A SYSTEM DYNAMICS MODEL FOR MANAGING AIRCRAFT SURVIVABILITY

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ABSTRACT

The aircraft survivability model developed is comprised of five submodels: (1) Economy Submodel, (2) Budget Submodel, (3) Procurement Submodel, (4) Attrition Submodel, and (5) Survivability Submodel.

The economy submodel generates the annual "Gross National Product" of the United States and "Federal Government Budget".

The budget Submodel uses the output of the economy Submodel to determine the "Department of Defense Military Budget". The DOD budget is broken down by service and function (Procurement, Operations and Maintenance, and RDT&E).

In the Procurement Submodel, the "Procurement Budget for Combat Aircraft" determined in the Budget Submodel is used to generate the parameters: "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 by the outputs of the Procurement Submodel over years of peacetime are reduced in wartime through the "Attrition Rate for Combat Aircraft", which depends on the number of "Combat Aircraft", the "Sortie Rate for Combat Aircraft", "Mission Survivability for Combat Aircraft", and the "Availability of Combat Aircraft".

The Survivability Submodel outputs are the "Mission Survivability for Combat Aircraft" and the "Availability of Combat Aircraft". The former is the product of the "Susceptibility of Combat Aircraft" and "Vulnerability of Combat Aircraft", both of which depend on the magnitude of the "Aircraft Survivability RDT&E Budget" outputed from the Budget Submodel. Reductions in the "Susceptibility of Combat Aircraft" and "Vulnerability of Combat Aircraft" affect the "Acquisition Cost of Combat Aircraft" and "Modification Cost of Combat Aircraft" used in the Procurement Submodel.

Additional feedback loops between the submodels are generated by monitoring the "Relative Strengths of U.S.S.R./U.S. Airpower" and incorporating the effects of this perception on the Economy Submodel, the Budget Submodel, the Procurement Submodel, and the Survivability Submodel. Thus, the five submodels interact to form a series of interacting positive and negative feedback loops. The positive loops reinforce themselves leading to increased air power over time. The negative loops act through such constraints as resource availability and spiraling procurement costs to suppress the growth of air power.

INTRODUCTION

The U.S. lost 2561 fixed wing aircraