFFFK.K)+SRFKEF.K*(1-MSEFFK.K)
X      +SRFKTF.K*(1-MSTFFK.K)+SRFKHF.K*(1-MSHFFK.K)+SRFKHV.K*(1-MSHVFK.K)
X      +SRFKIA.K*(1-MSIAFK.K)+SRFKXF.K*(1-MSXFFK.K)+SRFKXV.K*(1-MSXVFK.K)
X      +SRFKXA.K*(1-MSXAFK.K)                                (A-223FK)
NOTE  FFK$$ - EFFECTIVENESS OF FK VS U.S. AIRCRAFT
NOTE  *************************************************************
A    USAAR.K=DLINF3(USAA.K,TR$$CE)                           (A-219$$)
NOTE  USAA - U.S.A. AIRPOWER RECOGNIZED (DIM)
C    TR$$CE=3                                                (A-219.1$$)
NOTE  TR$$CE - TIME TO RECOGNIZE U.S. COMBAT EFFECTIVENESS (YR)
L    USAA.K=USAA.J+(DT)(USACV.J-USAA.J)                      (A-220$$)
N    USAA=0                                                  (A-220.1$$)
NOTE USAA - U.S.A. AIR POWER
A    USACV.K=HHCV.K+TACV.K+XSCV.K+FFCV.K+EFCV.K+TFCV.K+HFCV.K+
X      HVCV.K+IACV.K+XFCV.K+XVCV.K+XACV.K                     (A-221$$)
NOTE  USACV - U.S.A. COMBAT VALUE
A    HHCV.K=(HH.K*FSHHAT-((PRHD.JK*FSHDAT*EHDHH.K+PRFT.JK*FSFTAT*EFTHH.K
X      +PRFR.JK*FSFRAT*EFRHH.K+PRFD.JK*FSFDAT*EFDHH.K
X      +PRFH.JK*FSFHAT*EFHHH.K+PRFG.JK*FSFGAT*EFGHH.K
X      +PRFX.JK*FSFXAT*EFXHH.K+PRFL.JK*FSFLAT*EFLHH.K
X      +PRBK.JK*FSBKAT*EBKHH.K+PRFU.JK*FSFUAT*EFUHH.K
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X     +PRFO.JK*FSFOAT*EFOHH.K+PRFK.JK*FSFKAT*EFKHH.K)/(TCF.K*FHHXX.K)))
X     *SQRT(FHHXX.K)+(HH.K*SQRT(SRHHLT.K*(1-MSHHLT.K))*TDPSHH)  (A-222HH)
NOTE  HHCV - COMBAT VALUE OF HH
A   TACV.K=(TA.K*FSTAAT-((PRHD.JK*FSHDAT*EHDTA.K+PRFT.JK*FSFTAT*EFTTA.K
X     +PRFR.JK*FSFRAT*EFRTA.K+PRFD.JK*FSFDAT*EFDTA.K
X     +PRFH.JK*FSFHAT*EFHTA.K+PRFG.JK*FSFGAT*EFGTA.K
X     +PRFX.JK*FSFXAT*EFXTA.K+PRFL.JK*FSFLAT*EFLTA.K
X     +PRBK.JK*FSBKAT*EBKTA.K+PRFU.JK*FSFUAT*EFUTA.K
X     +PRFO.JK*FSFOAT*EFOTA.K+PRFK.JK*FSFKAT*EFKTA.K)/(TCF.K*FTAXX.K)))
X     *SQRT(FTAXX.K)+(TA.K*SQRT(SRTALT.K*(1-MSTALT.K))*TDPSTA)  (A-222TA)
NOTE  TACV - COMBAT VALUE OF TA
A   XSCV.K=(XS.K*FSXSAT-((PRHD.JK*FSHDAT*EHDXS.K+PRFT.JK*FSFTAT*EFTXS.K
X     +PRFR.JK*FSFRAT*EFRXS.K+PRFD.JK*FSFDAT*EFDXS.K
X     +PRFH.JK*FSFHAT*EFHXS.K+PRFG.JK*FSFGAT*EFGXS.K
X     +PRFX.JK*FSFXAT*EFXXS.K+PRFL.JK*FSFLAT*EFLXS.K
X     +PRBK.JK*FSBKAT*EBKXS.K+PRFU.JK*FSFUAT*EFUXS.K
X     +PRFO.JK*FSFOAT*EFOXS.K+PRFK.JK*FSFKAT*EFKXS.K)/(TCF.K*FXSXX.K)))
X     *SQRT(FXSXX.K)+(XS.K*SQRT(SRXSLT.K*(1-MSXSLT.K))*TDPSXS)  (A-222XS)
NOTE  XSCV - COMBAT VALUE OF XS
A   FFCV.K=(FF.K*FSFFAT-((PRHD.JK*FSHDAT*EHDFF.K+PRFT.JK*FSFTAT*EFTFF.K
X     +PRFR.JK*FSFRAT*EFRFF.K+PRFD.JK*FSFDAT*EFDFF.K
X     +PRFH.JK*FSFHAT*EFHFF.K+PRFG.JK*FSFGAT*EFGFF.K
X     +PRFX.JK*FSFXAT*EFXFF.K+PRFL.JK*FSFLAT*EFLFF.K
X     +PRBK.JK*FSBKAT*EBKFF.K+PRFU.JK*FSFUAT*EFUFF.K
X     +PRFO.JK*FSFOAT*EFOFF.K+PRFK.JK*FSFKAT*EFKFF.K)/(TCF.K*FFFXX.K)))
X     *SQRT(FFFXX.K)+(FF.K*SQRT(SRFFLT.K*(1-MSFFLT.K))*TDPSFF)  (A-222FF)
NOTE  FFCV - COMBAT VALUE OF FF
A   EFCV.K=(EF.K*FSEFAT-((PRHD.JK*FSHDAT*EHDEF.K+PRFT.JK*FSFTAT*EFTEF.K
X     +PRFR.JK*FSFRAT*EFREF.K+PRFD.JK*FSFDAT*EFDEF.K
X     +PRFH.JK*FSFHAT*EFHEF.K+PRFG.JK*FSFGAT*EFGEF.K
X     +PRFX.JK*FSFXAT*EFXEF.K+PRFL.JK*FSFLAT*EFLEF.K
X     +PRBK.JK*FSBKAT*EBKEF.K+PRFU.JK*FSFUAT*EFUEF.K
X     +PRFO.JK*FSFOAT*EFOEF.K+PRFK.JK*FSFKAT*EFKEF.K)/(TCF.K*FEFXX.K)))
X     *SQRT(FEFXX.K)+(EF.K*SQRT(SREFLT.K*(1-MSEFLT.K))*TDPSEF)  (A-222EF)
NOTE  EFCV - COMBAT VALUE OF EF
A   TFCV.K=(TF.K*FSTFAT-((PRHD.JK*FSHDAT*EHDTF.K+PRFT.JK*FSFTAT*EFTTF.K
X     +PRFR.JK*FSFRAT*EFRTF.K+PRFD.JK*FSFDAT*EFDTF.K
X     +PRFH.JK*FSFHAT*EFHTF.K+PRFG.JK*FSFGAT*EFGTF.K
X     +PRFX.JK*FSFXAT*EFXTF.K+PRFL.JK*FSFLAT*EFLTF.K
X     +PRBK.JK*FSBKAT*EBKTF.K+PRFU.JK*FSFUAT*EFUTF.K
X     +PRFO.JK*FSFOAT*EFOTF.K+PRFK.JK*FSFKAT*EFKTF.K)/(TCF.K*FTFXX.K)))
X     *SQRT(FTFXX.K)+(TF.K*SQRT(SRTFLT.K*(1-MSTFLT.K))*TDPSTF)  (A-222TF)
NOTE  TFCV - COMBAT VALUE OF TF
A   HFCV.K=(HF.K*FSHFAT-((PRHD.JK*FSHDAT*EHDHF.K+PRFT.JK*FSFTAT*EFTHF.K
X     +PRFR.JK*FSFRAT*EFRHF.K+PRFD.JK*FSFDAT*EFDHF.K
X     +PRFH.JK*FSFHAT*EFHHF.K+PRFG.JK*FSFGAT*EFGHF.K
X     +PRFX.JK*FSFXAT*EFXHF.K+PRFL.JK*FSFLAT*EFLHF.K
X     +PRBK.JK*FSBKAT*EBKHF.K+PRFU.JK*FSFUAT*EFUHF.K
X     +PRFO.JK*FSFOAT*EFOHF.K+PRFK.JK*FSFKAT*EFKHF.K)/(TCF.K*FHFXX.K)))
X     *SQRT(FHFXX.K)+(HF.K*SQRT(SRHFLT.K*(1-MSHFLT.K))*TDPSHF)  (A-222HF)
NOTE  HFCV - COMBAT VALUE OF HF
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A    HVCV.K=(HV.K*FSHVAT-((PRHD.JK*FSHDAT*EHDHV.K+PRFT.JK*FSFTAT*EFTHV.K
X      +PRFR.JK*FSFRAT*EFRHV.K+PRFD.JK*FSFDAT*EFDHV.K
X      +PRFH.JK*FSFHAT*EFHHV.K+PRFG.JK*FSFGAT*EFGHV.K
X      +PRFX.JK*FSFXAT*EFXHV.K+PRFL.JK*FSFLAT*EFLHV.K
X      +PRBK.JK*FSBKAT*EBKHV.K+PRFU.JK*FSFUAT*EFUHV.K
X      +PRFO.JK*FSFOAT*EFOHV.K+PRFK.JK*FSFKAT*EFKHV.K)/(TCF.K*FHVXX.K)))
X      *SQRT(FHVXX.K)+(HV.K*SQRT(SRHVLT.K*(1-MSHVLT.K))*TDPSHV)  (A-222HV)
NOTE  HVCV - COMBAT VALUE OF HV
A    IACV.K=(IA.K*FSIAAT-((PRHD.JK*FSHDAT*EHDIA.K+PRFT.JK*FSFTAT*EFTIA.K
X      +PRFR.JK*FSFRAT*EFRIA.K+PRFD.JK*FSFDAT*EFDIA.K
X      +PRFH.JK*FSFHAT*EFHIA.K+PRFG.JK*FSFGAT*EFGIA.K
X      +PRFX.JK*FSFXAT*EFXIA.K+PRFL.JK*FSFLAT*EFLIA.K
X      +PRBK.JK*FSBKAT*EBKIA.K+PRFU.JK*FSFUAT*EFUIA.K
X      +PRFO.JK*FSFOAT*EFOIA.K+PRFK.JK*FSFKAT*EFKIA.K)/(TCF.K*FIAXX.K)))
X      *SQRT(FIAXX.K)+(IA.K*SQRT(SRIALT.K*(1-MSIALT.K))*TDPSIA)  (A-222IA)
NOTE  IACV - COMBAT VALUE OF IA
A    XFCV.K=(XF.K*FSXFAT-((PRHD.JK*FSHDAT*EHDXF.K+PRFT.JK*FSFTAT*EFTXF.K
X      +PRFR.JK*FSFRAT*EFRXF.K+PRFD.JK*FSFDAT*EFDXF.K
X      +PRFH.JK*FSFHAT*EFHXF.K+PRFG.JK*FSFGAT*EFGXF.K
X      +PRFX.JK*FSFXAT*EFXXF.K+PRFL.JK*FSFLAT*EFLXF.K
X      +PRBK.JK*FSBKAT*EBKXF.K+PRFU.JK*FSFUAT*EFUXF.K
X      +PRFO.JK*FSFOAT*EFOXF.K+PRFK.JK*FSFKAT*EFKXF.K)/(TCF.K*FATFX.K)))
X      *SQRT(FATFX.K)+(XF.K*SQRT(SRXFLT.K*(1-MSXFLT.K))*TDPSXF)  (A-222XF)
NOTE  XFCV - COMBAT VALUE OF XF
A    XVCV.K=(XV.K*FSXVAT-((PRHD.JK*FSHDAT*EHDXV.K+PRFT.JK*FSFTAT*EFTXV.K
X      +PRFR.JK*FSFRAT*EFRXV.K+PRFD.JK*FSFDAT*EFDXV.K
X      +PRFH.JK*FSFHAT*EFHXV.K+PRFG.JK*FSFGAT*EFGXV.K
X      +PRFX.JK*FSFXAT*EFXXV.K+PRFL.JK*FSFLAT*EFLXV.K
X      +PRBK.JK*FSBKAT*EBKXV.K+PRFU.JK*FSFUAT*EFUXV.K
X      +PRFO.JK*FSFOAT*EFOXV.K+PRFK.JK*FSFKAT*EFKXV.K)/(TCF.K*FXVXX.K)))
X      *SQRT(FXVXX.K)+(XV.K*SQRT(SRXVLT.K*(1-MSXVLT.K))*TDPSXV)  (A-222XV)
NOTE  XVCV - COMBXV VALUE OF XV
A    XACV.K=(XA.K*FSXAAT-((PRHD.JK*FSHDAT*EHDXA.K+PRFT.JK*FSFTAT*EFTXA.K
X      +PRFR.JK*FSFRAT*EFRXA.K+PRFD.JK*FSFDAT*EFDXA.K
X      +PRFH.JK*FSFHAT*EFHXA.K+PRFG.JK*FSFGAT*EFGXA.K
X      +PRFX.JK*FSFXAT*EFXXA.K+PRFL.JK*FSFLAT*EFLXA.K
X      +PRBK.JK*FSBKAT*EBKXA.K+PRFU.JK*FSFUAT*EFUXA.K
X      +PRFO.JK*FSFOAT*EFOXA.K+PRFK.JK*FSFKAT*EFKXA.K)/(TCF.K*FXAXX.K)))
X      *SQRT(FXAXX.K)+(XA.K*SQRT(SRXALT.K*(1-MSXALT.K))*TDPSXA)  (A-222XA)
NOTE  XACV - COMBAT VALUE OF XA
A    TCF.K=CLIP(360,1,WAR,TIME.K)
A    FHHXX.K=SRHHHD.K*(1-MSHDHH.K)+SRHHFT.K*(1-MSFRHH.K)+SRHHFR.K*
X      (1-MSFRHH.K)+SRHHFD.K*(1-MSFDHH.K)+SRHHFH.K*(1-MSFHHH.K)
X      +SRHHFG.K*(1-MSFGHH.K)+SRHHFX.K*(1-MSFXHH.K)+SRHHFL.K*(1-MSFLHH.K)
X      +SRHHBK.K*(1-MSBKHH.K)+SRHHFU.K*(1-MSFUHH.K)+SRHHFO.K*(1-MSFOHH.K)
X      +SRHHFK.K*(1-MSFKHH.K)                                  (A-223HH)
NOTE  FHHXX - EFFECTIVENESS OF HH VS U.S.S.R. AIRCRAFT
A    FTAXX.K=SRTAHD.K*(1-MSHDTA.K)+SRTAFT.K*(1-MSFRTA.K)+SRTAFR.K*
X      (1-MSFRTA.K)+SRTAFD.K*(1-MSFDTA.K)+SRTAFH.K*(1-MSFHTA.K)
X      +SRTAFG.K*(1-MSFGTA.K)+SRTAFX.K*(1-MSFXTA.K)+SRTAFL.K*(1-MSFLTA.K)
X      +SRTABK.K*(1-MSBKTA.K)+SRTAFU.K*(1-MSFUTA.K)+SRTAFO.K*(1-MSFOTA.K)
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X     +SRTAFK.K*(1-MSFKTA.K)                                  (A-223TA)
NOTE  FTAXX - EFFECTIVENESS OF TA VS U.S.S.R. AIRCRAFT
A   FXSXX.K=SRXSHD.K*(1-MSHDXS.K)+SRXSFT.K*(1-MSFRXS.K)+SRXSFR.K*
X     (1-MSFRXS.K)+SRXSFD.K*(1-MSFDXS.K)+SRXSFH.K*(1-MSFHXS.K)
X     +SRXSFG.K*(1-MSFGXS.K)+SRXSFX.K*(1-MSFXXS.K)+SRXSFL.K*(1-MSFLXS.K)
X     +SRXSBK.K*(1-MSBKXS.K)+SRXSFU.K*(1-MSFUXS.K)+SRXSFO.K*(1-MSFOXS.K)
X     +SRXSFK.K*(1-MSFKXS.K)                                  (A-223XS)
NOTE  FXSXX - EFFECTIVENESS OF XS VS U.S.S.R. AIRCRAFT
A   FFFXX.K=SRFFHD.K*(1-MSHDFF.K)+SRFFFT.K*(1-MSFRFF.K)+SRFFFR.K*
X     (1-MSFRFF.K)+SRFFFD.K*(1-MSFDFF.K)+SRFFFH.K*(1-MSFHFF.K)
X     +SRFFFG.K*(1-MSFGFF.K)+SRFFFX.K*(1-MSFXFF.K)+SRFFFL.K*(1-MSFLFF.K)
X     +SRFFBK.K*(1-MSBKFF.K)+SRFFFU.K*(1-MSFUFF.K)+SRFFFO.K*(1-MSFOFF.K)
X     +SRFFFK.K*(1-MSFKFF.K)                                  (A-223FF)
NOTE  FFFXX - EFFECTIVENESS OF FF VS U.S.S.R. AIRCRAFT
A   FEFXX.K=SREFHD.K*(1-MSHDEF.K)+SREFFT.K*(1-MSFREF.K)+SREFFR.K*
X     (1-MSFREF.K)+SREFFD.K*(1-MSFDEF.K)+SREFFH.K*(1-MSFHEF.K)
X     +SREFFG.K*(1-MSFGEF.K)+SREFFX.K*(1-MSFXEF.K)+SREFFL.K*(1-MSFLEF.K)
X     +SREFBK.K*(1-MSBKEF.K)+SREFFU.K*(1-MSFUEF.K)+SREFFO.K*(1-MSFOEF.K)
X     +SREFFK.K*(1-MSFKEF.K)                                  (A-223EF)
NOTE  FEFXX - EFFECTIVENESS OF EF VS U.S.S.R. AIRCRAFT
A   FTFXX.K=SRTFHD.K*(1-MSHDTF.K)+SRTFFT.K*(1-MSFRTF.K)+SRTFFR.K*
X     (1-MSFRTF.K)+SRTFFD.K*(1-MSFDTF.K)+SRTFFH.K*(1-MSFHTF.K)
X     +SRTFFG.K*(1-MSFGTF.K)+SRTFFX.K*(1-MSFXTF.K)+SRTFFL.K*(1-MSFLTF.K)
X     +SRTFBK.K*(1-MSBKTF.K)+SRTFFU.K*(1-MSFUTF.K)+SRTFFO.K*(1-MSFOTF.K)
X     +SRTFFK.K*(1-MSFKTF.K)                                  (A-223TF)
NOTE  FTFXX - EFFECTIVENESS OF TF VS U.S.S.R. AIRCRAFT
A   FHFXX.K=SRHFHD.K*(1-MSHDHF.K)+SRHFFT.K*(1-MSFRHF.K)+SRHFFR.K*
X     (1-MSFRHF.K)+SRHFFD.K*(1-MSFDHF.K)+SRHFFH.K*(1-MSFHHF.K)
X     +SRHFFG.K*(1-MSFGHF.K)+SRHFFX.K*(1-MSFXHF.K)+SRHFFL.K*(1-MSFLHF.K)
X     +SRHFBK.K*(1-MSBKHF.K)+SRHFFU.K*(1-MSFUHF.K)+SRHFFO.K*(1-MSFOHF.K)
X     +SRHFFK.K*(1-MSFKHF.K)                                  (A-223HF)
NOTE  FHFXX - EFFECTIVENESS OF HF VS U.S.S.R. AIRCRAFT
A   FHVXX.K=SRHVHD.K*(1-MSHDHV.K)+SRHVFT.K*(1-MSFTHV.K)+SRHVFR.K*
X     (1-MSFRHV.K)+SRHVFD.K*(1-MSFDHV.K)+SRHVFH.K*(1-MSFHHV.K)
X     +SRHVFG.K*(1-MSFGHV.K)+SRHVFX.K*(1-MSFXHV.K)+SRHVFL.K*(1-MSFLHV.K)
X     +SRHVBK.K*(1-MSBKHV.K)+SRHVFU.K*(1-MSFUHV.K)+SRHVFO.K*(1-MSFOHV.K)
X     +SRHVFK.K*(1-MSFKHV.K)                                  (A-223HV)
NOTE  FHVXX - EFFECTIVENESS OF HV VS U.S.S.R. AIRCRAFT
A   FIAXX.K=SRIAHD.K*(1-MSHDIA.K)+SRIAFT.K*(1-MSFRIA.K)+SRIAFR.K*
X     (1-MSFRIA.K)+SRIAFD.K*(1-MSFDIA.K)+SRIAFH.K*(1-MSFHIA.K)
X     +SRIAFG.K*(1-MSFGIA.K)+SRIAFX.K*(1-MSFXIA.K)+SRIAFL.K*(1-MSFLIA.K)
X     +SRIABK.K*(1-MSBKIA.K)+SRIAFU.K*(1-MSFUIA.K)+SRIAFO.K*(1-MSFOIA.K)
X     +SRIAFK.K*(1-MSFKIA.K)                                  (A-223IA)
NOTE  FIAXX - EFFECTIVENESS OF IA VS U.S.S.R. AIRCRAFT
A   FATFX.K=SRXFHD.K*(1-MSHDXF.K)+SRXFFT.K*(1-MSFRXF.K)+SRXFFR.K*
X     (1-MSFRXF.K)+SRXFFD.K*(1-MSFDXF.K)+SRXFFH.K*(1-MSFHXF.K)
X     +SRXFFG.K*(1-MSFGXF.K)+SRXFFX.K*(1-MSFXXF.K)+SRXFFL.K*(1-MSFLXF.K)
X     +SRXFBK.K*(1-MSBKXF.K)+SRXFFU.K*(1-MSFUXF.K)+SRXFFO.K*(1-MSFOXF.K)
X     +SRXFFK.K*(1-MSFKXF.K)                                  (A-223XF)
NOTE  FXFFX - EFFECTIVENESS OF XF VS U.S.S.R. AIRCRAFT
A   FXVXX.K=SRXVHD.K*(1-MSHDXV.K)+SRXVFT.K*(1-MSFRXV.K)+SRXVFR.K*
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X      (1-MSFRXV.K)+SRXVFD.K*(1-MSFDXV.K)+SRXVFH.K*(1-MSFHXV.K)
X      +SRXVFG.K*(1-MSFGXV.K)+SRXVFX.K*(1-MSFXXV.K)+SRXVFL.K*(1-MSFLXV.K)
X      +SRXVBK.K*(1-MSBKXV.K)+SRXVFU.K*(1-MSFUXV.K)+SRXVFO.K*(1-MSFOXV.K)
X      +SRXVFK.K*(1-MSFKXV.K)                                 (A-223XV)
NOTE  FXVXX - EFFECTIVENESS OF XV VS U.S.S.R. AIRCRAFT
A    FXAXX.K=SRXAHD.K*(1-MSHDXA.K)+SRXAFT.K*(1-MSFRXA.K)+SRXAFR.K*
X      (1-MSFRXA.K)+SRXAFD.K*(1-MSFDXA.K)+SRXAFH.K*(1-MSFHXA.K)
X      +SRXAFG.K*(1-MSFGXA.K)+SRXAFX.K*(1-MSFXXA.K)+SRXAFL.K*(1-MSFLXA.K)
X      +SRXABK.K*(1-MSBKXA.K)+SRXAFU.K*(1-MSFUXA.K)+SRXAFO.K*(1-MSFOXA.K)
X      +SRXAFK.K*(1-MSFKXA.K)                                 (A-223XA)
NOTE  FXAXX - EFFECTIVENESS OF XA VS U.S.S.R. AIRCRAFT
*    JTCG/AS MODEL (TOP-DOWN SEGMENT)
NOTE  ******************************************************************
NOTE  ****************  SURVIVABILITY SUBMODEL  ************************
NOTE  ******************************************************************
NOTE  ******************************************************************
NOTE  *** AIRCRAFT MODIFICATION COMPONENT OF SURVIVABILITY SUBMODEL  ***
NOTE  ******************************************************************
L    MSHH.K=MSHH.J+CLIP(0,(DT/SCT)(FMSHH.J-MSHH.J),TIME.J,WAR)  (SS-1 HH)
L    MSTA.K=MSTA.J+CLIP(0,(DT/SCT)(FMSTA.J-MSTA.J),TIME.J,WAR)  (SS-1 TA)
L    MSFF.K=MSFF.J+CLIP(0,(DT/SCT)(FMSFF.J-MSFF.J),TIME.J,WAR)  (SS-1 FF)
L    MSEF.K=MSEF.J+CLIP(0,(DT/SCT)(FMSEF.J-MSEF.J),TIME.J,WAR)  (SS-1 EF)
L    MSXS.K=MSXS.J+CLIP(0,(DT/SCT)(FMSXS.J-MSXS.J),TIME.J,WAR)  (SS-1 XS)
L    MSXF.K=MSXF.J+CLIP(0,(DT/SCT)(FMSXF.J-MSXF.J),TIME.J,WAR)  (SS-1 XF)
L    MSTF.K=MSTF.J+CLIP(0,(DT/SCT)(FMSTF.J-MSTF.J),TIME.J,WAR)  (SS-1 TF)
L    MSHF.K=MSHF.J+CLIP(0,(DT/SCT)(FMSHF.J-MSHF.J),TIME.J,WAR)  (SS-1 HF)
L    MSHV.K=MSHV.J+CLIP(0,(DT/SCT)(FMSHV.J-MSHV.J),TIME.J,WAR)  (SS-1 HV)
L    MSIA.K=MSIA.J+CLIP(0,(DT/SCT)(FMSIA.J-MSIA.J),TIME.J,WAR)  (SS-1 IA)
L    MSXV.K=MSXV.J+CLIP(0,(DT/SCT)(FMSXV.J-MSXV.J),TIME.J,WAR)  (SS-1 XV)
L    MSXA.K=MSXA.J+CLIP(0,(DT/SCT)(FMSXA.J-MSXA.J),TIME.J,WAR)  (SS-1 XA)
N    MSHH=MSHHN                                               (SS-1.1 HH)
N    MSTA=MSTAN                                               (SS-1.1 TA)
N    MSFF=MSFFN                                               (SS-1.1 FF)
N    MSEF=MSEFN                                               (SS-1.1 EF)
N    MSXS=MSXSN                                               (SS-1.1 XS)
N    MSXF=MSXFN                                               (SS-1.1 XF)
N    MSTF=MSTFN                                               (SS-1.1 TF)
N    MSHF=MSHFN                                               (SS-1.1 HF)
N    MSHV=MSHVN                                               (SS-1.1 HV)
N    MSIA=MSIAN                                               (SS-1.1 IA)
N    MSXV=MSXVN                                               (SS-1.1 XV)
N    MSXA=MSXAN                                               (SS-1.1 XA)
NOTE  MSHH-SURVIVABILITY OF ARMY ATTACK HELICOPTER APPACHE AH-64 (PROB)
NOTE  MSTA-SURVIV OF AIRFORCE COMBAT AIRCRAFT THUNDERBOLT A-10 (PROB)
NOTE  MSFF-SURVIVABILITY OF AIRFORCE COMBAT AIRCRAFT FALCON F-16 (PROB)
NOTE  MSEF-SURVIVABILITY OF AIRFORCE COMBAT AIRCRAFT EAGLE F-15 (PROB)
NOTE  MSXS-SURVIVABILITY OF AIRFORCE STEALTH STRIKE AIRCRAFT (PROB)
NOTE  MSXF-SURVIVABILITY OF AIRFORCE ADVANCED TACTICAL FIGHTER ATF (PROB)
NOTE  MSTF-SURVIVABILITY OF NAVY COMBAT AIRCRAFT TOMCAT F-14 (PROB)
NOTE  MSHF-SURVIVABILITY OF NAVY COMBAT AIRCRAFT HORNET F-18 (PROB)
NOTE  MSHV-SURVIVABILITY OF NAVY COMBAT AIRCRAFT HARRIER AV-8 (PROB)
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NOTE  MSIA-SURVIVABILITY OF NAVY COMBAT AIRCRAFT INTRUDER A-6 (PROB)
NOTE  MSXV-SURVIVABILITY OF NAVY VTOL FIGHTER MULTIMISSION VFMX (PROB)
NOTE  MSXA-SURVIVABILITY OF NAVY ADVANCED TACTICAL ATTACK ATA (PROB)
C   MSHHN=.97                                                (SS-1.2 HH)
C   MSTAN=.99                                                (SS-1.2 TA)
C   MSFFN=.98                                                (SS-1.2 FF)
C   MSEFN=.99                                                (SS-1.2 EF)
C   MSXSN=.98                                                (SS-1.2 XS)
C   MSXFN=.98                                                (SS-1.2 XF)
C   MSTFN=.983                                               (SS-1.2 TF)
C   MSHFN=.988                                               (SS-1.2 HF)
C   MSHVN=.97                                                (SS-1.2 HV)
C   MSIAN=.977                                               (SS-1.2 IA)
C   MSXVN=.98                                                (SS-1.2 XV)
C   MSXAN=.98                                                (SS-1.2 XA)
NOTE  MSHHN-SURVIV OF ARMY ATTACK HELICOPTER APPACHE AH-64 NORM (PROB)
NOTE  MSTAN-SURVIV OF AIRFORCE COMBAT A/C THUNDERBOLT A-10 NORM (PROB)
NOTE  MSFFN-SURVIV OF AIRFORCE COMBAT AIRCRAFT FALCON F-16 NORM (PROB)
NOTE  MSEFN-SURVIV OF AIRFORCE COMBAT AIRCRAFT EAGLE F-15 NORM (PROB)
NOTE  MSXSN-SURVIV OF AIRFORCE STEALTH STRIKE AIRCRAFT NORM (PROB)
NOTE  MSXFN-SURVIV OF AIRFORCE ADVANCED TACTICAL FIGHTER ATF NORM (PROB)
NOTE  MSTFN-SURVIVABILITY OF NAVY COMBAT AIRCRAFT TOMCAT F-14 NORM (PROB)
NOTE  MSHFN-SURVIVABILITY OF NAVY COMBAT AIRCRAFT HORNET F-18 NORM (PROB)
NOTE  MSHVN-SURVIVABILITY OF NAVY COMBAT A/C HARRIER AV-8 NORM (PROB)
NOTE  MSIAN-SURVIV OF NAVY COMBAT AIRCRAFT INTRUDER A-6 NORM (PROB)
NOTE  MSXVN-SURVIV OF NAVY VTOL FIGHTER MULTIMISSION VFMX NORM (PROB)
NOTE  MSXAN-SURVIV OF NAVY ADVANCED TACTICAL ATTACK ATA NORM (PROB)
C   SCT=20                                                    (SS-1.3)
NOTE  SCT-SURVIVABILITY CHANGE TIME (YEARS)
A   FMSHH.K=MSHHN+MSHHAE.K+MSHHTE                             (SS-2 HH)
A   FMSTA.K=MSTAN+MSTAAE.K+MSTATE                             (SS-2 TA)
A   FMSFF.K=MSFFN+MSFFAE.K+MSFFTE                             (SS-2 FF)
A   FMSEF.K=MSEFN+MSEFAE.K+MSEFTE                             (SS-2 EF)
A   FMSXS.K=MSXSN+MSXSAE.K+MSXSTE                             (SS-2 XS)
A   FMSXF.K=MSXFN+MSXFAE.K+MSXFTE                             (SS-2 XF)
A   FMSTF.K=MSTFN+MSTFAE.K+MSTFTE                             (SS-2 TF)
A   FMSHF.K=MSHFN+MSHFAE.K+MSHFTE                             (SS-2 HF)
A   FMSHV.K=MSHVN+MSHVAE.K+MSHVTE                             (SS-2 HV)
A   FMSIA.K=MSIAN+MSIAAE.K+MSIATE                             (SS-2 IA)
A   FMSXV.K=MSXVN+MSXVAE.K+MSXVTE                             (SS-2 XV)
A   FMSXA.K=MSXAN+MSXAAE.K+MSXATE                             (SS-2 XA)
NOTE  FMSHH-FORECASTED MISSION SURVIVABILITY OF HH AIRCRAFT (PROB)
NOTE  FMSTA-FORECASTED MISSION SURVIVABILITY OF TA AIRCRAFT (PROB)
NOTE  FMSFF-FORECASTED MISSION SURVIVABILITY OF FF AIRCRAFT (PROB)
NOTE  FMSEF-FORECASTED MISSION SURVIVABILITY OF EF AIRCRAFT (PROB)
NOTE  FMSXS-FORECASTED MISSION SURVIVABILITY OF XS AIRCRAFT (PROB)
NOTE  FMSXF-FORECASTED MISSION SURVIVABILITY OF XF AIRCRAFT (PROB)
NOTE  FMSTF-FORECASTED MISSION SURVIVABILITY OF TF AIRCRAFT (PROB)
NOTE  FMSHF-FORECASTED MISSION SURVIVABILITY OF HF AIRCRAFT (PROB)
NOTE  FMSHV-FORECASTED MISSION SURVIVABILITY OF HV AIRCRAFT (PROB)
NOTE  FMSIA-FORECASTED MISSION SURVIVABILITY OF IA AIRCRAFT (PROB)
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NOTE  FMSXV-FORECASTED MISSION SURVIVABILITY OF XV AIRCRAFT (PROB)
NOTE  FMSXA-FORECASTED MISSION SURVIVABILITY OF XA AIRCRAFT (PROB)
A    MSHHAE.K=CLIP(((SM.K-SB)/(1-SB))(1-MSHHN)/2,0,IPDTPL.K,0)    (SS-3 HH)
A    MSTAAE.K=CLIP(((SM.K-SB)/(1-SB))(1-MSTAN)/2,0,IPDTPL.K,0)    (SS-3 TA)
A    MSFFAE.K=CLIP(((SM.K-SB)/(1-SB))(1-MSFFN)/2,0,DPLCC.K,0)     (SS-3 FF)
A    MSEFAE.K=CLIP(((SM.K-SB)/(1-SB))(1-MSEFN)/2,0,DPLCC.K,0)     (SS-3 EF)
A    MSXSAE.K=CLIP(((SM.K-SB)/(1-SB))(1-MSXSN)/2,0,DPLCC.K,0)     (SS-3 XS)
A    MSXFAE.K=CLIP(((SM.K-SB)/(1-SB))(1-MSXFN)/2,0,DPLCC.K,0)     (SS-3 XF)
A    MSTFAE.K=CLIP(((SM.K-SB)/(1-SB))(1-MSTFN)/2,0,DPLCC.K,0)     (SS-3 TF)
A    MSHFAE.K=CLIP(((SM.K-SB)/(1-SB))(1-MSHFN)/2,0,DPLCC.K,0)     (SS-3 HF)
A    MSHVAE.K=CLIP(((SM.K-SB)/(1-SB))(1-MSHVN)/2,0,IPDTPL.K,0)    (SS-3 HV)
A    MSIAAE.K=CLIP(((SM.K-SB)/(1-SB))(1-MSIAN)/2,0,IPDTPL.K,0)    (SS-3 IA)
A    MSXVAE.K=CLIP(((SM.K-SB)/(1-SB))(1-MSXVN)/2,0,DPLCC.K,0)     (SS-3 XV)
A    MSXAAE.K=CLIP(((SM.K-SB)/(1-SB))(1-MSXAN)/2,0,IPDTPL.K,0)    (SS-3 XA)
NOTE  MSHHAE-MISSION SURVIVABILITY OF HH DUE TO A/C ENHANCEMENT (PROB)
NOTE  MSTAAE-MISSION SURVIVABILITY OF TA DUE TO A/C ENHANCEMENT (PROB)
NOTE  MSFFAE-MISSION SURVIVABILITY OF FF DUE TO A/C ENHANCEMENT (PROB)
NOTE  MSEFAE-MISSION SURVIVABILITY OF EF DUE TO A/C ENHANCEMENT (PROB)
NOTE  MSXSAE-MISSION SURVIVABILITY OF XS DUE TO A/C ENHANCEMENT (PROB)
NOTE  MSXFAE-MISSION SURVIVABILITY OF XF DUE TO A/C ENHANCEMENT (PROB)
NOTE  MSTFAE-MISSION SURVIVABILITY OF TF DUE TO A/C ENHANCEMENT (PROB)
NOTE  MSHFAE-MISSION SURVIVABILITY OF HF DUE TO A/C ENHANCEMENT (PROB)
NOTE  MSHVAE-MISSION SURVIVABILITY OF HV DUE TO A/C ENHANCEMENT (PROB)
NOTE  MSIAAE-MISSION SURVIVABILITY OF IA DUE TO A/C ENHANCEMENT (PROB)
NOTE  MSXVAE-MISSION SURVIVABILITY OF XV DUE TO A/C ENHANCEMENT (PROB)
NOTE  MSXAAE-MISSION SURVIVABILITY OF XA DUE TO A/C ENHANCEMENT (PROB)
N    MSHHTE=((SBF-SB)/(1-SB))(1-MSHHN)/2                        (SS-4 HH)
N    MSTATE=((SBF-SB)/(1-SB))(1-MSTAN)/2                        (SS-4 TA)
N    MSFFTE=((SBF-SB)/(1-SB))(1-MSFFN)/2                        (SS-4 FF)
N    MSEFTE=((SBF-SB)/(1-SB))(1-MSEFN)/2                        (SS-4 EF)
N    MSXSTE=((SBF-SB)/(1-SB))(1-MSXSN)/2                        (SS-4 XS)
N    MSXFTE=((SBF-SB)/(1-SB))(1-MSXFN)/2                        (SS-4 XF)
N    MSTFTE=((SBF-SB)/(1-SB))(1-MSTFN)/2                        (SS-4 TF)
N    MSHFTE=((SBF-SB)/(1-SB))(1-MSHFN)/2                        (SS-4 HF)
N    MSHVTE=((SBF-SB)/(1-SB))(1-MSHVN)/2                        (SS-4 HV)
N    MSIATE=((SBF-SB)/(1-SB))(1-MSIAN)/2                        (SS-4 IA)
N    MSXVTE=((SBF-SB)/(1-SB))(1-MSXVN)/2                        (SS-4 XV)
N    MSXATE=((SBF-SB)/(1-SB))(1-MSXAN)/2                        (SS-4 XA)
NOTE  MSHHTE-MISSION SURVIVABILITY OF HH DUE TO THREAT ENHANCEMENT (PROB)
NOTE  MSTATE-MISSION SURVIVABILITY OF TA DUE TO THREAT ENHANCEMENT (PROB)
NOTE  MSFFTE-MISSION SURVIVABILITY OF FF DUE TO THREAT ENHANCEMENT (PROB)
NOTE  MSEFTE-MISSION SURVIVABILITY OF EF DUE TO THREAT ENHANCEMENT (PROB)
NOTE  MSXSTE-MISSION SURVIVABILITY OF XS DUE TO THREAT ENHANCEMENT (PROB)
NOTE  MSXFTE-MISSION SURVIVABILITY OF XF DUE TO THREAT ENHANCEMENT (PROB)
NOTE  MSTFTE-MISSION SURVIVABILITY OF TF DUE TO THREAT ENHANCEMENT (PROB)
NOTE  MSHFTE-MISSION SURVIVABILITY OF HF DUE TO THREAT ENHANCEMENT (PROB)
NOTE  MSHVTE-MISSION SURVIVABILITY OF HV DUE TO THREAT ENHANCEMENT (PROB)
NOTE  MSIATE-MISSION SURVIVABILITY OF IA DUE TO THREAT ENHANCEMENT (PROB)
NOTE  MSXVTE-MISSION SURVIVABILITY OF XV DUE TO THREAT ENHANCEMENT (PROB)
NOTE  MSXATE-MISSION SURVIVABILITY OF XA DUE TO THREAT ENHANCEMENT (PROB)
C    SB=.950                                                    (SS-4.1)
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NOTE  SB-SURVIV OF GENERIC BASELINE AIRCRAFT IN BASE YEAR (PROB)
C    SBF=.95                                                   (SS-4.2)
NOTE  SBF-SURVIV OF GENERIC BASELINE A/C IN FORECAST YEAR (PROB)
A    SM.K=(SB*(1-DS.K))                                        (SS-5)
NOTE  SM-SURVIV OF GENERIC MODIFIED A/C IN BASE YEAR (PROB)
A    DS.K=DSSR.K+DSVR.K                                       (SS-6)
NOTE  DS-DELTA SURVIVABILITY (FRACT)
NOTE  *******************************************************************
NOTE  **   DELTA VULNERABILITY  COMPONENT OF  SURVIVABILITY SUBMODEL   **
NOTE  *******************************************************************
A    DSVR.K=DSBVR.K*ROTOR+DSWVR.K*ROTOR+DSEVR.K*FIXED+DSCVR.K*FIXED
X         +DSDVR.K*FIXED+DSIVR.K*FIXED+DSOVR.K*FIXED+DSRVR.K*FIXED
X         +DSLVR.K*FIXED+DSVVR.K*FIXED+DSHVR.K*FIXED+DSAVR.K*FIXED
X         +DSTVR.K*FIXED+DSSVR.K*FIXED+DSPVR.K*FIXED+DSFVR.K*FIXED (SS-7)
NOTE  DSVR-DELTA SURVIVABILITY DUE TO VULNERABILITY REDUCTION (FRACT)
NOTE  IF THE AIRCRAFT TYPE IS FIXED WING, FIXED=1 AND ROTOR=0
NOTE  IF THE AIRCRAFT TYPE IS ROTOR WING, FIXED=0 AND ROTOR=1
A    DSBVR.K=DSBS.K+DSBR.K+DSBA.K+DSBP.K+DSBI.K+DSBE.K+DSBH.K  (SS-8)
NOTE  DSBVR-DELTA SURVIV DUE TO ROTOR BLADES VULNER REDUCTION (FRACT)
A    DSBS.K=-.0005                                             (SS-8.1)
NOTE  DSBS-DELTA SURVIV SUBSYS B DUE TO SHIELDING (FRACT)
A    DSBR.K=-.0005                                             (SS-8.2)
NOTE  DSBR-DELTA SURVIV SUBSYS B DUE TO REDUNDANCY (FRACT)
A    DSBA.K=0                                                  (SS-8.3)
NOTE  DSBA-DELTA SURVIV SUBSYS B DUE TO ACTIVE D.S. (FRACT)
A    DSBP.K=0                                                  (SS-8.4)
NOTE  DSBP-DELTA SURVIV SUBSYS B DUE TO PASSIVE D.S. (FRACT)
A    DSBI.K=0                                                  (SS-8.5)
NOTE  DSBI-DELTA SURVIV SUBSYS B DUE TO COMP ISOLATION (FRACT)
A    DSBE.K=0                                                  (SS-8.6)
NOTE  DSBE-DELTA SURVIV SUBSYS B DUE TO COMP ELIMINATION (FRACT))
A    DSBH.K=0                                                  (SS-8.7)
NOTE  DSBH-DELTA SURVIV SUBSYS B DUE TO MATL HARDENING (FRACT))
A    DSWVR.K=DSWS.K+DSWR.K+DSWA.K+DSWP.K+DSWI.K+DSWE.K+DSWH.K  (SS-9)
NOTE  DSWVR-DELTA SURVIV DUE TO POWER TRAIN VULNER REDUCTION (FRACT)
A    DSWS.K=-.0005                                             (SS-9.1)
NOTE  DSWS-DELTA SURVIV SUBSYS W DUE TO SHIELDING (FRACT)
A    DSWR.K=-.0005                                             (SS-9.2)
NOTE  DSWR-DELTA SURVIV SUBSYS W DUE TO REDUNDANCY (FRACT)
A    DSWA.K=0                                                  (SS-9.3)
NOTE  DSWA-DELTA SURVIV SUBSYS W DUE TO ACTIVE D.S. (FRACT)
A    DSWP.K=0                                                  (SS-9.4)
NOTE  DSWP-DELTA SURVIV SUBSYS W DUE TO PASSIVE D.S. (FRACT)
A    DSWI.K=0                                                  (SS-9.5)
NOTE  DSWI-DELTA SURVIV SUBSYS W DUE TO COMP ISOLATION (FRACT)
A    DSWE.K=0                                                  (SS-9.6)
NOTE  DSWE-DELTA SURVIV SUBSYS W DUE TO COMP ELIMINATION (FRACT))
A    DSWH.K=0                                                  (SS-9.7)
NOTE  DSWH-DELTA SURVIV SUBSYS W DUE TO MATL HARDENING (FRACT))
A    DSEVR.K=DSES.K+DSER.K+DSEA.K+DSEP.K+DSEI.K+DSEE.K+DSEH.K  (SS-10)
NOTE  DSEVR-DELTA SURVIV DUE TO ENGINE VULNER REDUCTION (FRACT)
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A    DSES.K=-.0050                                               (SS-10.1)
NOTE  DSES-DELTA SURVIV SUBSYS E DUE TO SHIELDING (FRACT)
A    DSER.K=-.005                                                (SS-10.2)
NOTE  DSER-DELTA SURVIV SUBSYS E DUE TO REDUNDANCY (FRACT)
A    DSEA.K=0                                                    (SS-10.3)
NOTE  DSEA-DELTA SURVIV SUBSYS E DUE TO ACTIVE D.S. (FRACT)
A    DSEP.K=0                                                    (SS-10.4)
NOTE  DSEP-DELTA SURVIV SUBSYS E DUE TO PASSIVE D.S. (FRACT)
A    DSEI.K=0                                                    (SS-10.5)
NOTE  DSEI-DELTA SURVIV SUBSYS E DUE TO COMP ISOLATION (FRACT)
A    DSEE.K=0                                                    (SS-10.6)
NOTE  DSEE-DELTA SURVIV SUBSYS E DUE TO COMP ELIMINATION (FRACT))
A    DSEH.K=0                                                    (SS-10.7)
NOTE  DSEH-DELTA SURVIV SUBSYS E DUE TO MATL HARDENING (FRACT))
A    DSCVR.K=DSCS.K+DSCR.K+DSCA.K+DSCP.K+DSCI.K+DSCE.K+DSCH.K  (SS-11)
NOTE  DSCVR-DELTA SURVIV DUE TO FLIGHT CONTROL VULNER REDUCTION (FRACT)
A    DSCS.K=-.0005                                               (SS-11.1)
NOTE  DSCS-DELTA SURVIV SUBSYS C DUE TO SHIELDING (FRACT)
A    DSCR.K=-.0005                                               (SS-11.2)
NOTE  DSCR-DELTA SURVIV SUBSYS C DUE TO REDUNDANCY (FRACT)
A    DSCA.K=0                                                    (SS-11.3)
NOTE  DSCA-DELTA SURVIV SUBSYS C DUE TO ACTIVE D.S. (FRACT)
A    DSCP.K=0                                                    (SS-11.4)
NOTE  DSCP-DELTA SURVIV SUBSYS C DUE TO PASSIVE D.S. (FRACT)
A    DSCI.K=0                                                    (SS-11.5)
NOTE  DSCI-DELTA SURVIV SUBSYS C DUE TO COMP ISOLATION (FRACT)
A    DSCE.K=0                                                    (SS-11.6)
NOTE  DSCE-DELTA SURVIV SUBSYS C DUE TO COMP ELIMINATION (FRACT))
A    DSCH.K=0                                                    (SS-11.7)
NOTE  DSCH-DELTA SURVIV SUBSYS C DUE TO MATL HARDENING (FRACT))
A    DSDVR.K=DSDS.K+DSDRD.K+DSDA.K+DSDP.K+DSDI.K+DSDE.K+DSDH.K  (SS-12)
NOTE  DSDVR-DELTA SURVIV DUE TO FLUID POWER VULNER REDUCTION (FRACT)
A    DSDS.K=-.005                                                (SS-12.1)
NOTE  DSDS-DELTA SURVIV SUBSYS D DUE TO SHIELDING (FRACT)
A    DSDRD.K=-.009                                               (SS-12.2)
NOTE  DSDRD-DELTA SURVIV SUBSYS D DUE TO REDUNDANCY (FRACT)
A    DSDA.K=0                                                    (SS-12.3)
NOTE  DSDA-DELTA SURVIV SUBSYS D DUE TO ACTIVE D.S. (FRACT)
A    DSDP.K=0                                                    (SS-12.4)
NOTE  DSDP-DELTA SURVIV SUBSYS D DUE TO PASSIVE D.S. (FRACT)
A    DSDI.K=0                                                    (SS-12.5)
NOTE  DSDI-DELTA SURVIV SUBSYS D DUE TO COMP ISOLATION (FRACT)
A    DSDE.K=0                                                    (SS-12.6)
NOTE  DSDE-DELTA SURVIV SUBSYS D DUE TO COMP ELIMINATION (FRACT))
A    DSDH.K=0                                                    (SS-12.7)
NOTE  DSDH-DELTA SURVIV SUBSYS D DUE TO MATL HARDENING (FRACT))
A    DSIVR.K=DSIS.K+DSIR.K+DSIA.K+DSIP.K+DSII.K+DSIE.K+DSIH.K  (SS-13)
NOTE  DSIVR-DELTA SURVIV DUE TO ENVIRON CONTROL VULNER REDUCTION (FRACT)
A    DSIS.K=-.005                                               (SS-13.1)
NOTE  DSIS-DELTA SURVIV SUBSYS I DUE TO SHIELDING (FRACT)
A    DSIR.K=-.005                                               (SS-13.2)
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NOTE  DSIR-DELTA SURVIV SUBSYS I DUE TO REDUNDANCY (FRACT)
A   DSIA.K=0                                                  (SS-13.3)
NOTE  DSIA-DELTA SURVIV SUBSYS I DUE TO ACTIVE D.S. (FRACT)
A   DSIP.K=0                                                  (SS-13.4)
NOTE  DSIP-DELTA SURVIV SUBSYS I DUE TO PASSIVE D.S. (FRACT)
A   DSII.K=0                                                  (SS-13.5)
NOTE  DSII-DELTA SURVIV SUBSYS I DUE TO COMP ISOLATION (FRACT)
A   DSIE.K=0                                                  (SS-13.6)
NOTE  DSIE-DELTA SURVIV SUBSYS I DUE TO COMP ELIMINATION (FRACT))
A   DSIH.K=0                                                  (SS-13.7)
NOTE  DSIH-DELTA SURVIV SUBSYS I DUE TO MATL HARDENING (FRACT))
A   DSOVR.K=DSOS.K+DSOR.K+DSOA.K+DSOP.K+DSOI.K+DSOE.K+DSOH.K  (SS-14)
NOTE  DSOVR-DELTA SURVIV DUE TO OXYGEN VULNER REDUCTION (FRACT)
A   DSOS.K=-.0005                                             (SS-14.1)
NOTE  DSOS-DELTA SURVIV SUBSYS O DUE TO SHIELDING (FRACT)
A   DSOR.K=-.0005                                             (SS-14.2)
NOTE  DSOR-DELTA SURVIV SUBSYS O DUE TO REDUNDANCY (FRACT)
A   DSOA.K=0                                                  (SS-14.3)
NOTE  DSOA-DELTA SURVIV SUBSYS O DUE TO ACTIVE D.S. (FRACT)
A   DSOP.K=0                                                  (SS-14.4)
NOTE  DSOP-DELTA SURVIV SUBSYS O DUE TO PASSIVE D.S. (FRACT)
A   DSOI.K=0                                                  (SS-14.5)
NOTE  DSOI-DELTA SURVIV SUBSYS O DUE TO COMP ISOLATION (FRACT)
A   DSOE.K=0                                                  (SS-14.6)
NOTE  DSOE-DELTA SURVIV SUBSYS O DUE TO COMP ELIMINATION (FRACT))
A   DSOH.K=0                                                  (SS-14.7)
NOTE  DSOH-DELTA SURVIV SUBSYS O DUE TO MATL HARDENING (FRACT))
A   DSRVR.K=DSRS.K+DSRR.K+DSRA.K+DSRP.K+DSRI.K+DSRE.K+DSRH.K  (SS-15)
NOTE  DSRVR-DELTA SURVIV DUE TO ARMAMENT VULNER REDUCTION (FRACT)
A   DSRS.K=-.0005                                             (SS-15.1)
NOTE  DSRS-DELTA SURVIV SUBSYS R DUE TO SHIELDING (FRACT)
A   DSRR.K=-.0005                                             (SS-15.2)
NOTE  DSRR-DELTA SURVIV SUBSYS R DUE TO REDUNDANCY (FRACT)
A   DSRA.K=0                                                  (SS-15.3)
NOTE  DSRA-DELTA SURVIV SUBSYS R DUE TO ACTIVE D.S. (FRACT)
A   DSRP.K=0                                                  (SS-15.4)
NOTE  DSRP-DELTA SURVIV SUBSYS R DUE TO PASSIVE D.S. (FRACT)
A   DSRI.K=0                                                  (SS-15.5)
NOTE  DSRI-DELTA SURVIV SUBSYS R DUE TO COMP ISOLATION (FRACT)
A   DSRE.K=0                                                  (SS-15.6)
NOTE  DSRE-DELTA SURVIV SUBSYS R DUE TO COMP ELIMINATION (FRACT))
A   DSRH.K=0                                                  (SS-15.7)
NOTE  DSRH-DELTA SURVIV SUBSYS R DUE TO MATL HARDENING (FRACT))
A   DSLVR.K=DSLS.K+DSLR.K+DSLA.K+DSLP.K+DSLI.K+DSLE.K+DSLH.K  (SS-16)
NOTE  DSLVR-DELTA SURVIV DUE TO ELECTRICAL POWER VULNER REDUCTION (FRACT)
A   DSLS.K=-.0005                                             (SS-16.1)
NOTE  DSLS-DELTA SURVIV SUBSYS L DUE TO SHIELDING (FRACT)
A   DSLR.K=-.0005                                             (SS-16.2)
NOTE  DSLR-DELTA SURVIV SUBSYS L DUE TO REDUNDANCY (FRACT)
A   DSLA.K=0                                                  (SS-16.3)
NOTE  DSLA-DELTA SURVIV SUBSYS L DUE TO ACTIVE D.S. (FRACT)
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A   DSLP.K=0                                                    (SS-16.4)
NOTE  DSLP-DELTA SURVIV SUBSYS L DUE TO PASSIVE D.S. (FRACT)
A   DSLI.K=0                                                    (SS-16.5)
NOTE  DSLI-DELTA SURVIV SUBSYS L DUE TO COMP ISOLATION (FRACT)
A   DSLE.K=0                                                    (SS-16.6)
NOTE  DSLE-DELTA SURVIV SUBSYS L DUE TO COMP ELIMINATION (FRACT))
A   DSLH.K=0                                                    (SS-16.7)
NOTE  DSLH-DELTA SURVIV SUBSYS L DUE TO MATL HARDENING (FRACT))
A   DSVVR.K=DSVS.K+DSVRD.K+DSVA.K+DSVP.K+DSVI.K+DSVE.K+DSVH.K (SS-17)
NOTE  DSVVR-DELTA SURVIV DUE TO AVIONIC VULNER REDUCTION (FRACT)
A   DSVS.K=-.0005                                               (SS-17.1)
NOTE  DSVS-DELTA SURVIV SUBSYS V DUE TO SHIELDING (FRACT)
A   DSVRD.K=-.0005                                              (SS-17.2)
NOTE  DSVRD-DELTA SURVIV SUBSYS V DUE TO REDUNDANCY (FRACT)
A   DSVA.K=0                                                    (SS-17.3)
NOTE  DSVA-DELTA SURVIV SUBSYS V DUE TO ACTIVE D.S. (FRACT)
A   DSVP.K=0                                                    (SS-17.4)
NOTE  DSVP-DELTA SURVIV SUBSYS V DUE TO PASSIVE D.S. (FRACT)
A   DSVI.K=0                                                    (SS-17.5)
NOTE  DSVI-DELTA SURVIV SUBSYS V DUE TO COMP ISOLATION (FRACT)
A   DSVE.K=0                                                    (SS-17.6)
NOTE  DSVE-DELTA SURVIV SUBSYS V DUE TO COMP ELIMINATION (FRACT))
A   DSVH.K=0                                                    (SS-17.7)
NOTE  DSVH-DELTA SURVIV SUBSYS V DUE TO MATL HARDENING (FRACT))
A   DSHVR.K=DSHS.K+DSHRD.K+DSHA.K+DSHP.K+DSHI.K+DSHE.K+DSHH.K  (SS-18)
NOTE  DSHVR-DELTA SURVIV DUE TO LAUNCH & RECOVERY VULNER REDUCTION (FRACT
A   DSHS.K=-.0005                                               (SS-18.1)
NOTE  DSHS-DELTA SURVIV SUBSYS H DUE TO SHIELDING (FRACT)
A   DSHRD.K=-.0005                                              (SS-18.2)
NOTE  DSHRD-DELTA SURVIV SUBSYS H DUE TO REDUNDANCY (FRACT)
A   DSHA.K=0                                                    (SS-18.3)
NOTE  DSHA-DELTA SURVIV SUBSYS H DUE TO ACTIVE D.S. (FRACT)
A   DSHP.K=0                                                    (SS-18.4)
NOTE  DSHP-DELTA SURVIV SUBSYS H DUE TO PASSIVE D.S. (FRACT)
A   DSHI.K=0                                                    (SS-18.5)
NOTE  DSHI-DELTA SURVIV SUBSYS H DUE TO COMP ISOLATION (FRACT)
A   DSHE.K=0                                                    (SS-18.6)
NOTE  DSHE-DELTA SURVIV SUBSYS H DUE TO COMP ELIMINATION (FRACT))
A   DSHH.K=0                                                    (SS-18.7)
NOTE  DSHH-DELTA SURVIV SUBSYS H DUE TO MATL HARDENING (FRACT))
A   DSAVR.K=DSAS.K+DSAR.K+DSAA.K+DSAP.K+DSAI.K+DSAE.K+DSAH.K  (SS-19)
NOTE  DSAVR-DELTA SURVIV DUE TO ARMOR VULNER REDUCTION (FRACT)
A   DSAS.K=-.0005                                               (SS-19.1)
NOTE  DSAS-DELTA SURVIV SUBSYS A DUE TO SHIELDING (FRACT)
A   DSAR.K=-.0005                                               (SS-19.2)
NOTE  DSAR-DELTA SURVIV SUBSYS A DUE TO REDUNDANCY (FRACT)
A   DSAA.K=0                                                    (SS-19.3)
NOTE  DSAA-DELTA SURVIV SUBSYS A DUE TO ACTIVE D.S. (FRACT)
A   DSAP.K=0                                                    (SS-19.4)
NOTE  DSAP-DELTA SURVIV SUBSYS A DUE TO PASSIVE D.S. (FRACT)
A   DSAI.K=0                                                    (SS-19.5)
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NOTE  DSAI-DELTA SURVIV SUBSYS A DUE TO COMP ISOLATION (FRACT)
A   DSAE.K=0                                                  (SS-19.6)
NOTE  DSAE-DELTA SURVIV SUBSYS A DUE TO COMP ELIMINATION (FRACT))
A   DSAH.K=0                                                  (SS-19.7)
NOTE  DSAH-DELTA SURVIV SUBSYS A DUE TO MATL HARDENING (FRACT))
A   DSTVR.K=DSTS.K+DSTR.K+DSTAD.K+DSTP.K+DSTI.K+DSTE.K+DSTH.K  (SS-20)
NOTE  DSTVR-DELTA SURVIV DUE TO A/C STRUCTURE VULNER REDUCTION (FRACT)
A   DSTS.K=-.0005                                             (SS-20.1)
NOTE  DSTS-DELTA SURVIV SUBSYS T DUE TO SHIELDING (FRACT)
A   DSTR.K=-.0005                                             (SS-20.2)
NOTE  DSTR-DELTA SURVIV SUBSYS T DUE TO REDUNDANCY (FRACT)
A   DSTAD.K=0                                                 (SS-20.3)
NOTE  DSTAD-DELTA SURVIV SUBSYS T DUE TO ACTIVE D.S. (FRACT)
A   DSTP.K=0                                                  (SS-20.4)
NOTE  DSTP-DELTA SURVIV SUBSYS T DUE TO PASSIVE D.S. (FRACT)
A   DSTI.K=0                                                  (SS-20.5)
NOTE  DSTI-DELTA SURVIV SUBSYS T DUE TO COMP ISOLATION (FRACT)
A   DSTE.K=0                                                  (SS-20.6)
NOTE  DSTE-DELTA SURVIV SUBSYS T DUE TO COMP ELIMINATION (FRACT))
A   DSTH.K=0                                                  (SS-20.7)
NOTE  DSTH-DELTA SURVIV SUBSYS T DUE TO MATL HARDENING (FRACT))
A   DSSVR.K=DSSS.K+DSSRD.K+DSSA.K+DSSP.K+DSSI.K+DSSE.K+DSSH.K  (SS-21)
NOTE  DSSVR-DELTA SURVIV DUE TO PERSONNEL STATION VULNER REDUCT (FRACT)
A   DSSS.K=-.0005                                             (SS-21.1)
NOTE  DSSS-DELTA SURVIV SUBSYS S DUE TO SHIELDING (FRACT)
A   DSSRD.K=-.0005                                            (SS-21.2)
NOTE  DSSRD-DELTA SURVIV SUBSYS S DUE TO REDUNDANCY (FRACT)
A   DSSA.K=0                                                  (SS-21.3)
NOTE  DSSA-DELTA SURVIV SUBSYS S DUE TO ACTIVE D.S. (FRACT)
A   DSSP.K=0                                                  (SS-21.4)
NOTE  DSSP-DELTA SURVIV SUBSYS S DUE TO PASSIVE D.S. (FRACT)
A   DSSI.K=0                                                  (SS-21.5)
NOTE  DSSI-DELTA SURVIV SUBSYS S DUE TO COMP ISOLATION (FRACT)
A   DSSE.K=0                                                  (SS-21.6)
NOTE  DSSE-DELTA SURVIV SUBSYS S DUE TO COMP ELIMINATION (FRACT))
A   DSSH.K=0                                                  (SS-21.7)
NOTE  DSSH-DELTA SURVIV SUBSYS S DUE TO MATL HARDENING (FRACT))
A   DSPVR.K=DSPS.K+DSPR.K+DSPA.K+DSPP.K+DSPI.K+DSPE.K+DSPH.K  (SS-22)
NOTE  DSPVR-DELTA SURVIV DUE TO PROPULSION VULNER REDUCTION (FRACT)
A   DSPS.K=-.0005                                             (SS-22.1)
NOTE  DSPS-DELTA SURVIV SUBSYS P DUE TO SHIELDING (FRACT)
A   DSPR.K=-.0005                                             (SS-22.2)
NOTE  DSPR-DELTA SURVIV SUBSYS P DUE TO REDUNDANCY (FRACT)
A   DSPA.K=0                                                  (SS-22.3)
NOTE  DSPA-DELTA SURVIV SUBSYS P DUE TO ACTIVE D.S. (FRACT)
A   DSPP.K=0                                                  (SS-22.4)
NOTE  DSPP-DELTA SURVIV SUBSYS P DUE TO PASSIVE D.S. (FRACT)
A   DSPI.K=0                                                  (SS-22.5)
NOTE  DSPI-DELTA SURVIV SUBSYS P DUE TO COMP ISOLATION (FRACT)
A   DSPE.K=0                                                  (SS-22.6)
NOTE  DSPE-DELTA SURVIV SUBSYS P DUE TO COMP ELIMINATION (FRACT))
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A    DSPH.K=0                                                      (SS-22.7)
NOTE  DSPH-DELTA SURVIV SUBSYS P DUE TO MATL HARDENING (FRACT))
A    DSFVR.K=DSFS.K+DSFR.K+DSFA.K+DSFP.K+DSFI.K+DSFE.K+DSFH.K  (SS-23)
NOTE  DSFVR-DELTA SURVIV DUE TO FUEL VULNER REDUCTION (FRACT)
A    DSFS.K=-.0005                                                 (SS-23.1)
NOTE  DSFS-DELTA SURVIV SUBSYS F DUE TO SHIELDING (FRACT)
A    DSFR.K=-.0005                                                 (SS-23.2)
NOTE  DSFR-DELTA SURVIV SUBSYS F DUE TO REDUNDANCY (FRACT)
A    DSFA.K=0                                                      (SS-23.3)
NOTE  DSFA-DELTA SURVIV SUBSYS F DUE TO ACTIVE D.S. (FRACT)
A    DSFP.K=0                                                      (SS-23.4)
NOTE  DSFP-DELTA SURVIV SUBSYS F DUE TO PASSIVE D.S. (FRACT)
A    DSFI.K=0                                                      (SS-23.5)
NOTE  DSFI-DELTA SURVIV SUBSYS F DUE TO COMP ISOLATION (FRACT)
A    DSFE.K=0                                                      (SS-23.6)
NOTE  DSFE-DELTA SURVIV SUBSYS F DUE TO COMP ELIMINATION (FRACT))
A    DSFH.K=0                                                      (SS-23.7)
NOTE  DSFH-DELTA SURVIV SUBSYS F DUE TO MATL HARDENING (FRACT))
NOTE  *************************************************************
NOTE  **   DELTA SUSCEPTIBILITY COMPONENT OF SURVIVABILITY SUBMODEL   **
NOTE  *************************************************************
A    DSSR.K=DSDR.K+DSHR.K                                          (SS-24)
NOTE  DSSR-DELTA SURVIV A/C DUE TO SUSCEP. REDUCTION (DIM)
A    DSDR.K=DSGR.K+DSTA.K                                          (SS-25)
NOTE  DSDR-DELTA SURVIV A/C DUE TO DETECTION REDUCTION (DIM)
A    DSGR.K=DSVSR.K+DSASR.K+DSRSR.K+DSISR.K                        (SS-26)
NOTE  DSGR-DELTA SURVIV A/C DUE TO SIGNATURE REDUCTION (DIM)
A    DSVSR.K=DSEVS.K+DSAVS.K                                       (SS-27)
NOTE  DSVSR-DELTA SURVIV A/C VISUAL SIGNATURE REDUCTION (DIM)
A    DSASR.K=DSEAS.K+DSAAS.K                                       (SS-28)
NOTE  DSASR-DELTA SURVIV A/C AURAL SIGNATURE REDUCTION (DIM)
A    DSRSR.K=DSERS.K+DSARS.K                                       (SS-29)
NOTE  DSRSR-DELTA SURVIV A/C RADAR SIGNATURE REDUCTION (DIM)
A    DSISR.K=DSEIS.K+DSAIS.K                                       (SS-30)
NOTE  DSISR-DELTA SURVIV A/C INFRARED SIGNATURE REDUCT (DIM)
A    DSEVS.K=-.0005                                                (SS-31)
NOTE  DSEVS-DELTA SURVIV A/C ENGINE VISUAL SIGNATURE (DIM)
A    DSAVS.K=+.0005                                                (SS-32)
NOTE  DSAVS-DELTA SURVIV A/C AIRFRAME VISUAL SIGNATURE (DIM)
A    DSEAS.K=+.0055                                                (SS-33)
NOTE  DSEAS-DELTA SURVIV A/C ENGINE AURAL SIGNATURE (DIM)
A    DSAAS.K=+.0055                                                (SS-34)
NOTE  DSAAS-DELTA SURVIV A/C AIRFRAME AURAL SIGNATURE (DIM)
A    DSERS.K=0                                                     (SS-35)
NOTE  DSERS-DELTA SURVIV A/C ENGINE RADAR SIGNATURE (DIM)
A    DSARS.K=0                                                     (SS-36)
NOTE  DSARS-DELTA SURVIV A/C AIRFRAME RADAR SIGNATURE (DIM)
A    DSEIS.K=0                                                     (SS-37)
NOTE  DSEIS-DELTA SURVIV A/C ENGINE INFRARED SIGNATURE (DIM)
A    DSAIS.K=0                                                     (SS-38)
NOTE  DSAIS-DELTA SURVIV A/C AIRFRAME INFRARED SIGN (DIM)
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A   DSTA.K=0                                                  (SS-39)
NOTE  DSTA-DELTA SURVIV A/C DUE TO THREAT AVOIDANCE (DIM)
A   DSHR.K=DSEW.K+DSTEC.K+DSTDC.K                             (SS-40)
NOTE  DSHR-DELTA SURVIV A/C DUE TO HIT REDUCTION (DIM)
A   DSEW.K=DSRW.K+DSJ.K+DSD.K                                 (SS-41)
NOTE  DSEW-DELTA SURVIV A/C DUE TO ELECTRONIC WARFARE (DIM)
A   DSRW.K=-.0005                                             (SS-42)
NOTE  DSRW-DELTA SURVIVABILITY A/C DUE TO RADAR WARNING (DIM)
A   DSJ.K=-.0005                                              (SS-43)
NOTE  DSJ-DELTA SURVIVABILITY A/C DUE TO JAMMERS (DIM)
A   DSD.K=-.0005                                              (SS-44)
NOTE  DSD-DELTA SURVIVABILITY A/C DUE TO DECEPTORS (DIM)
A   DSTEC.K=-.0005                                            (SS-45)
NOTE  DSTEC-DELTA SURVIV A/C DUE TO THREAT EVASION CAPABILITY (DIM)
A   DSTDC.K=-.0005                                            (SS-46)
NOTE  DSTDC-DELTA SURVIV A/C DUE TO THREAT DESTRUCTION CAPAB (DIM)
NOTE  ******************************************************************
NOTE  ****    DELTA WEIGHT COMPONENT OF SURVIABILITY SUBMODEL       ****
NOTE  ******************************************************************
A   DW.K=DWSR.K+DWVR.K                                        (SS-47)
NOTE  DW-DELTA WEIGHT AIRCRAFT (FRACT)
A   DWSR.K=DWDR.K+DWHR.K                                      (SS-48)
NOTE  DWSR-DELTA WEIGHT A/C DUE TO SUSCEP. REDUCTION (DIM)
A   DWDR.K=DWGR.K+DWTA.K                                      (SS-49)
NOTE  DWDR-DELTA WEIGHT A/C DUE TO DETECTION REDUCTION (DIM)
A   DWGR.K=DWVSR.K+DWASR.K+DWRSR.K+DWISR.K                    (SS-50)
NOTE  DWGR-DELTA WEIGHT A/C DUE TO SIGNATURE REDUCTION (DIM)
A   DWVSR.K=DWEVS.K+DWAVS.K                                   (SS-51)
NOTE  DWVSR-DELTA WEIGHT A/C VISUAL SIGNATURE REDUCTION (DIM)
A   DWASR.K=DWEAS.K+DWAAS.K                                   (SS-52)
NOTE  DWASR-DELTA WEIGHT A/C AURAL SIGNATURE REDUCTION (DIM)
A   DWRSR.K=DWERS.K+DWARS.K                                   (SS-53)
NOTE  DWRSR-DELTA WEIGHT A/C RADAR SIGNATURE REDUCTION (DIM)
A   DWISR.K=DWEIS.K+DWAIS.K                                   (SS-54)
NOTE  DWISR-DELTA WEIGHT A/C INFRARED SIGNATURE REDUCT (DIM)
A   DWEVS.K=-.0005                                            (SS-55)
NOTE  DWEVS-DELTA WEIGHT A/C ENGINE VISUAL SIGNATURE (DIM)
A   DWAVS.K=-.0025                                            (SS-56)
NOTE  DWAVS-DELTA WEIGHT A/C AIRFRAME VISUAL SIGNATURE (DIM)
A   DWEAS.K=-.0025                                            (SS-57)
NOTE  DWEAS-DELTA WEIGHT A/C ENGINE AURAL SIGNATURE (DIM)
A   DWAAS.K=-.0005                                            (SS-58)
NOTE  DWAAS-DELTA WEIGHT A/C AIRFRAME AURAL SIGNATURE (DIM)
A   DWERS.K=-.0005                                            (SS-59)
NOTE  DWERS-DELTA WEIGHT A/C ENGINE RADAR SIGNATURE (DIM)
A   DWARS.K=0                                                 (SS-60)
NOTE  DWARS-DELTA WEIGHT A/C AIRFRAME RADAR SIGNATURE (DIM)
A   DWEIS.K=0                                                 (SS-61)
NOTE  DWEIS-DELTA WEIGHT A/C ENGINE INFRARED SIGNATURE (DIM)
A   DWAIS.K=0                                                 (SS-62)
NOTE  DWAIS-DELTA WEIGHT A/C AIRFRAME INFRARED SIGN (DIM)
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A   DWTA.K=0                                                     (SS-63)
NOTE  DWTA-DELTA WEIGHT A/C DUE TO THREAT AVOIDANCE (DIM)
A   DWHR.K=DWEW.K+DWTEC.K+DWTDC.K                                (SS-64)
NOTE  DWHR-DELTA WEIGHT A/C DUE TO HIT REDUCTION (DIM)
A   DWEW.K=DWW.K+DWJ.K+DWD.K                                     (SS-65)
NOTE  DWEW-DELTA WEIGHT A/C DUE TO ELECTRONIC WARFARE (DIM)
A   DWW.K=-.0005                                                 (SS-66)
NOTE  DWW-DELTA WEIGHT A/C DUE TO RADAR WARNING (DIM)
A   DWJ.K=-.0005                                                 (SS-67)
NOTE  DWJ-DELTA WEIGHT A/C DUE TO JAMMERS (DIM)
A   DWD.K=-.0005                                                 (SS-68)
NOTE  DWD-DELTA WEIGHT A/C DUE TO DECEPTORS (DIM)
A   DWTEC.K=0                                                    (SS-69)
NOTE  DWTEC-DELTA WEIGHT A/C DUE TO THREAT EVASION CAPABILITY (DIM)
A   DWTDC.K=0                                                    (SS-70)
NOTE  DWTDC-DELTA WEIGHT A/C DUE TO THREAT DESTRUCTION CAPAB (DIM)
NOTE  *************************************************************
A   DWVR.K=DWBVR.K*ROTOR+DWWVR.K*ROTOR+DWEVR.K*FIXED+DWCVR.K*FIXED
X      +DWDVR.K*FIXED+DWIVR.K*FIXED+DWOVR.K*FIXED+DWRVR.K*FIXED
X      +DWLVR.K*FIXED+DWVVR.K*FIXED+DWHVR.K*FIXED+DWAVR.K*FIXED
X      +DWTVR.K*FIXED+DWSVR.K*FIXED+DWPVR.K*FIXED+DWFVR.K*FIXED  (SS-71)
NOTE  DWVR-DELTA WEIGHT DUE TO VULNERABILITY REDUCTION (FRACT)
A   DWBVR.K=DWBS.K+DWBR.K+DWBA.K+DWBP.K+DWBI.K+DWBE.K+DWBH.K  (SS-72)
NOTE  DWBVR-DELTA WEIGHT DUE TO ROTOR BLADES VULNER REDUCTION (FRACT)
A   DWBS.K=-.0005                                                (SS-72.1)
NOTE  DWBS-DELTA WEIGHT SUBSYS B DUE TO SHIELDING (FRACT)
A   DWBR.K=-.0005                                                (SS-72.2)
NOTE  DWBR-DELTA WEIGHT SUBSYS B DUE TO REDUNDANCY (FRACT)
A   DWBA.K=0                                                     (SS-72.3)
NOTE  DWBA-DELTA WEIGHT SUBSYS B DUE TO ACTIVE D.S. (FRACT)
A   DWBP.K=0                                                     (SS-72.4)
NOTE  DWBP-DELTA WEIGHT SUBSYS B DUE TO PASSIVE D.S. (FRACT)
A   DWBI.K=0                                                     (SS-72.5)
NOTE  DWBI-DELTA WEIGHT SUBSYS B DUE TO COMP ISOLATION (FRACT)
A   DWBE.K=0                                                     (SS-72.6)
NOTE  DWBE-DELTA WEIGHT SUBSYS B DUE TO COMP ELIMINATION (FRACT))
A   DWBH.K=0                                                     (SS-72.7)
NOTE  DWBH-DELTA WEIGHT SUBSYS B DUE TO MATL HARDENING (FRACT))
A   DWWVR.K=DWWS.K+DWWR.K+DWWA.K+DWWP.K+DWWI.K+DWWE.K+DWWH.K  (SS-73)
NOTE  DWWVR-DELTA WEIGHT DUE TO POWER TRAIN VULNER REDUCTION (FRACT)
A   DWWS.K=-.0005                                                (SS-73.1)
NOTE  DWWS-DELTA WEIGHT SUBSYS W DUE TO SHIELDING (FRACT)
A   DWWR.K=-.0005                                                (SS-73.2)
NOTE  DWWR-DELTA WEIGHT SUBSYS W DUE TO REDUNDANCY (FRACT)
A   DWWA.K=0                                                     (SS-73.3)
NOTE  DWWA-DELTA WEIGHT SUBSYS W DUE TO ACTIVE D.S. (FRACT)
A   DWWP.K=0                                                     (SS-73.4)
NOTE  DWWP-DELTA WEIGHT SUBSYS W DUE TO PASSIVE D.S. (FRACT)
A   DWWI.K=0                                                     (SS-73.5)
NOTE  DWWI-DELTA WEIGHT SUBSYS W DUE TO COMP ISOLATION (FRACT)
A   DWWE.K=0                                                     (SS-73.6)
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NOTE  DWWE-DELTA WEIGHT SUBSYS W DUE TO COMP ELIMINATION (FRACT))
A    DWWH.K=0                                                 (SS-73.7)
NOTE  DWWH-DELTA WEIGHT SUBSYS W DUE TO MATL HARDENING (FRACT))
A    DWEVR.K=DWES.K+DWER.K+DWEA.K+DWEP.K+DWEI.K+DWEE.K+DWEH.K  (SS-74)
NOTE  DWEVR-DELTA WEIGHT DUE TO ENGINE VULNER REDUCTION (FRACT)
A    DWES.K=-.0005                                            (SS-74.1)
NOTE  DWES-DELTA WEIGHT SUBSYS E DUE TO SHIELDING (FRACT)
A    DWER.K=-.0005                                            (SS-74.2)
NOTE  DWER-DELTA WEIGHT SUBSYS E DUE TO REDUNDANCY (FRACT)
A    DWEA.K=0                                                 (SS-74.3)
NOTE  DWEA-DELTA WEIGHT SUBSYS E DUE TO ACTIVE D.S. (FRACT)
A    DWEP.K=0                                                 (SS-74.4)
NOTE  DWEP-DELTA WEIGHT SUBSYS E DUE TO PASSIVE D.S. (FRACT)
A    DWEI.K=0                                                 (SS-74.5)
NOTE  DWEI-DELTA WEIGHT SUBSYS E DUE TO COMP ISOLATION (FRACT)
A    DWEE.K=0                                                 (SS-74.6)
NOTE  DWEE-DELTA WEIGHT SUBSYS E DUE TO COMP ELIMINATION (FRACT))
A    DWEH.K=0                                                 (SS-74.7)
NOTE  DWEH-DELTA WEIGHT SUBSYS E DUE TO MATL HARDENING (FRACT))
A    DWCVR.K=DWCS.K+DWCR.K+DWCA.K+DWCP.K+DWCI.K+DWCE.K+DWCH.K  (SS-75)
NOTE  DWCVR-DELTA WEIGHT DUE TO FLIGHT CONTROL VULNER REDUCTION (FRACT)
A    DWCS.K=-.0005                                            (SS-75.1)
NOTE  DWCS-DELTA WEIGHT SUBSYS C DUE TO SHIELDING (FRACT)
A    DWCR.K=-.0005                                            (SS-75.2)
NOTE  DWCR-DELTA WEIGHT SUBSYS C DUE TO REDUNDANCY (FRACT)
A    DWCA.K=0                                                 (SS-75.3)
NOTE  DWCA-DELTA WEIGHT SUBSYS C DUE TO ACTIVE D.S. (FRACT)
A    DWCP.K=0                                                 (SS-75.4)
NOTE  DWCP-DELTA WEIGHT SUBSYS C DUE TO PASSIVE D.S. (FRACT)
A    DWCI.K=0                                                 (SS-75.5)
NOTE  DWCI-DELTA WEIGHT SUBSYS C DUE TO COMP ISOLATION (FRACT)
A    DWCE.K=0                                                 (SS-75.6)
NOTE  DWCE-DELTA WEIGHT SUBSYS C DUE TO COMP ELIMINATION (FRACT))
A    DWCH.K=0                                                 (SS-75.7)
NOTE  DWCH-DELTA WEIGHT SUBSYS C DUE TO MATL HARDENING (FRACT))
A    DWDVR.K=DWDW.K+DWDRD.K+DWDA.K+DWDP.K+DWDI.K+DWDE.K+DWDH.K  (SS-76)
NOTE  DWDVR-DELTA WEIGHT DUE TO FLUID POWER VULNER REDUCTION (FRACT)
A    DWDW.K=-.0005                                            (SS-76.1)
NOTE  DWDW-DELTA WEIGHT SUBSYS D DUE TO SHIELDING (FRACT)
A    DWDRD.K=-.0005                                           (SS-76.2)
NOTE  DWDRD-DELTA WEIGHT SUBSYS D DUE TO REDUNDANCY (FRACT)
A    DWDA.K=0                                                 (SS-76.3)
NOTE  DWDA-DELTA WEIGHT SUBSYS D DUE TO ACTIVE D.S. (FRACT)
A    DWDP.K=0                                                 (SS-76.4)
NOTE  DWDP-DELTA WEIGHT SUBSYS D DUE TO PASSIVE D.S. (FRACT)
A    DWDI.K=0                                                 (SS-76.5)
NOTE  DWDI-DELTA WEIGHT SUBSYS D DUE TO COMP ISOLATION (FRACT)
A    DWDE.K=0                                                 (SS-76.6)
NOTE  DWDE-DELTA WEIGHT SUBSYS D DUE TO COMP ELIMINATION (FRACT))
A    DWDH.K=0                                                 (SS-76.7)
NOTE  DWDH-DELTA WEIGHT SUBSYS D DUE TO MATL HARDENING (FRACT))
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A    DWIVR.K=DWIS.K+DWIR.K+DWIA.K+DWIP.K+DWII.K+DWIE.K+DWIH.K  (SS-77)
NOTE  DWIVR-DELTA WEIGHT DUE TO ENVIRON CONTROL VULNER REDUCTION (FRACT)
A    DWIS.K=-.0005                                              (SS-77.1)
NOTE  DWIS-DELTA WEIGHT SUBSYS I DUE TO SHIELDING (FRACT)
A    DWIR.K=-.0005                                              (SS-77.2)
NOTE  DWIR-DELTA WEIGHT SUBSYS I DUE TO REDUNDANCY (FRACT)
A    DWIA.K=0                                                   (SS-77.3)
NOTE  DWIA-DELTA WEIGHT SUBSYS I DUE TO ACTIVE D.S. (FRACT)
A    DWIP.K=0                                                   (SS-77.4)
NOTE  DWIP-DELTA WEIGHT SUBSYS I DUE TO PASSIVE D.S. (FRACT)
A    DWII.K=0                                                   (SS-77.5)
NOTE  DWII-DELTA WEIGHT SUBSYS I DUE TO COMP ISOLATION (FRACT)
A    DWIE.K=0                                                   (SS-77.6)
NOTE  DWIE-DELTA WEIGHT SUBSYS I DUE TO COMP ELIMINATION (FRACT))
A    DWIH.K=0                                                   (SS-77.7)
NOTE  DWIH-DELTA WEIGHT SUBSYS I DUE TO MATL HARDENING (FRACT))
A    DWOVR.K=DWOS.K+DWOR.K+DWOA.K+DWOP.K+DWOI.K+DWOE.K+DWOH.K   (SS-78)
NOTE  DWOVR-DELTA WEIGHT DUE TO OXYGEN VULNER REDUCTION (FRACT)
A    DWOS.K=-.0005                                              (SS-78.1)
NOTE  DWOS-DELTA WEIGHT SUBSYS O DUE TO SHIELDING (FRACT)
A    DWOR.K=-.0005                                              (SS-78.2)
NOTE  DWOR-DELTA WEIGHT SUBSYS O DUE TO REDUNDANCY (FRACT)
A    DWOA.K=0                                                   (SS-78.3)
NOTE  DWOA-DELTA WEIGHT SUBSYS O DUE TO ACTIVE D.S. (FRACT)
A    DWOP.K=0                                                   (SS-78.4)
NOTE  DWOP-DELTA WEIGHT SUBSYS O DUE TO PASSIVE D.S. (FRACT)
A    DWOI.K=0                                                   (SS-78.5)
NOTE  DWOI-DELTA WEIGHT SUBSYS O DUE TO COMP ISOLATION (FRACT)
A    DWOE.K=0                                                   (SS-78.6)
NOTE  DWOE-DELTA WEIGHT SUBSYS O DUE TO COMP ELIMINATION (FRACT))
A    DWOH.K=0                                                   (SS-78.7)
NOTE  DWOH-DELTA WEIGHT SUBSYS O DUE TO MATL HARDENING (FRACT))
A    DWRVR.K=DWRS.K+DWRR.K+DWRA.K+DWRP.K+DWRI.K+DWRE.K+DWRH.K  (SS-79)
NOTE  DWRVR-DELTA WEIGHT DUE TO ARMAMENT VULNER REDUCTION (FRACT)
A    DWRS.K=-.0005                                              (SS-79.1)
NOTE  DWRS-DELTA WEIGHT SUBSYS R DUE TO SHIELDING (FRACT)
A    DWRR.K=-.0005                                              (SS-79.2)
NOTE  DWRR-DELTA WEIGHT SUBSYS R DUE TO REDUNDANCY (FRACT)
A    DWRA.K=0                                                   (SS-79.3)
NOTE  DWRA-DELTA WEIGHT SUBSYS R DUE TO ACTIVE D.S. (FRACT)
A    DWRP.K=0                                                   (SS-79.4)
NOTE  DWRP-DELTA WEIGHT SUBSYS R DUE TO PASSIVE D.S. (FRACT)
A    DWRI.K=0                                                   (SS-79.5)
NOTE  DWRI-DELTA WEIGHT SUBSYS R DUE TO COMP ISOLATION (FRACT)
A    DWRE.K=0                                                   (SS-79.6)
NOTE  DWRE-DELTA WEIGHT SUBSYS R DUE TO COMP ELIMINATION (FRACT))
A    DWRH.K=0                                                   (SS-79.7)
NOTE  DWRH-DELTA WEIGHT SUBSYS R DUE TO MATL HARDENING (FRACT))
A    DWLVR.K=DWLS.K+DWLR.K+DWLA.K+DWLP.K+DWLI.K+DWLE.K+DWLH.K  (SS-80)
NOTE  DWLVR-DELTA WEIGHT DUE TO ELECTRICAL POWER VULNER REDUCTION (FRACT)
A    DWLS.K=-.0005                                              (SS-80.1)
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NOTE  DWLS-DELTA WEIGHT SUBSYS L DUE TO SHIELDING (FRACT)
A   DWLR.K=-.0005                                         (SS-80.2)
NOTE  DWLR-DELTA WEIGHT SUBSYS L DUE TO REDUNDANCY (FRACT)
A   DWLA.K=0                                              (SS-80.3)
NOTE  DWLA-DELTA WEIGHT SUBSYS L DUE TO ACTIVE D.S. (FRACT)
A   DWLP.K=0                                              (SS-80.4)
NOTE  DWLP-DELTA WEIGHT SUBSYS L DUE TO PASSIVE D.S. (FRACT)
A   DWLI.K=0                                              (SS-80.5)
NOTE  DWLI-DELTA WEIGHT SUBSYS L DUE TO COMP ISOLATION (FRACT)
A   DWLE.K=0                                              (SS-80.6)
NOTE  DWLE-DELTA WEIGHT SUBSYS L DUE TO COMP ELIMINATION (FRACT))
A   DWLH.K=0                                              (SS-80.7)
NOTE  DWLH-DELTA WEIGHT SUBSYS L DUE TO MATL HARDENING (FRACT))
A   DWVVR.K=DWVS.K+DWVRD.K+DWVA.K+DWVP.K+DWVI.K+DWVE.K+DWVH.K  (SS-81)
NOTE  DWVVR-DELTA WEIGHT DUE TO AVIONIC VULNER REDUCTION (FRACT)
A   DWVS.K=-.0005                                         (SS-81.1)
NOTE  DWVS-DELTA WEIGHT SUBSYS V DUE TO SHIELDING (FRACT)
A   DWVRD.K=-.0005                                        (SS-81.2)
NOTE  DWVRD-DELTA WEIGHT SUBSYS V DUE TO REDUNDANCY (FRACT)
A   DWVA.K=0                                              (SS-81.3)
NOTE  DWVA-DELTA WEIGHT SUBSYS V DUE TO ACTIVE D.S. (FRACT)
A   DWVP.K=0                                              (SS-81.4)
NOTE  DWVP-DELTA WEIGHT SUBSYS V DUE TO PASSIVE D.S. (FRACT)
A   DWVI.K=0                                              (SS-81.5)
NOTE  DWVI-DELTA WEIGHT SUBSYS V DUE TO COMP ISOLATION (FRACT)
A   DWVE.K=0                                              (SS-81.6)
NOTE  DWVE-DELTA WEIGHT SUBSYS V DUE TO COMP ELIMINATION (FRACT))
A   DWVH.K=0                                              (SS-81.7)
NOTE  DWVH-DELTA WEIGHT SUBSYS V DUE TO MATL HARDENING (FRACT))
A   DWHVR.K=DWHS.K+DWHRD.K+DWHA.K+DWHP.K+DWHI.K+DWHE.K+DWHH.K  (SS-82)
NOTE  DWHVR-DELTA WEIGHT DUE TO LAUNCH&RECOVERY VULNER REDUCTION (FRACT)
A   DWHS.K=-.0005                                         (SS-82.1)
NOTE  DWHS-DELTA WEIGHT SUBSYS H DUE TO SHIELDING (FRACT)
A   DWHRD.K=-.0005                                        (SS-82.2)
NOTE  DWHRD-DELTA WEIGHT SUBSYS H DUE TO REDUNDANCY (FRACT)
A   DWHA.K=0                                              (SS-82.3)
NOTE  DWHA-DELTA WEIGHT SUBSYS H DUE TO ACTIVE D.S. (FRACT)
A   DWHP.K=0                                              (SS-82.4)
NOTE  DWHP-DELTA WEIGHT SUBSYS H DUE TO PASSIVE D.S. (FRACT)
A   DWHI.K=0                                              (SS-82.5)
NOTE  DWHI-DELTA WEIGHT SUBSYS H DUE TO COMP ISOLATION (FRACT)
A   DWHE.K=0                                              (SS-82.6)
NOTE  DWHE-DELTA WEIGHT SUBSYS H DUE TO COMP ELIMINATION (FRACT))
A   DWHH.K=0                                              (SS-82.7)
NOTE  DWHH-DELTA WEIGHT SUBSYS H DUE TO MATL HARDENING (FRACT))
A   DWAVR.K=DWAS.K+DWAR.K+DWAA.K+DWAP.K+DWAI.K+DWAE.K+DWAH.K  (SS-83)
NOTE  DWAVR-DELTA WEIGHT DUE TO ARMOR VULNER REDUCTION (FRACT)
A   DWAS.K=-.0005                                         (SS-83.1)
NOTE  DWAS-DELTA WEIGHT SUBSYS A DUE TO SHIELDING (FRACT)
A   DWAR.K=-.0005                                         (SS-83.2)
NOTE  DWAR-DELTA WEIGHT SUBSYS A DUE TO REDUNDANCY (FRACT)
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A    DWAA.K=0                                                   (SS-83.3)
NOTE  DWAA-DELTA WEIGHT SUBSYS A DUE TO ACTIVE D.S. (FRACT)
A    DWAP.K=0                                                   (SS-83.4)
NOTE  DWAP-DELTA WEIGHT SUBSYS A DUE TO PASSIVE D.S. (FRACT)
A    DWAI.K=0                                                   (SS-83.5)
NOTE  DWAI-DELTA WEIGHT SUBSYS A DUE TO COMP ISOLATION (FRACT)
A    DWAE.K=0                                                   (SS-83.6)
NOTE  DWAE-DELTA WEIGHT SUBSYS A DUE TO COMP ELIMINATION (FRACT))
A    DWAH.K=0                                                   (SS-83.7)
NOTE  DWAH-DELTA WEIGHT SUBSYS A DUE TO MATL HARDENING (FRACT)
A    DWTVR.K=DWTS.K+DWTR.K+DWTAD.K+DWTP.K+DWTI.K+DWTE.K+DWTH.K  (SS-84)
NOTE  DWTVR-DELTA WEIGHT DUE TO A/C STRUCTURE VULNER REDUCTION (FRACT)
A    DWTS.K=-.0005                                              (SS-84.1)
NOTE  DWTS-DELTA WEIGHT SUBSYS T DUE TO SHIELDING (FRACT)
A    DWTR.K=-.0005                                              (SS-84.2)
NOTE  DWTR-DELTA WEIGHT SUBSYS T DUE TO REDUNDANCY (FRACT)
A    DWTAD.K=0                                                  (SS-84.3)
NOTE  DWTAD-DELTA WEIGHT SUBSYS T DUE TO ACTIVE D.S. (FRACT)
A    DWTP.K=0                                                   (SS-84.4)
NOTE  DWTP-DELTA WEIGHT SUBSYS T DUE TO PASSIVE D.S. (FRACT)
A    DWTI.K=0                                                   (SS-84.5)
NOTE  DWTI-DELTA WEIGHT SUBSYS T DUE TO COMP ISOLATION (FRACT)
A    DWTE.K=0                                                   (SS-84.6)
NOTE  DWTE-DELTA WEIGHT SUBSYS T DUE TO COMP ELIMINATION (FRACT))
A    DWTH.K=0                                                   (SS-84.7)
NOTE  DWTH-DELTA WEIGHT SUBSYS T DUE TO MATL HARDENING (FRACT))
A    DWSVR.K=DWSS.K+DWSRD.K+DWSA.K+DWSP.K+DWSI.K+DWSE.K+DWSH.K  (SS-85)
NOTE  DWSVR-DELTA WEIGHT DUE TO PERSONNEL STATION VULNER REDUCT (FRACT)
A    DWSS.K=-.0005                                              (SS-85.1)
NOTE  DWSS-DELTA WEIGHT SUBSYS S DUE TO SHIELDING (FRACT)
A    DWSRD.K=-.0005                                             (SS-85.2)
NOTE  DWSRD-DELTA WEIGHT SUBSYS S DUE TO REDUNDANCY (FRACT)
A    DWSA.K=0                                                   (SS-85.3)
NOTE  DWSA-DELTA WEIGHT SUBSYS S DUE TO ACTIVE D.S. (FRACT)
A    DWSP.K=0                                                   (SS-85.4)
NOTE  DWSP-DELTA WEIGHT SUBSYS S DUE TO PASSIVE D.S. (FRACT)
A    DWSI.K=0                                                   (SS-85.5)
NOTE  DWSI-DELTA WEIGHT SUBSYS S DUE TO COMP ISOLATION (FRACT)
A    DWSE.K=0                                                   (SS-85.6)
NOTE  DWSE-DELTA WEIGHT SUBSYS S DUE TO COMP ELIMINATION (FRACT))
A    DWSH.K=0                                                   (SS-85.7)
NOTE  DWSH-DELTA WEIGHT SUBSYS S DUE TO MATL HARDENING (FRACT))
A    DWPVR.K=DWPS.K+DWPR.K+DWPA.K+DWPP.K+DWPI.K+DWPE.K+DWPH.K  (SS-86)
NOTE  DWPVR-DELTA WEIGHT DUE TO PROPULSION VULNER REDUCTION (FRACT)
A    DWPS.K=-.0005                                              (SS-86.1)
NOTE  DWPS-DELTA WEIGHT SUBSYS P DUE TO SHIELDING (FRACT)
A    DWPR.K=-.0005                                              (SS-86.2)
NOTE  DWPR-DELTA WEIGHT SUBSYS P DUE TO REDUNDANCY (FRACT)
A    DWPA.K=0                                                   (SS-86.3)
NOTE  DWPA-DELTA WEIGHT SUBSYS P DUE TO ACTIVE D.S. (FRACT)
A    DWPP.K=0                                                   (SS-86.4)
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NOTE  DWPP-DELTA WEIGHT SUBSYS P DUE TO PASSIVE D.S. (FRACT)
A   DWPI.K=0                                                  (SS-86.5)
NOTE  DWPI-DELTA WEIGHT SUBSYS P DUE TO COMP ISOLATION (FRACT)
A   DWPE.K=0                                                  (SS-86.6)
NOTE  DWPE-DELTA WEIGHT SUBSYS P DUE TO COMP ELIMINATION (FRACT)
A   DWPH.K=0                                                  (SS-86.7)
NOTE  DWPH-DELTA WEIGHT SUBSYS P DUE TO MATL HARDENING (FRACT)
A   DWFVR.K=DWFS.K+DWFR.K+DWFA.K+DWFP.K+DWFI.K+DWFE.K+DWFH.K  (SS-87)
NOTE  DWFVR-DELTA WEIGHT DUE TO FUEL VULNER REDUCTION (FRACT)
A   DWFS.K=-.0005                                             (SS-87.1)
NOTE  DWFS-DELTA WEIGHT SUBSYS F DUE TO SHIELDING (FRACT)
A   DWFR.K=-.0005                                             (SS-87.2)
NOTE  DWFR-DELTA WEIGHT SUBSYS F DUE TO REDUNDANCY (FRACT)
A   DWFA.K=0                                                  (SS-87.3)
NOTE  DWFA-DELTA WEIGHT SUBSYS F DUE TO ACTIVE D.S. (FRACT)
A   DWFP.K=0                                                  (SS-87.4)
NOTE  DWFP-DELTA WEIGHT SUBSYS F DUE TO PASSIVE D.S. (FRACT)
A   DWFI.K=0                                                  (SS-87.5)
NOTE  DWFI-DELTA WEIGHT SUBSYS F DUE TO COMP ISOLATION (FRACT)
A   DWFE.K=0                                                  (SS-87.6)
NOTE  DWFE-DELTA WEIGHT SUBSYS F DUE TO COMP ELIMINATION (FRACT)
A   DWFH.K=0                                                  (SS-87.7)
NOTE  DWFH-DELTA WEIGHT SUBSYS F DUE TO MATL HARDENING (FRACT)
NOTE  ******************************************************************
NOTE  *******      AIRCRAFT DELTA ACQUISITION COMPONENT OF       *******
NOTE  ********            SURVIVABILITY    SUBMODEL             ********
NOTE  ******************************************************************
A   DA.K=DASR.K+DAVR.K                                        (SS-88)
NOTE  DA-DELTA ACQUISITION COST  AIRCRAFT (FRACT)
A   DASR.K=DADR.K+DAHR.K                                      (SS-89)
NOTE  DASR-DELTA ACQUIS COST A/C DUE TO SUSCEP. REDUCTION (DIM)
A   DADR.K=DAGR.K+DATF.K                                      (SS-90)
NOTE  DADR-DELTA ACQUIS COST A/C DUE TO DETECTION REDUCTION (DIM)
A   DAGR.K=DAVSR.K+DAASR.K+DARSR.K+DAISR.K                    (SS-91)
NOTE  DAGR-DELTA ACQUIS COST A/C DUE TO SIGNATURE REDUCTION (DIM)
A   DAVSR.K=DAEVS.K+DAAVS.K                                   (SS-92)
NOTE  DAVSR-DELTA ACQUIS COST A/C VISUAL SIGNATURE REDUCTION (DIM)
A   DAASR.K=DAEAS.K+DAAAS.K                                   (SS-93)
NOTE  DAASR-DELTA ACQUIS COST A/C AURAL SIGNATURE REDUCTION (DIM)
A   DARSR.K=DAERS.K+DAARS.K                                   (SS-94)
NOTE  DASR-DELTA ACQUIS COST A/C RADAR SIGNATURE REDUCTION (DIM)
A   DAISR.K=DAEIS.K+DAAIS.K                                   (SS-95)
NOTE  DAISR-DELTA ACQUIS COST A/C INFRARED SIGNATURE REDUCT (DIM)
A   DAEVS.K=-.0005                                            (SS-96)
NOTE  DAEVS-DELTA ACQUIS COST A/C ENGINE VISUAL SIGNATURE (DIM)
A   DAAVS.K=-.0005                                            (SS-97)
NOTE  DAAVS-DELTA ACQUIS COST A/C AIRFRAME VISUAL SIGNATURE (DIM)
A   DAEAS.K=-.004                                             (SS-98)
NOTE  DAEAS-DELTA ACQUIS COST A/C ENGINE AURAL SIGNATURE (DIM)
A   DAAAS.K=-.0005                                            (SS-99)
NOTE  DAAAS-DELTA ACQUIS COST A/C AIRFRAME AURAL SIGNATURE (DIM)
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A   DAERS.K=-.0005                                            (SS-100)
NOTE  DAERS-DELTA ACQUIS COST A/C ENGINE RADAR SIGNATURE (DIM)
A   DAARS.K=0                                                 (SS-101)
NOTE  DAARS-DELTA ACQUIS COST A/C AIRFRAME RADAR SIGNATURE (DIM)
A   DAEIS.K=0                                                 (SS-102)
NOTE  DAEIS-DELTA ACQUIS COST A/C ENGINE INFRARED SIGNATURE (DIM)
A   DAAIS.K=0                                                 (SS-103)
NOTE  DAAIS-DELTA ACQUIS COST A/C AIRFRAME INFRARED SIGN (DIM)
A   DATF.K=0                                                  (SS-104)
NOTE  DATF-DELTA ACQUIS COST A/C DUE TO THREAT AVOIDANCE (DIM)
A   DAHR.K=DAEW.K+DATEC.K+DATDC.K                             (SS-105)
NOTE  DAHR-DELTA ACQUIS COST A/C DUE TO HIT REDUCTION (DIM)
A   DAEW.K=DAW.K+DAJ.K+DAD.K                                  (SS-106)
NOTE  DAEW-DELTA ACQUIS COST A/C DUE TO ELECTRONIC WARFARE (DIM)
A   DAW.K=-.0005                                               (SS-107)
NOTE  DAW-DELTA ACQUIS COST A/C DUE TO RADAR WARNING (DIM)
A   DAJ.K=-.0005                                               (SS-108)
NOTE  DAJ-DELTA ACQUIS COST A/C DUE TO JAMMERS (DIM)
A   DAD.K=-.0005                                               (SS-109)
NOTE  DAD-DELTA ACQUIS COST A/C DUE TO DECEPTORS (DIM)
A   DATEC.K=-.002                                             (SS-110)
NOTE  DATEC-DELTA ACQUIS COST A/C DUE TO THREAT EVASION CAPABILITY (DIM)
A   DATDC.K=-.002                                             (SS-111)
NOTE  DATDC-DELTA ACQUIS COST A/C DUE TO THREAT DESTRUCTION CAPAB (DIM)
NOTE  *******************************************************************
A   DAVR.K=DABVR.K*ROTOR+DAWVR.K*ROTOR+DAEVR.K*FIXED+DACVR.K*FIXED
X      +DADVR.K*FIXED+DAIVR.K*FIXED+DAOVR.K*FIXED+DARVR.K*FIXED
X      +DALVR.K*FIXED+DAVVR.K*FIXED+DAHVR.K*FIXED+DAAVR.K*FIXED
X      +DATVR.K*FIXED+DASVR.K*FIXED+DAPVR.K*FIXED+DAFVR.K*FIXED (SS-112)
NOTE  DAVR-DELTA ACQUIS COST DUE TO VULNERABILITY REDUCT (FRACT)
A   DABVR.K=DABS.K+DABR.K+DABA.K+DABP.K+DABI.K+DABE.K+DABH.K  (SS-113)
NOTE  DABVR-DELTA ACQUIS COST DUE TO ROTOR BLADES VULNER REDUCT (FRACT)
A   DABS.K=-.0005                                              (SS-113.1)
NOTE  DABS-DELTA ACQUIS COST SUBSYS B DUE TO SHIELDING (FRACT)
A   DABR.K=-.0005                                              (SS-113.2)
NOTE  DABR-DELTA ACQUIS COST SUBSYS B DUE TO REDUNDANCY (FRACT)
A   DABA.K=0                                                  (SS-113.3)
NOTE  DABA-DELTA ACQUIS COST SUBSYS B DUE TO ACTIVE D.S. (FRACT)
A   DABP.K=0                                                  (SS-113.4)
NOTE  DABP-DELTA ACQUIS COST SUBSYS B DUE TO PASSIVE D.S. (FRACT)
A   DABI.K=0                                                  (SS-113.5)
NOTE  DABI-DELTA ACQUIS COST SUBSYS B DUE TO COMP ISOLATION (FRACT)
A   DABE.K=0                                                  (SS-113.6)
NOTE  DABE-DELTA ACQUIS COST SUBSYS B DUE TO COMP ELIMINATION (FRACT)
A   DABH.K=0                                                  (SS-113.7)
NOTE  DABH-DELTA ACQUIS COST SUBSYS B DUE TO MATL HARDENING (FRACT)
A   DAWVR.K=DAWS.K+DAWR.K+DAWA.K+DAWP.K+DAWI.K+DAWE.K+DAWH.K  (SS-114)
NOTE  DAWVR-DELTA ACQUIS COST DUE TO POWER TRAIN VULNER REDUCTION (FRACT)
A   DAWS.K=-.0005                                             (SS-114.1)
NOTE  DAWS-DELTA ACQUIS COST SUBSYS W DUE TO SHIELDING (FRACT)
A   DAWR.K=-.0005                                             (SS-114.2)
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NOTE  DAWR-DELTA ACQUIS COST SUBSYS W DUE TO REDUNDANCY (FRACT)
A   DAWA.K=0                                                 (SS-114.3)
NOTE  DAWA-DELTA ACQUIS COST SUBSYS W DUE TO ACTIVE D.S. (FRACT)
A   DAWP.K=0                                                 (SS-114.4)
NOTE  DAWP-DELTA ACQUIS COST SUBSYS W DUE TO PASSIVE D.S. (FRACT)
A   DAWI.K=0                                                 (SS-114.5)
NOTE  DAWI-DELTA ACQUIS COST SUBSYS W DUE TO COMP ISOLATION (FRACT)
A   DAWE.K=0                                                 (SS-114.6)
NOTE  DAWE-DELTA ACQUIS COST SUBSYS W DUE TO COMP ELIMINATION (FRACT)
A   DAWH.K=0                                                 (SS-114.7)
NOTE  DAWH-DELTA ACQUIS COST SUBSYS W DUE TO MATL HARDENING (FRACT)
A   DAEVR.K=DAES.K+DAER.K+DAEA.K+DAEP.K+DAEI.K+DAEE.K+DAEH.K (SS-115)
NOTE  DAEVR-DELTA ACQUIS COST DUE TO ENGINE VULNER REDUCTION (FRACT)
A   DAES.K=-.0005                                            (SS-115.1)
NOTE  DAES-DELTA ACQUIS COST SUBSYS E DUE TO SHIELDING (FRACT)
A   DAER.K=-.0005                                            (SS-115.2)
NOTE  DAER-DELTA ACQUIS COST SUBSYS E DUE TO REDUNDANCY (FRACT)
A   DAEA.K=0                                                 (SS-115.3)
NOTE  DAEA-DELTA ACQUIS COST SUBSYS E DUE TO ACTIVE D.S. (FRACT)
A   DAEP.K=0                                                 (SS-115.4)
NOTE  DAEP-DELTA ACQUIS COST SUBSYS E DUE TO PASSIVE D.S. (FRACT)
A   DAEI.K=0                                                 (SS-115.5)
NOTE  DAEI-DELTA ACQUIS COST SUBSYS E DUE TO COMP ISOLATION (FRACT)
A   DAEE.K=0                                                 (SS-115.6)
NOTE  DAEE-DELTA ACQUIS COST SUBSYS E DUE TO COMP ELIMINATION (FRACT)
A   DAEH.K=0                                                 (SS-115.7)
NOTE  DAEH-DELTA ACQUIS COST SUBSYS E DUE TO MATL HARDENING (FRACT)
A   DACVR.K=DACS.K+DACR.K+DACA.K+DACP.K+DACI.K+DACE.K+DACH.K (SS-116)
NOTE  DACVR-DELTA ACQUIS COST DUE TO FLIGHT CONTROL VULNER REDUCT (FRACT)
A   DACS.K=-.0005                                             (SS-116.1)
NOTE  DACS-DELTA ACQUIS COST SUBSYS C DUE TO SHIELDING (FRACT)
A   DACR.K=-.0005                                             (SS-116.2)
NOTE  DACR-DELTA ACQUIS COST SUBSYS C DUE TO REDUNDANCY (FRACT)
A   DACA.K=0                                                 (SS-116.3)
NOTE  DACA-DELTA ACQUIS COST SUBSYS C DUE TO ACTIVE D.S. (FRACT)
A   DACP.K=0                                                 (SS-116.4)
NOTE  DACP-DELTA ACQUIS COST SUBSYS C DUE TO PASSIVE D.S. (FRACT)
A   DACI.K=0                                                 (SS-116.5)
NOTE  DACI-DELTA ACQUIS COST SUBSYS C DUE TO COMP ISOLATION (FRACT)
A   DACE.K=0                                                 (SS-116.6)
NOTE  DACE-DELTA ACQUIS COST SUBSYS C DUE TO COMP ELIMINATION (FRACT)
A   DACH.K=0                                                 (SS-116.7)
NOTE  DACH-DELTA ACQUIS COST SUBSYS C DUE TO MATL HARDENING (FRACT)
A   DADVR.K=DADS.K+DADRD.K+DADA.K+DADP.K+DADI.K+DADE.K+DADH.K  (SS-117)
NOTE  DADVR-DELTA ACQUIS COST DUE TO FLUID POWER VULNER REDUCTION (FRACT)
A   DADS.K=-.0005                                            (SS-117.1)
NOTE  DADS-DELTA ACQUIS COST SUBSYS D DUE TO SHIELDING (FRACT)
A   DADRD.K=-.0005                                           (SS-117.2)
NOTE  DADRD-DELTA ACQUIS COST SUBSYS D DUE TO REDUNDANCY (FRACT)
A   DADA.K=0                                                 (SS-117.3)
NOTE  DADA-DELTA ACQUIS COST SUBSYS D DUE TO ACTIVE D.S. (FRACT)
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A    DADP.K=0                                                   (SS-117.4)
NOTE  DADP-DELTA ACQUIS COST SUBSYS D DUE TO PASSIVE D.S. (FRACT)
A    DADI.K=0                                                   (SS-117.5)
NOTE  DADI-DELTA ACQUIS COST SUBSYS D DUE TO COMP ISOLATION (FRACT)
A    DADE.K=0                                                   (SS-117.6)
NOTE  DADE-DELTA ACQUIS COST SUBSYS D DUE TO COMP ELIMINATION (FRACT)
A    DADH.K=0                                                   (SS-117.7)
NOTE  DADH-DELTA ACQUIS COST SUBSYS D DUE TO MATL HARDENING (FRACT)
A    DAIVR.K=DAIS.K+DAIR.K+DAIA.K+DAIP.K+DAII.K+DAIE.K+DAIH.K  (SS-118)
NOTE  DAIVR-DELTA ACQUIS COST DUE TO ENVIRON CONTROL VULNER REDUC (FRACT)
A    DAIS.K=-.0005                                              (SS-118.1)
NOTE  DAIS-DELTA ACQUIS COST SUBSYS I DUE TO SHIELDING (FRACT)
A    DAIR.K=-.0005                                              (SS-118.2)
NOTE  DAIR-DELTA ACQUIS COST SUBSYS I DUE TO REDUNDANCY (FRACT)
A    DAIA.K=0                                                   (SS-118.3)
NOTE  DAIA-DELTA ACQUIS COST SUBSYS I DUE TO ACTIVE D.S. (FRACT)
A    DAIP.K=0                                                   (SS-118.4)
NOTE  DAIP-DELTA ACQUIS COST SUBSYS I DUE TO PASSIVE D.S. (FRACT)
A    DAII.K=0                                                   (SS-118.5)
NOTE  DAII-DELTA ACQUIS COST SUBSYS I DUE TO COMP ISOLATION (FRACT)
A    DAIE.K=0                                                   (SS-118.6)
NOTE  DAIE-DELTA ACQUIS COST SUBSYS I DUE TO COMP ELIMINATION (FRACT)
A    DAIH.K=0                                                   (SS-118.7)
NOTE  DAIH-DELTA ACQUIS COST SUBSYS I DUE TO MATL HARDENING (FRACT)
A    DAOVR.K=DAOS.K+DAOR.K+DAOA.K+DAOP.K+DAOI.K+DAOE.K+DAOH.K  (SS-119)
NOTE  DAOVR-DELTA ACQUIS COST DUE TO OXYGEN VULNER REDUCTION (FRACT)
A    DAOS.K=-.0005                                              (SS-119.1)
NOTE  DAOS-DELTA ACQUIS COST SUBSYS O DUE TO SHIELDING (FRACT)
A    DAOR.K=-.0005                                              (SS-119.2)
NOTE  DAOR-DELTA ACQUIS COST SUBSYS O DUE TO REDUNDANCY (FRACT)
A    DAOA.K=0                                                   (SS-119.3)
NOTE  DAOA-DELTA ACQUIS COST SUBSYS O DUE TO ACTIVE D.S. (FRACT)
A    DAOP.K=0                                                   (SS-119.4)
NOTE  DAOP-DELTA ACQUIS COST SUBSYS O DUE TO PASSIVE D.S. (FRACT)
A    DAOI.K=0                                                   (SS-119.5)
NOTE  DAOI-DELTA ACQUIS COST SUBSYS O DUE TO COMP ISOLATION (FRACT)
A    DAOE.K=0                                                   (SS-119.6)
NOTE  DAOE-DELTA ACQUIS COST SUBSYS O DUE TO COMP ELIMINATION (FRACT)
A    DAOH.K=0                                                   (SS-119.7)
NOTE  DAOH-DELTA ACQUIS COST SUBSYS O DUE TO MATL HARDENING (FRACT)
A    DARVR.K=DARS.K+DARR.K+DARA.K+DARP.K+DARI.K+DARE.K+DARH.K  (SS-120)
NOTE  DARVR-DELTA ACQUIS COST DUE TO ARMAMENT VULNER REDUCTION (FRACT)
A    DARS.K=-.0005                                              (SS-120.1)
NOTE  DARS-DELTA ACQUIS COST SUBSYS R DUE TO SHIELDING (FRACT)
A    DARR.K=-.0005                                              (SS-120.2)
NOTE  DARR-DELTA ACQUIS COST SUBSYS R DUE TO REDUNDANCY (FRACT)
A    DARA.K=0                                                   (SS-120.3)
NOTE  DARA-DELTA ACQUIS COST SUBSYS R DUE TO ACTIVE D.S. (FRACT)
A    DARP.K=0                                                   (SS-120.4)
NOTE  DARP-DELTA ACQUIS COST SUBSYS R DUE TO PASSIVE D.S. (FRACT)
A    DARI.K=0                                                   (SS-120.5)
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NOTE  DARI-DELTA ACQUIS COST SUBSYS R DUE TO COMP ISOLATION (FRACT)
A   DARE.K=0                                                 (SS-120.6)
NOTE  DARE-DELTA ACQUIS COST SUBSYS R DUE TO COMP ELIMINATION (FRACT)
A   DARH.K=0                                                 (SS-120.7)
NOTE  DARH-DELTA ACQUIS COST SUBSYS R DUE TO MATL HARDENING (FRACT)
A   DALVR.K=DALS.K+DALR.K+DALA.K+DALP.K+DALI.K+DALE.K+DALH.K  (SS-121)
NOTE  DALVR-DELTA ACQ. COST DUE TO ELECTRICAL POWER VULNER REDUCT (FRACT)
A   DALS.K=-.0005                                            (SS-121.1)
NOTE  DALS-DELTA ACQUIS COST SUBSYS L DUE TO SHIELDING (FRACT)
A   DALR.K=-.0005                                            (SS-121.2)
NOTE  DALR-DELTA ACQUIS COST SUBSYS L DUE TO REDUNDANCY (FRACT)
A   DALA.K=0                                                 (SS-121.3)
NOTE  DALA-DELTA ACQUIS COST SUBSYS L DUE TO ACTIVE D.S. (FRACT)
A   DALP.K=0                                                 (SS-121.4)
NOTE  DALP-DELTA ACQUIS COST SUBSYS L DUE TO PASSIVE D.S. (FRACT)
A   DALI.K=0                                                 (SS-121.5)
NOTE  DALI-DELTA ACQUIS COST SUBSYS L DUE TO COMP ISOLATION (FRACT)
A   DALE.K=0                                                 (SS-121.6)
NOTE  DALE-DELTA ACQUIS COST SUBSYS L DUE TO COMP ELIMINATION (FRACT)
A   DALH.K=0                                                 (SS-121.7)
NOTE  DALH-DELTA ACQUIS COST SUBSYS L DUE TO MATL HARDENING (FRACT)
A   DAVVR.K=DAVS.K+DAVRD.K+DAVA.K+DAVP.K+DAVI.K+DAVE.K+DAVH.K  (SS-122)
NOTE  DAVVR-DELTA ACQUIS COST DUE TO AVIONIC VULNER REDUCTION (FRACT)
A   DAVS.K=-.0005                                            (SS-122.1)
NOTE  DAVS-DELTA ACQUIS COST SUBSYS V DUE TO SHIELDING (FRACT)
A   DAVRD.K=-.0005                                           (SS-122.2)
NOTE  DAVRD-DELTA ACQUIS COST SUBSYS V DUE TO REDUNDANCY (FRACT)
A   DAVA.K=0                                                 (SS-122.3)
NOTE  DAVA-DELTA ACQUIS COST SUBSYS V DUE TO ACTIVE D.S. (FRACT)
A   DAVP.K=0                                                 (SS-122.4)
NOTE  DAVP-DELTA ACQUIS COST SUBSYS V DUE TO PASSIVE D.S. (FRACT)
A   DAVI.K=0                                                 (SS-122.5)
NOTE  DAVI-DELTA ACQUIS COST SUBSYS V DUE TO COMP ISOLATION (FRACT)
A   DAVE.K=0                                                 (SS-122.6)
NOTE  DAVE-DELTA ACQUIS COST SUBSYS V DUE TO COMP ELIMINATION (FRACT)
A   DAVH.K=0                                                 (SS-122.7)
NOTE  DAVH-DELTA ACQUIS COST SUBSYS V DUE TO MATL HARDENING (FRACT)
A   DAHVR.K=DAHS.K+DAHRD.K+DAHA.K+DAHP.K+DAHI.K+DAHE.K+DAHH.K  (SS-123)
NOTE  DAHVR-DELTA ACQUIS COST DUE TO LAUNCH&RECOVERY VULNER REDUCT (FRACT
A   DAHS.K=-.0005                                            (SS-123.1)
NOTE  DAHS-DELTA ACQUIS COST SUBSYS H DUE TO SHIELDING (FRACT)
A   DAHRD.K=-.0005                                           (SS-123.2)
NOTE  DAHRD-DELTA ACQUIS COST SUBSYS H DUE TO REDUNDANCY (FRACT)
A   DAHA.K=0                                                 (SS-123.3)
NOTE  DAHA-DELTA ACQUIS COST SUBSYS H DUE TO ACTIVE D.S. (FRACT)
A   DAHP.K=0                                                 (SS-123.4)
NOTE  DAHP-DELTA ACQUIS COST SUBSYS H DUE TO PASSIVE D.S. (FRACT)
A   DAHI.K=0                                                 (SS-123.5)
NOTE  DAHI-DELTA ACQUIS COST SUBSYS H DUE TO COMP ISOLATION (FRACT)
A   DAHE.K=0                                                 (SS-123.6)
NOTE  DAHE-DELTA ACQUIS COST SUBSYS H DUE TO COMP ELIMINATION (FRACT)
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A   DAHH.K=0                                                (SS-123.7)
NOTE  DAHH-DELTA ACQUIS COST SUBSYS H DUE TO MATL HARDENING (FRACT)
A   DAAVR.K=DAAS.K+DAAR.K+DAAA.K+DAAP.K+DAAI.K+DAAE.K+DAAH.K  (SS-124)
NOTE  DAAVR-DELTA ACQUIS COST DUE TO ARMOR VULNER REDUCTION (FRACT)
A   DAAS.K=-.0005                                           (SS-124.1)
NOTE  DAAS-DELTA ACQUIS COST SUBSYS A DUE TO SHIELDING (FRACT)
A   DAAR.K=-.0005                                           (SS-124.2)
NOTE  DAAR-DELTA ACQUIS COST SUBSYS A DUE TO REDUNDANCY (FRACT)
A   DAAA.K=0                                                (SS-124.3)
NOTE  DAAA-DELTA ACQUIS COST SUBSYS A DUE TO ACTIVE D.S. (FRACT)
A   DAAP.K=0                                                (SS-124.4)
NOTE  DAAP-DELTA ACQUIS COST SUBSYS A DUE TO PASSIVE D.S. (FRACT)
A   DAAI.K=0                                                (SS-124.5)
NOTE  DAAI-DELTA ACQUIS COST SUBSYS A DUE TO COMP ISOLATION (FRACT)
A   DAAE.K=0                                                (SS-124.6)
NOTE  DAAE-DELTA ACQUIS COST SUBSYS A DUE TO COMP ELIMINATION (FRACT)
A   DAAH.K=0                                                (SS-124.7)
NOTE  DAAH-DELTA ACQUIS COST SUBSYS A DUE TO MATL HARDENING (FRACT)
A   DATVR.K=DATS.K+DATR.K+DATFD.K+DATP.K+DATI.K+DATE.K+DATH.K  (SS-125)
NOTE  DATVR-DELTA ACQUIS COST DUE TO A/C STRUCTURE VULNER REDUCT (FRACT)
A   DATS.K=-.0005                                           (SS-125.1)
NOTE  DATS-DELTA ACQUIS COST SUBSYS T DUE TO SHIELDING (FRACT)
A   DATR.K=-.0005                                           (SS-125.2)
NOTE  DATR-DELTA ACQUIS COST SUBSYS T DUE TO REDUNDANCY (FRACT)
A   DATFD.K=0                                               (SS-125.3)
NOTE  DATFD-DELTA ACQUIS COST SUBSYS T DUE TO ACTIVE D.S. (FRACT)
A   DATP.K=0                                                (SS-125.4)
NOTE  DATP-DELTA ACQUIS COST SUBSYS T DUE TO PASSIVE D.S. (FRACT)
A   DATI.K=0                                                (SS-125.5)
NOTE  DATI-DELTA ACQUIS COST SUBSYS T DUE TO COMP ISOLATION (FRACT)
A   DATE.K=0                                                (SS-125.6)
NOTE  DATE-DELTA ACQUIS COST SUBSYS T DUE TO COMP ELIMINATION (FRACT)
A   DATH.K=0                                                (SS-125.7)
NOTE  DATH-DELTA ACQUIS COST SUBSYS T DUE TO MATL HARDENING (FRACT)
A   DASVR.K=DASS.K+DASRD.K+DASA.K+DASP.K+DASI.K+DASE.K+DASH.K  (SS-126)
NOTE  DASVR-DELTA ACQ. COST DUE TO PERSONNEL STATION VULNER REDUCT (FRACT
A   DASS.K=-.0005                                           (SS-126.1)
NOTE  DASS-DELTA ACQUIS COST SUBSYS S DUE TO SHIELDING (FRACT)
A   DASRD.K=-.0005                                          (SS-126.2)
NOTE  DASRD-DELTA ACQUIS COST SUBSYS S DUE TO REDUNDANCY (FRACT)
A   DASA.K=0                                                (SS-126.3)
NOTE  DASA-DELTA ACQUIS COST SUBSYS S DUE TO ACTIVE D.S. (FRACT)
A   DASP.K=0                                                (SS-126.4)
NOTE  DASP-DELTA ACQUIS COST SUBSYS S DUE TO PASSIVE D.S. (FRACT)
A   DASI.K=0                                                (SS-126.5)
NOTE  DASI-DELTA ACQUIS COST SUBSYS S DUE TO COMP ISOLATION (FRACT)
A   DASE.K=0                                                (SS-126.6)
NOTE  DASE-DELTA ACQUIS COST SUBSYS S DUE TO COMP ELIMINATION (FRACT)
A   DASH.K=0                                                (SS-126.7)
NOTE  DASH-DELTA ACQUIS COST SUBSYS S DUE TO MATL HARDENING (FRACT)
A   DAPVR.K=DAPS.K+DAPR.K+DAPA.K+DAPP.K+DAPI.K+DAPE.K+DAPH.K  (SS-127)
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NOTE  DAPVR-DELTA ACQUIS COST DUE TO PROPULSION VULNER REDUCTION (FRACT)
A   DAPS.K=-.0005                                             (SS-127.1)
NOTE  DAPS-DELTA ACQUIS COST SUBSYS P DUE TO SHIELDING (FRACT)
A   DAPR.K=-.0005                                             (SS-127.2)
NOTE  DAPR-DELTA ACQUIS COST SUBSYS P DUE TO REDUNDANCY (FRACT)
A   DAPA.K=0                                                  (SS-127.3)
NOTE  DAPA-DELTA ACQUIS COST SUBSYS P DUE TO ACTIVE D.S. (FRACT)
A   DAPP.K=0                                                  (SS-127.4)
NOTE  DAPP-DELTA ACQUIS COST SUBSYS P DUE TO PASSIVE D.S. (FRACT)
A   DAPI.K=0                                                  (SS-127.5)
NOTE  DAPI-DELTA ACQUIS COST SUBSYS P DUE TO COMP ISOLATION (FRACT)
A   DAPE.K=0                                                  (SS-127.6)
NOTE  DAPE-DELTA ACQUIS COST SUBSYS P DUE TO COMP ELIMINATION (FRACT)
A   DAPH.K=0                                                  (SS-127.7)
NOTE  DAPH-DELTA ACQUIS COST SUBSYS P DUE TO MATL HARDENING (FRACT)
A   DAFVR.K=DAFS.K+DAFR.K+DAFA.K+DAFP.K+DAFI.K+DAFE.K+DAFH.K  (SS-128)
NOTE  DAFVR-DELTA ACQUIS COST DUE TO FUEL VULNER REDUCTION (FRACT)
A   DAFS.K=-.0005                                             (SS-128.1)
NOTE  DAFS-DELTA ACQUIS COST SUBSYS F DUE TO SHIELDING (FRACT)
A   DAFR.K=-.0005                                             (SS-128.2)
NOTE  DAFR-DELTA ACQUIS COST SUBSYS F DUE TO REDUNDANCY (FRACT)
A   DAFA.K=0                                                  (SS-128.3)
NOTE  DAFA-DELTA ACQUIS COST SUBSYS F DUE TO ACTIVE D.S. (FRACT)
A   DAFP.K=0                                                  (SS-128.4)
NOTE  DAFP-DELTA ACQUIS COST SUBSYS F DUE TO PASSIVE D.S. (FRACT)
A   DAFI.K=0                                                  (SS-128.5)
NOTE  DAFI-DELTA ACQUIS COST SUBSYS F DUE TO COMP ISOLATION (FRACT)
A   DAFE.K=0                                                  (SS-128.6)
NOTE  DAFE-DELTA ACQUIS COST SUBSYS F DUE TO COMP ELIMINATION (FRACT)
A   DAFH.K=0                                                  (SS-128.7)
NOTE  DAFH-DELTA ACQUIS COST SUBSYS F DUE TO MATL HARDENING (FRACT)
NOTE  *************************************************************
NOTE  *******      AIRCRAFT DELTA MAINTENANCE COMPONENT OF      *******
NOTE  ********            SURVIVABILITY   SUBMODEL          ********
NOTE  *************************************************************
A   DM.K=DMSR.K+DMVR.K                                        (SS-129)
NOTE  DM-DELTA MAINTENANCE AIRCRAFT (FRACT)
A   DMSR.K=DMDR.K+DMHR.K                                      (SS-130)
NOTE  DMSR-DELTA MAINT A/C DUE TO SUSCEP. REDUCTION (DIM)
A   DMDR.K=DMGR.K+DMTA.K                                      (SS-131)
NOTE  DMDR-DELTA MAINT A/C DUE TO DETECTION REDUCTION (DIM)
A   DMGR.K=DMVSR.K+DMASR.K+DMRSR.K+DMISR.K                    (SS-132)
NOTE  DMGR-DELTA MAINT A/C DUE TO SIGNATURE REDUCTION (DIM)
A   DMVSR.K=DMEVS.K+DMAVS.K                                   (SS-133)
NOTE  DMVSR-DELTA MAINT A/C VISUAL SIGNATURE REDUCTION (DIM)
A   DMASR.K=DMEAS.K+DMAAS.K                                   (SS-134)
NOTE  DMASR-DELTA MAINT A/C AURAL SIGNATURE REDUCTION (DIM)
A   DMRSR.K=DMERS.K+DMARS.K                                   (SS-135)
NOTE  DMSR-DELTA MAINT A/C RADAR SIGNATURE REDUCTION (DIM)
A   DMISR.K=DMEIS.K+DMAIS.K                                   (SS-136)
NOTE  DMISR-DELTA MAINT A/C INFRARED SIGNATURE REDUCT (DIM)
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A    DMEVS.K=-.0005                                              (SS-137)
NOTE  DMEVS-DELTA MAINT A/C ENGINE VISUAL SIGNATURE (DIM)
A    DMAVS.K=-.0005                                              (SS-138)
NOTE  DMAVS-DELTA MAINT A/C AIRFRAME VISUAL SIGNATURE (DIM)
A    DMEAS.K=-.0005                                              (SS-139)
NOTE  DMEAS-DELTA MAINT A/C ENGINE AURAL SIGNATURE (DIM)
A    DMAAS.K=-.0005                                              (SS-140)
NOTE  DMAAS-DELTA MAINT A/C AIRFRAME AURAL SIGNATURE (DIM)
A    DMERS.K=0                                                   (SS-141)
NOTE  DMERS-DELTA MAINT A/C ENGINE RADAR SIGNATURE (DIM)
A    DMARS.K=0                                                   (SS-142)
NOTE  DMARS-DELTA MAINT A/C AIRFRAME RADAR SIGNATURE (DIM)
A    DMEIS.K=0                                                   (SS-143)
NOTE  DMEIS-DELTA MAINT A/C ENGINE INFRARED SIGNATURE (DIM)
A    DMAIS.K=0                                                   (SS-144)
NOTE  DMAIS-DELTA MAINT A/C AIRFRAME INFRARED SIGN (DIM)
A    DMTA.K=0                                                    (SS-145)
NOTE  DMTA-DELTA MAINT A/C DUE TO THREAT AVOIDANCE (DIM)
A    DMHR.K=DMEW.K+DMTEC.K+DMTDC.K                               (SS-146)
NOTE  DMHR-DELTA MAINT A/C DUE TO HIT REDUCTION (DIM)
A    DMEW.K=DMW.K+DMJ.K+DMD.K                                    (SS-147)
NOTE  DMEW-DELTA MAINT A/C DUE TO ELECTRONIC WARFARE (DIM)
A    DMW.K=0                                                     (SS-148)
NOTE  DMW-DELTA MAINTENANCE A/C DUE TO RADAR WARNING (DIM)
A    DMJ.K=0                                                     (SS-149)
NOTE  DMJ-DELTA MAINTENANCE A/C DUE TO JAMMERS (DIM)
A    DMD.K=0                                                     (SS-150)
NOTE  DMD-DELTA MAINTENANCE A/C DUE TO DECEPTORS (DIM)
A    DMTEC.K=0                                                   (SS-151)
NOTE  DMTEC-DELTA MAINT A/C DUE TO THREAT EVASION CAPABILITY (DIM)
A    DMTDC.K=0                                                   (SS-152)
NOTE  DMTDC-DELTA MAINT A/C DUE TO THREAT DESTRUCTION CAPAB (DIM)
NOTE  *****************************************************************
A    DMVR.K=DMBVR.K*ROTOR+DMWVR.K*ROTOR+DMEVR.K*FIXED+DMCVR.K*FIXED
X       +DMDVR.K*FIXED+DMIVR.K*FIXED+DMOVR.K*FIXED+DMRVR.K*FIXED
X       +DMLVR.K*FIXED+DMVVR.K*FIXED+DMHVR.K*FIXED+DMAVR.K*FIXED
X       +DMTVR.K*FIXED+DMSVR.K*FIXED+DMPVR.K*FIXED+DMFVR.K*FIXED (SS-153)
NOTE  DMVR-DELTA MAINTENANCE COST DUE TO VULNERABILITY REDUCTION (FRACT)
A    DMBVR.K=DMBS.K+DMBR.K+DMBA.K+DMBP.K+DMBI.K+DMBE.K+DMBH.K   (SS-154)
NOTE  DMBVR-DELTA MAINT COST DUE TO ROTOR BLADES VULNER REDUCTION (FRACT)
A    DMBS.K=-.0005                                             (SS-154.1)
NOTE  DMBS-DELTA MAINT COST SUBSYS B DUE TO SHIELDING (FRACT)
A    DMBR.K=-.0005                                             (SS-154.2)
NOTE  DMBR-DELTA MAINT COST SUBSYS B DUE TO REDUNDANCY (FRACT)
A    DMBA.K=0                                                  (SS-154.3)
NOTE  DMBA-DELTA MAINT COST SUBSYS B DUE TO ACTIVE D.S. (FRACT)
A    DMBP.K=0                                                  (SS-154.4)
NOTE  DMBP-DELTA MAINT COST SUBSYS B DUE TO PASSIVE D.S. (FRACT)
A    DMBI.K=0                                                  (SS-154.5)
NOTE  DMBI-DELTA MAINT COST SUBSYS B DUE TO COMP ISOLATION (FRACT)
A    DMBE.K=0                                                  (SS-154.6)
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NOTE  DMBE-DELTA MAINT COST SUBSYS B DUE TO COMP ELIMINATION (FRACT)
A   DMBH.K=0                                                (SS-154.7)
NOTE  DMBH-DELTA MAINT COST SUBSYS B DUE TO MATL HARDENING (FRACT)
A   DMWVR.K=DMWS.K+DMWR.K+DMWA.K+DMWP.K+DMWI.K+DMWE.K+DMWH.K  (SS-155)
NOTE  DMWVR-DELTA MAINT COST DUE TO POWER TRAIN VULNER REDUCTION (FRACT)
A   DMWS.K=-.0001                                           (SS-155.1)
NOTE  DMWS-DELTA MAINT COST SUBSYS W DUE TO SHIELDING (FRACT)
A   DMWR.K=-.0001                                           (SS-155.2)
NOTE  DMWR-DELTA MAINT COST SUBSYS W DUE TO REDUNDANCY (FRACT)
A   DMWA.K=0                                                (SS-155.3)
NOTE  DMWA-DELTA MAINT COST SUBSYS W DUE TO ACTIVE D.S. (FRACT)
A   DMWP.K=0                                                (SS-155.4)
NOTE  DMWP-DELTA MAINT COST SUBSYS W DUE TO PASSIVE D.S. (FRACT)
A   DMWI.K=0                                                (SS-155.5)
NOTE  DMWI-DELTA MAINT COST SUBSYS W DUE TO COMP ISOLATION (FRACT)
A   DMWE.K=0                                                (SS-155.6)
NOTE  DMWE-DELTA MAINT COST SUBSYS W DUE TO COMP ELIMINATION (FRACT)
A   DMWH.K=0                                                (SS-155.7)
NOTE  DMWH-DELTA MAINT COST SUBSYS W DUE TO MATL HARDENING (FRACT)
A   DMEVR.K=DMES.K+DMER.K+DMEA.K+DMEP.K+DMEI.K+DMEE.K+DMEH.K  (SS-156)
NOTE  DMEVR-DELTA MAINT COST DUE TO ENGINE VULNER REDUCTION (FRACT)
A   DMES.K=-.0005                                           (SS-156.1)
NOTE  DMES-DELTA MAINT COST SUBSYS E DUE TO SHIELDING (FRACT)
A   DMER.K=-.0005                                           (SS-156.2)
NOTE  DMER-DELTA MAINT COST SUBSYS E DUE TO REDUNDANCY (FRACT)
A   DMEA.K=0                                                (SS-156.3)
NOTE  DMEA-DELTA MAINT COST SUBSYS E DUE TO ACTIVE D.S. (FRACT)
A   DMEP.K=0                                                (SS-156.4)
NOTE  DMEP-DELTA MAINT COST SUBSYS E DUE TO PASSIVE D.S. (FRACT)
A   DMEI.K=0                                                (SS-156.5)
NOTE  DMEI-DELTA MAINT COST SUBSYS E DUE TO COMP ISOLATION (FRACT)
A   DMEE.K=0                                                (SS-156.6)
NOTE  DMEE-DELTA MAINT COST SUBSYS E DUE TO COMP ELIMINATION (FRACT)
A   DMEH.K=0                                                (SS-156.7)
NOTE  DMEH-DELTA MAINT COST SUBSYS E DUE TO MATL HARDENING (FRACT)
A   DMCVR.K=DMCS.K+DMCR.K+DMCA.K+DMCP.K+DMCI.K+DMCE.K+DMCH.K  (SS-157)
NOTE  DMCVR-DELTA MAINT COST DUE TO FLIGHT CONTROL VULNER REDUCT (FRACT)
A   DMCS.K=-.0005                                           (SS-157.1)
NOTE  DMCS-DELTA MAINT COST SUBSYS C DUE TO SHIELDING (FRACT)
A   DMCR.K=-.0005                                           (SS-157.2)
NOTE  DMCR-DELTA MAINT COST SUBSYS C DUE TO REDUNDANCY (FRACT)
A   DMCA.K=0                                                (SS-157.3)
NOTE  DMCA-DELTA MAINT COST SUBSYS C DUE TO ACTIVE D.S. (FRACT)
A   DMCP.K=0                                                (SS-157.4)
NOTE  DMCP-DELTA MAINT COST SUBSYS C DUE TO PASSIVE D.S. (FRACT)
A   DMCI.K=0                                                (SS-157.5)
NOTE  DMCI-DELTA MAINT COST SUBSYS C DUE TO COMP ISOLATION (FRACT)
A   DMCE.K=0                                                (SS-157.6)
NOTE  DMCE-DELTA MAINT COST SUBSYS C DUE TO COMP ELIMINATION (FRACT)
A   DMCH.K=0                                                (SS-157.7)
NOTE  DMCH-DELTA MAINT COST SUBSYS C DUE TO MATL HARDENING (FRACT)
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A    DMDVR.K=DMDM.K+DMDRD.K+DMDA.K+DMDP.K+DMDI.K+DMDE.K+DMDH.K  (SS-158)
NOTE  DMDVR-DELTA MAINT COST DUE TO FLUID POWER VULNER REDUCTION (FRACT)
A    DMDM.K=-.0005                                            (SS-158.1)
NOTE  DMDM-DELTA MAINT COST SUBSYS D DUE TO SHIELDING (FRACT)
A    DMDRD.K=-.0005                                           (SS-158.2)
NOTE  DMDRD-DELTA MAINT COST SUBSYS D DUE TO REDUNDANCY (FRACT)
A    DMDA.K=0                                                 (SS-158.3)
NOTE  DMDA-DELTA MAINT COST SUBSYS D DUE TO ACTIVE D.S. (FRACT)
A    DMDP.K=0                                                 (SS-158.4)
NOTE  DMDP-DELTA MAINT COST SUBSYS D DUE TO PASSIVE D.S. (FRACT)
A    DMDI.K=0                                                 (SS-158.5)
NOTE  DMDI-DELTA MAINT COST SUBSYS D DUE TO COMP ISOLATION (FRACT)
A    DMDE.K=0                                                 (SS-158.6)
NOTE  DMDE-DELTA MAINT COST SUBSYS D DUE TO COMP ELIMINATION (FRACT)
A    DMDH.K=0                                                 (SS-158.7)
NOTE  DMDH-DELTA MAINT COST SUBSYS D DUE TO MATL HARDENING (FRACT)
A    DMIVR.K=DMIS.K+DMIR.K+DMIA.K+DMIP.K+DMII.K+DMIE.K+DMIH.K  (SS-159)
NOTE  DMIVR-DELTA MAINT COST DUE TO ENVIRON CONTROL VULNER REDUCT (FRACT)
A    DMIS.K=-.0005                                            (SS-159.1)
NOTE  DMIS-DELTA MAINT COST SUBSYS I DUE TO SHIELDING (FRACT)
A    DMIR.K=-.0005                                            (SS-159.2)
NOTE  DMIR-DELTA MAINT COST SUBSYS I DUE TO REDUNDANCY (FRACT)
A    DMIA.K=0                                                 (SS-159.3)
NOTE  DMIA-DELTA MAINT COST SUBSYS I DUE TO ACTIVE D.S. (FRACT)
A    DMIP.K=0                                                 (SS-159.4)
NOTE  DMIP-DELTA MAINT COST SUBSYS I DUE TO PASSIVE D.S. (FRACT)
A    DMII.K=0                                                 (SS-159.5)
NOTE  DMII-DELTA MAINT COST SUBSYS I DUE TO COMP ISOLATION (FRACT)
A    DMIE.K=0                                                 (SS-159.6)
NOTE  DMIE-DELTA MAINT COST SUBSYS I DUE TO COMP ELIMINATION (FRACT)
A    DMIH.K=0                                                 (SS-159.7)
NOTE  DMIH-DELTA MAINT COST SUBSYS I DUE TO MATL HARDENING (FRACT)
A    DMOVR.K=DMOS.K+DMOR.K+DMOA.K+DMOP.K+DMOI.K+DMOE.K+DMOH.K  (SS-160)
NOTE  DMOVR-DELTA MAINT COST DUE TO OXYGEN VULNER REDUCTION (FRACT)
A    DMOS.K=-.0005                                            (SS-160.1)
NOTE  DMOS-DELTA MAINT COST SUBSYS O DUE TO SHIELDING (FRACT)
A    DMOR.K=-.0005                                            (SS-160.2)
NOTE  DMOR-DELTA MAINT COST SUBSYS O DUE TO REDUNDANCY (FRACT)
A    DMOA.K=+.001                                             (SS-160.3)
NOTE  DMOA-DELTA MAINT COST SUBSYS O DUE TO ACTIVE D.S. (FRACT)
A    DMOP.K=0                                                 (SS-160.4)
NOTE  DMOP-DELTA MAINT COST SUBSYS O DUE TO PASSIVE D.S. (FRACT)
A    DMOI.K=0                                                 (SS-160.5)
NOTE  DMOI-DELTA MAINT COST SUBSYS O DUE TO COMP ISOLATION (FRACT)
A    DMOE.K=0                                                 (SS-160.6)
NOTE  DMOE-DELTA MAINT COST SUBSYS O DUE TO COMP ELIMINATION (FRACT)
A    DMOH.K=0                                                 (SS-160.7)
NOTE  DMOH-DELTA MAINT COST SUBSYS O DUE TO MATL HARDENING (FRACT)
A    DMRVR.K=DMRS.K+DMRR.K+DMRA.K+DMRP.K+DMRI.K+DMRE.K+DMRH.K  (SS-161)
NOTE  DMRVR-DELTA MAINT COST DUE TO ARMAMENT VULNER REDUCTION (FRACT)
A    DMRS.K=-.0005                                            (SS-161.1)
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NOTE  DMRS-DELTA MAINT COST SUBSYS R DUE TO SHIELDING (FRACT)
A   DMRR.K=-.0005                                               (SS-161.2)
NOTE  DMRR-DELTA MAINT COST SUBSYS R DUE TO REDUNDANCY (FRACT)
A   DMRA.K=0                                                    (SS-161.3)
NOTE  DMRA-DELTA MAINT COST SUBSYS R DUE TO ACTIVE D.S. (FRACT)
A   DMRP.K=0                                                    (SS-161.4)
NOTE  DMRP-DELTA MAINT COST SUBSYS R DUE TO PASSIVE D.S. (FRACT)
A   DMRI.K=0                                                    (SS-161.5)
NOTE  DMRI-DELTA MAINT COST SUBSYS R DUE TO COMP ISOLATION (FRACT)
A   DMRE.K=0                                                    (SS-161.6)
NOTE  DMRE-DELTA MAINT COST SUBSYS R DUE TO COMP ELIMINATION (FRACT)
A   DMRH.K=0                                                    (SS-161.7)
NOTE  DMRH-DELTA MAINT COST SUBSYS R DUE TO MATL HARDENING (FRACT)
A   DMLVR.K=DMLS.K+DMLR.K+DMLA.K+DMLP.K+DMLI.K+DMLE.K+DMLH.K  (SS-162)
NOTE  DMLVR-DELTA MAINT COST DUE TO ELECTRICAL POWER VULNER REDUC (FRACT)
A   DMLS.K=-.0005                                               (SS-162.1)
NOTE  DMLS-DELTA MAINT COST SUBSYS L DUE TO SHIELDING (FRACT)
A   DMLR.K=-.0005                                               (SS-162.2)
NOTE  DMLR-DELTA MAINT COST SUBSYS L DUE TO REDUNDANCY (FRACT)
A   DMLA.K=0                                                    (SS-162.3)
NOTE  DMLA-DELTA MAINT COST SUBSYS L DUE TO ACTIVE D.S. (FRACT)
A   DMLP.K=0                                                    (SS-162.4)
NOTE  DMLP-DELTA MAINT COST SUBSYS L DUE TO PASSIVE D.S. (FRACT)
A   DMLI.K=0                                                    (SS-162.5)
NOTE  DMLI-DELTA MAINT COST SUBSYS L DUE TO COMP ISOLATION (FRACT)
A   DMLE.K=0                                                    (SS-162.6)
NOTE  DMLE-DELTA MAINT COST SUBSYS L DUE TO COMP ELIMINATION (FRACT)
A   DMLH.K=0                                                    (SS-162.7)
NOTE  DMLH-DELTA MAINT COST SUBSYS L DUE TO MATL HARDENING (FRACT)
A   DMVVR.K=DMVS.K+DMVRD.K+DMVA.K+DMVP.K+DMVI.K+DMVE.K+DMVH.K  (SS-163)
NOTE  DMVVR-DELTA MAINT COST DUE TO AVIONIC VULNER REDUCTION (FRACT)
A   DMVS.K=-.0005                                               (SS-163.1)
NOTE  DMVS-DELTA MAINT COST SUBSYS V DUE TO SHIELDING (FRACT)
A   DMVRD.K=-.0005                                              (SS-163.2)
NOTE  DMVRD-DELTA MAINT COST SUBSYS V DUE TO REDUNDANCY (FRACT)
A   DMVA.K=0                                                    (SS-163.3)
NOTE  DMVA-DELTA MAINT COST SUBSYS V DUE TO ACTIVE D.S. (FRACT)
A   DMVP.K=0                                                    (SS-163.4)
NOTE  DMVP-DELTA MAINT COST SUBSYS V DUE TO PASSIVE D.S. (FRACT)
A   DMVI.K=0                                                    (SS-163.5)
NOTE  DMVI-DELTA MAINT COST SUBSYS V DUE TO COMP ISOLATION (FRACT)
A   DMVE.K=0                                                    (SS-163.6)
NOTE  DMVE-DELTA MAINT COST SUBSYS V DUE TO COMP ELIMINATION (FRACT)
A   DMVH.K=0                                                    (SS-163.7)
NOTE  DMVH-DELTA MAINT COST SUBSYS V DUE TO MATL HARDENING (FRACT)
A   DMHVR.K=DMHS.K+DMHRD.K+DMHA.K+DMHP.K+DMHI.K+DMHE.K+DMHH.K  (SS-164)
NOTE  DMHVR-DELTA MAINT COST DUE TO LAUNCH&RECOVERY VULNER REDUCT (FRACT
A   DMHS.K=-.0005                                               (SS-164.1)
NOTE  DMHS-DELTA MAINT COST SUBSYS H DUE TO SHIELDING (FRACT)
A   DMHRD.K=-.0005                                              (SS-164.2)
NOTE  DMHRD-DELTA MAINT COST SUBSYS H DUE TO REDUNDANCY (FRACT)
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A   DMHA.K=0                                                   (SS-164.3)
NOTE  DMHA-DELTA MAINT COST SUBSYS H DUE TO ACTIVE D.S. (FRACT)
A   DMHP.K=0                                                   (SS-164.4)
NOTE  DMHP-DELTA MAINT COST SUBSYS H DUE TO PASSIVE D.S. (FRACT)
A   DMHI.K=0                                                   (SS-164.5)
NOTE  DMHI-DELTA MAINT COST SUBSYS H DUE TO COMP ISOLATION (FRACT)
A   DMHE.K=0                                                   (SS-164.6)
NOTE  DMHE-DELTA MAINT COST SUBSYS H DUE TO COMP ELIMINATION (FRACT)
A   DMHH.K=0                                                   (SS-164.7)
NOTE  DMHH-DELTA MAINT COST SUBSYS H DUE TO MATL HARDENING (FRACT)
A   DMAVR.K=DMAS.K+DMAR.K+DMAA.K+DMAP.K+DMAI.K+DMAE.K+DMAH.K  (SS-165)
NOTE  DMAVR-DELTA MAINT COST DUE TO ARMOR VULNER REDUCTION (FRACT)
A   DMAS.K=-.0005                                              (SS-165.1)
NOTE  DMAS-DELTA MAINT COST SUBSYS A DUE TO SHIELDING (FRACT)
A   DMAR.K=-.0005                                              (SS-165.2)
NOTE  DMAR-DELTA MAINT COST SUBSYS A DUE TO REDUNDANCY (FRACT)
A   DMAA.K=0                                                   (SS-165.3)
NOTE  DMAA-DELTA MAINT COST SUBSYS A DUE TO ACTIVE D.S. (FRACT)
A   DMAP.K=0                                                   (SS-165.4)
NOTE  DMAP-DELTA MAINT COST SUBSYS A DUE TO PASSIVE D.S. (FRACT)
A   DMAI.K=0                                                   (SS-165.5)
NOTE  DMAI-DELTA MAINT COST SUBSYS A DUE TO COMP ISOLATION (FRACT)
A   DMAE.K=0                                                   (SS-165.6)
NOTE  DMAE-DELTA MAINT COST SUBSYS A DUE TO COMP ELIMINATION (FRACT)
A   DMAH.K=0                                                   (SS-165.7)
NOTE  DMAH-DELTA MAINT COST SUBSYS A DUE TO MATL HARDENING (FRACT)
A   DMTVR.K=DMTS.K+DMTR.K+DMTAD.K+DMTP.K+DMTI.K+DMTE.K+DMTH.K  (SS-166)
NOTE  DMTVR-DELTA MAINT COST DUE TO A/C STRUCTURE VULNER REDUCT (FRACT)
A   DMTS.K=-.0005                                              (SS-166.1)
NOTE  DMTS-DELTA MAINT COST SUBSYS T DUE TO SHIELDING (FRACT)
A   DMTR.K=-.0005                                              (SS-166.2)
NOTE  DMTR-DELTA MAINT COST SUBSYS T DUE TO REDUNDANCY (FRACT)
A   DMTAD.K=0                                                  (SS-166.3)
NOTE  DMTAD-DELTA MAINT COST SUBSYS T DUE TO ACTIVE D.S. (FRACT)
A   DMTP.K=0                                                   (SS-166.4)
NOTE  DMTP-DELTA MAINT COST SUBSYS T DUE TO PASSIVE D.S. (FRACT)
A   DMTI.K=0                                                   (SS-166.5)
NOTE  DMTI-DELTA MAINT COST SUBSYS T DUE TO COMP ISOLATION (FRACT)
A   DMTE.K=0                                                   (SS-166.6)
NOTE  DMTE-DELTA MAINT COST SUBSYS T DUE TO COMP ELIMINATION (FRACT)
A   DMTH.K=0                                                   (SS-166.7)
NOTE  DMTH-DELTA MAINT COST SUBSYS T DUE TO MATL HARDENING (FRACT)
A   DMSVR.K=DMSS.K+DMSRD.K+DMSA.K+DMSP.K+DMSI.K+DMSE.K+DMSH.K  (SS-167)
NOTE  DMSVR-DELTA MAINT COST DUE TO PERSON. STATION VULNER REDUCT (FRACT)
A   DMSS.K=-.0005                                              (SS-167.1)
NOTE  DMSS-DELTA MAINT COST SUBSYS S DUE TO SHIELDING (FRACT)
A   DMSRD.K=-.0005                                             (SS-167.2)
NOTE  DMSRD-DELTA MAINT COST SUBSYS S DUE TO REDUNDANCY (FRACT)
A   DMSA.K=0                                                   (SS-167.3)
NOTE  DMSA-DELTA MAINT COST SUBSYS S DUE TO ACTIVE D.S. (FRACT)
A   DMSP.K=0                                                   (SS-167.4)
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NOTE  DMSP-DELTA MAINT COST SUBSYS S DUE TO PASSIVE D.S. (FRACT)
A   DMSI.K=0                                                  (SS-167.5)
NOTE  DMSI-DELTA MAINT COST SUBSYS S DUE TO COMP ISOLATION (FRACT)
A   DMSE.K=0                                                  (SS-167.6)
NOTE  DMSE-DELTA MAINT COST SUBSYS S DUE TO COMP ELIMINATION (FRACT)
A   DMSH.K=0                                                  (SS-167.7)
NOTE  DMSH-DELTA MAINT COST SUBSYS S DUE TO MATL HARDENING (FRACT)
A   DMPVR.K=DMPS.K+DMPR.K+DMPA.K+DMPP.K+DMPI.K+DMPE.K+DMPH.K  (SS-168)
NOTE  DMPVR-DELTA MAINT COST DUE TO PROPULSION VULNER REDUCTION (FRACT)
A   DMPS.K=-.0005                                             (SS-168.1)
NOTE  DMPS-DELTA MAINT COST SUBSYS P DUE TO SHIELDING (FRACT)
A   DMPR.K=-.0005                                             (SS-168.2)
NOTE  DMPR-DELTA MAINT COST SUBSYS P DUE TO REDUNDANCY (FRACT)
A   DMPA.K=0                                                  (SS-168.3)
NOTE  DMPA-DELTA MAINT COST SUBSYS P DUE TO ACTIVE D.S. (FRACT)
A   DMPP.K=0                                                  (SS-168.4)
NOTE  DMPP-DELTA MAINT COST SUBSYS P DUE TO PASSIVE D.S. (FRACT)
A   DMPI.K=0                                                  (SS-168.5)
NOTE  DMPI-DELTA MAINT COST SUBSYS P DUE TO COMP ISOLATION (FRACT)
A   DMPE.K=0                                                  (SS-168.6)
NOTE  DMPE-DELTA MAINT COST SUBSYS P DUE TO COMP ELIMINATION (FRACT)
A   DMPH.K=0                                                  (SS-168.7)
NOTE  DMPH-DELTA MAINT COST SUBSYS P DUE TO MATL HARDENING (FRACT)
A   DMFVR.K=DMFS.K+DMFR.K+DMFA.K+DMFP.K+DMFI.K+DMFE.K+DMFH.K  (SS-169)
NOTE  DMFVR-DELTA MAINT COST DUE TO FUEL VULNER REDUCTION (FRACT)
A   DMFS.K=-.0005                                             (SS-169.1)
NOTE  DMFS-DELTA MAINT COST SUBSYS F DUE TO SHIELDING (FRACT)
A   DMFR.K=-.0005                                             (SS-169.2)
NOTE  DMFR-DELTA MAINT COST SUBSYS F DUE TO REDUNDANCY (FRACT)
A   DMFA.K=0                                                  (SS-169.3)
NOTE  DMFA-DELTA MAINT COST SUBSYS F DUE TO ACTIVE D.S. (FRACT)
A   DMFP.K=0                                                  (SS-169.4)
NOTE  DMFP-DELTA MAINT COST SUBSYS F DUE TO PASSIVE D.S. (FRACT)
A   DMFI.K=0                                                  (SS-169.5)
NOTE  DMFI-DELTA MAINT COST SUBSYS F DUE TO COMP ISOLATION (FRACT)
A   DMFE.K=0                                                  (SS-169.6)
NOTE  DMFE-DELTA MAINT COST SUBSYS F DUE TO COMP ELIMINATION (FRACT)
A   DMFH.K=0                                                  (SS-169.7)
NOTE  DMFH-DELTA MAINT COST SUBSYS F DUE TO MATL HARDENING (FRACT)
NOTE  ******************************************************************
NOTE   AIRCRAFT SURVIVABILITY TRADEOFF COMPONENT SURVIVABILITY SUBMODEL
NOTE  ******************************************************************
A   DPL.K=(PB-PM.K)/PB                                        (SS-170)
NOTE  DPL - DELTA PAYLOAD (FRACT)
C   PB=8000                                                   (SS-170.1)
NOTE  PB - PAYLOAD OF BASELINE AIRCRAFT (LBS)
A   PM.K=(((WB+PB+FB-WM.K)/FB)(2*WB+PB)-2*WM.K)/(1+((2*WB+PB)/FB)) (SS-171)
NOTE  PM - PAYLOAD OF MODIFIED AIRCRAFT (LBS)
C   WB=20000                                                  (SS-171.1)
NOTE  WB - WEIGHT (EMPTY) OF BASELINE AIRCRAFT (LBS)
C   FB=12000                                                  (SS-171.2)
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NOTE  FB - FUEL WEIGHT OF BASELINE AIRCRAFT (LBS)
A   WM.K=WB*(1-DW.K*ROTOR-DW.K*FIXED-DW.K*VTOL)               (SS-172)
NOTE  WM - WEIGHT (EMPTY) OF MODIFIED AIRCRAFT (LBS)
C   ROTOR=0                                                   (SS-172.1)
C   FIXED=1                                                   (SS-172.2)
C   VTOL=0                                                    (SS-172.3)
NOTE  CONSTANTS FOR IDENTIFYING TYPE OF AIRCRAFT USED
A   MSB.K=SB*ROTOR+SB*FIXED+SB*VTOL                           (SS-173)
NOTE  MSB - MISSION SURVIVABILITY OF BASELINE AIRCRAFT (PROB)
A   MSM.K=SM.K*ROTOR+SM.K*FIXED+SM.K*VTOL                     (SS-174)
NOTE  MSM - MISSION SURVIVABILITY OF MODIFIED AIRCRAFT (PROB)
A   SR$$M.K=(PM.K/PB)*SR$$B                                   (SS-175)
NOTE  SR$$M - SORTIE RATE OF MODIFIED AIRCRAFT (FRACT/DAY)
C   SR$$B=2                                                   (SS-175.1)
NOTE  SR$$B - SORTIE RATE OF BASELINE AIRCRAFT (FRACT/DAY)
A   A$$M.K=A$$B/(1-DM.K)                                      (SS-176)
NOTE  A$$M - AVAILABILITY OF MODIFIED AIRCRAFT (PROB)
A   $$MN.K=$$BN/(1-DA.K)                                      (SS-177)
NOTE  $$MN - NUMBER OF MODIFIED AIRCRAFT INITIALLY (AIRCRAFT)
C   $$BN=600                                                  (SS-177.1)
NOTE  $$BN - NUMBER OF BASELINE AIRCRAFT INITIALLY (AIRCRAFT)
NOTE  ******************************************************************
NOTE  ***********   ANALYTICAL SOLUTION OF ATTRITION MODEL   ************
NOTE
A   $$B.K=(((($$MN.K/B.K)*(R1.K+LAM1.K)(R1.K+LAM2.K))*(E1.K-E2.K))
X      +$$BN*((R1.K+LAM1.K)*E1.K-(R1.K+LAM2.K)*E2.K))/(LAM1.K-LAM2.K)
NOTE  $$B - NUMBER OF BASELINE AIRCRAFT AT THE END OF THE WAR (AIRCRAFT)
A   $$M.K=(B.K*$$BN*(E2.K-E1.K)+$$MN.K*((R1.K+LAM1.K)*E2.K-(R1.K+LAM2.K)
X      *E1.K))/(LAM1.K-LAM2.K)
NOTE  $$M - NUMBER OF MODIFIED AIRCRAFT AT THE END OF THE WAR (AIRCRAFT)
A   B.K=SR$$B*A$$B*(1-MSM.K)
NOTE  B - ATTRITION FACTOR OF MODIFIED AIRCRAFT DUE TO AIR THREAT
A   R1.K=SR$$B*A$$M.K*(1-MSM.K)
NOTE  R1 - ATTRITION FACTOR OF MODIFIED AIRCRAFT DUE TO SURFACE THREAT
A   C.K=SR$$M.K*A$$M.K*(1-MSB.K)
NOTE  C - ATTRITION FACTOR OF BASELINE AIRCRAFT DUE TO AIR THREAT
A   R2.K=SR$$B*A$$B*(1-MSB.K)
NOTE  R2 - ATTRITION FACTOR OF BASELINE AIRCRAFT DUE TO SURFACE THREAT
A   LAM1.K=(-(R1.K+R2.K)+SQRT((R1.K-R2.K)*(R1.K-R2.K)+4*B.K*C.K))/2
A   LAM2.K=(-(R1.K+R2.K)-SQRT((R1.K-R2.K)*(R1.K-R2.K)+4*B.K*C.K))/2
A   E1.K=EXP(LAM1.K*T.K)
A   E2.K=EXP(LAM2.K*T.K)
A   T.K=CLIP((1/(LAM1.K-LAM2.K))*LOGN(Q1.K+(($$MN.K/B.K)*(R1.K+LAM1.K)
X      *(R1.K+LAM2.K)+$$BN*(R1.K+LAM2.K))/(($$MN.K/B.K)*(R1.K+LAM1.K)
X      *(R1.K+LAM2.K)+$$BN*(R1.K+LAM1.K))),(1/(LAM1.K-LAM2.K))*LOGN(Q2.K
X      +(B.K*$$BN+$$MN.K*(R1.K+LAM1.K))/(B.K*$$BN+$$MN.K*(R1.K+LAM2.K)))
X      ,$$BL1D.K,$$ML1D.K)
NOTE  T - THE TIME AT WHICH THE WAR END (DAYS)
A   $$BL1D.K=(C.K*$$MN.K+R2.K*$$BN)/$$BN
NOTE  $$BL1D - FRACTION LOST OF BASELINE AC ON THE FIRST STRIKE (FRACT)
A   $$ML1D.K=(B.K*$$BN+R1.K*$$MN.K)/$$MN.K
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NOTE  $$ML1D - FRACTION LOST OF MODIFIED AC ON THE FIRST STRIKE (FRACT)
A   Q1.K=CLIP(0,100,$$BL1D.K,$$ML1D.K)
A   Q2.K=CLIP(100,0,$$BL1D.K,$$ML1D.K)
NOTE  Q1 AND Q2 ARE CONSTANTS TO ELIMINATE THE LOG OF NEGATIVE NUMBERS
A   I$$B.K=((($$MN.K/B.K)*(R1.K+LAM1.K)(R1.K+LAM2.K))((1/LAM1.K)
X      *(E1.K-1)-(1/LAM2.K)*(E2.K-1))+$$BN*(((R1.K+LAM1.K)/LAM1.K)
X      *(E1.K-1)-((R1.K+LAM2.K)/LAM2.K)*(E2.K-1)))/(LAM1.K-LAM2.K)
NOTE  I$$B - INTEGRATION OF $$B FROM T=0 TO T=T
A   I$$M.K=(B.K*$$BN*(((E2.K-1)/LAM2.K)-(E1.K-1)/LAM1.K)+$$MN.K*((R1.K
X      +LAM1.K)*((E2.K-1)/LAM2.K)-(R1.K+LAM2.K)*((E1.K-1)/LAM1.K)))
X      /(LAM1.K-LAM2.K)
NOTE  I$$M - INTEGRATION OF $$M FROM T=0 TO T=T
A   $$BL.K=SR$$B*A$$B*(1-MSB.K)*I$$B.K+SR$$M.K*A$$M.K*(1-MSB.K)*I$$M.K
NOTE  $$BL - NUMBER OF BASELINE AIRCRAFT LOST (AIRCRAFT)
A   $$ML.K=SR$$B*A$$M.K*(1-MSM.K)*I$$M.K+SR$$B*A$$B*(1-MSM.K)*I$$B.K
NOTE  $$ML - NUMBER OF MODIFIED AIRCRAFT LOST (AIRCRAFT)
A   DPLCC.K=1-((1-$$M.K/$$MN.K)/(1-$$B.K/$$BN))
NOTE  DPLCC - DECREASED PROGRAM LIFE CYCLE COST (FRACT)
A   PDTPBL.K=2*SR$$B*A$$B*I$$B.K*PB/$$BL.K
NOTE  PDTPBL - CUMULATIVE PAYLOAD DELIVER PER BASELINE AC LOST (LBS)
A   PDTPML.K=2*SR$$B*A$$M.K*I$$M.K*PM.K/$$ML.K
NOTE  PDTPML - CUMULATIVE PAYLOAD DELIVER PER MODIFIED AC LOST (LBS)
A   IPDTPL.K=(PDTPML.K-PDTPBL.K)/PDTPBL.K
NOTE  IPDTPL - INCREASED PAYLOAD DELIVERED TO TARGET PER AC LOST
NOTE  ******************************************************************
NOTE  ***********   SIMULATION OF THE ATTRITION MODEL    ***************
NOTE  B.K=B.J+(DT)(-ARB.JK)                                   (SS-178)
NOTE  B - NUMBER OF BASELINE AIRCRAFT (AIRCRAFT)
NOTE  PRB=BUDGET/ACB                                          (SS-201)
NOTE  PRB - PROCUREMENT RATE OF BASELINE AIRCRAFT (AIRCRAFT/DAY)
NOTE  ACB=                                                    (SS-201.1)
NOTE  ACB - ACQUISITION COST OF BASELINE AIRCRAFT ($)
NOTE  ARB.KL=SRB*AB*B.K*(1-SB)+SRM.K*AM.K*M.K*(1-SB)          (SS-202)
NOTE  ARB - ATTRITION RATE OF BASELINE AIRCRAFT (AIRCRAFT/DAY)
NOTE  CLB.K=CLB.J+(DT)(ARB.JK)                                (SS-195)
NOTE  CLB - CUMULATIVE LOST OF BASELINE AIRCRAFT (AIRCRAFT)
NOTE  CPDTB.K=CPDTB.J+(DT)(PDTB.JK)                           (SS-203)
NOTE  CPDTB - CUMULATIVE PAYLOAD DELIVER TO TARGET BY BASELINE AC (LBS)
NOTE  PDTB.KL=2*SRB*AB*B.K*PB                                 (SS-204)
NOTE  PDTB - PAYLOAD DELIVER TO TARGET BY BASELINE AIRCRAFT (LBS/DAY)
NOTE  PDTPBL.K=CPDTB.K/CLB.K                                  (SS-198)
NOTE  PDTPBL - CUMULATIVE PAYLOAD DELIVER TO TARGET PER LOST (LBS/AC)
NOTE
NOTE  M.K=M.J+(DT)(-ARM.JK)                                   (SS-179)
NOTE  M - NUMBER OF MODIFIED AIRCRAFT (AIRCRAFT)
NOTE  PRM.K=BUDGET/ACM.K                                      (SS-205)
NOTE  PRM - PROCUREMENT RATE OF MODIFIED AIRCRAFT (AIRCRAFT/DAY)
NOTE  ACM.K=ACB*(1-DAC)                                       (SS-206)
NOTE  ACM - ACQUISITION COST OF MODIFIED AIRCRAFT ($)
NOTE  ARM.KL=SRB*AB*B.K*(1-SM.K)+SRB*AM.K*M.K*(1-SM.K)        (SS-207)
NOTE  ARM - ATTRITION RATE OF MODIFIED AIRCRAFT (AIRCRAFT/DAY)
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NOTE  CLM.K=CLM.J+(DT)(ARM.JK)                                   (SS-196)
NOTE  CLM - CUMULATIVE LOST OF MODIFIED AIRCRAFT (AIRCRAFT)
NOTE  CPDTM.K=CPDTM.J+(DT)(2*SRB.K*AM.K*M.K*PM.K)                (SS-208)
NOTE  CPDTM - CUMULATIVE PAYLOAD DELIVER TO TARGET BY MODIFIED AC (LBS)
NOTE  PDTM.KL=2*SRB*AM.K*M.K*PM.K                                (SS-209)
NOTE  PDTM - PAYLOAD DELIVER TO TARGET BY MODIFIED AIRCRAFT (LBS/DAY)
NOTE  PDTPML.K=CPDTM.K/CLM.K                                     (SS-199)
NOTE  PDTPML - CUMULATIVE PAYLOAD DELIVER TO TARGET PER LOST (LBS/AC)
NOTE  ************************************************************
NOTE  *******  ANALYTICAL SOLUTION OF AVAILABILITY COMPONENT **********
NOTE  ************************************************************
N   A$$B=1/(1+($$MDTN/$$MTBM)+((1-$$FRTD)*$$TTRN/$$TBFN))      (SS-210)
NOTE  A$$B-AVAILABILITY OF BASELINE $$ (PROB)
C   $$MDTN=1.0                                                   (SS-211)
NOTE  $$MDTN-$$ MEAN MAINTENANCE DOWN-TIME NORMAL (DAYS)
C   $$MTBM=3                                                     (SS-212)
NOTE  $$MTBM-$$ MEAN TIME BET MAINTENANCE NORMAL (DAYS)
C   $$FRTD=.5                                                    (SS-213)
NOTE  $$FRTD-$$ FRACT FOR REPAIR TO DEPOT MAINTENANCE (DIM)
C   $$TTRN=2                                                     (SS-214)
NOTE  $$TTRN-$$ MEAN TIME TO REPAIR NORMAL (DAYS)
C   $$TBFN=3                                                     (SS-215)
NOTE  $$TBFN-$$ MEAN TIME BET FAILURE NORMAL (DAYS)
NOTE
SPEC DT=1/PRTPER=2/PLTPER=1/LENGTH=2050
PLOT HH=1,TA=2,FF=3,EF=4,HF=5(0,2400)
PLOT XF=X,XV=V,XA=A,XS=S,TF=F,HV=H,IA=I(0,800)
PLOT HD=1,FD=2,FG=3(0,4800)
PLOT FU=U,FO=0,FK=K,FT=T,FR=R,FH=H,FX=X,FL=L,BK=B(0,1200)
PRINT HH,TA,XS,FF,EF,TF,HF,HV,IA,XF,XV,XA
PRINT HD,FT,FR,FD,FH,FG,FX,FL,BK,FU,FO,FK
PRINT CTDBXX,CTDB$$,TDPXXL,TDP$$L,KP$$L,KPXXL
PRINT USSRCV,USACV,USSRAR,USAAR,USSRA,USAA
PRINT DS,DW,DA,DM,IPDTPL,DPLCC,MSM
RUN
QUIT
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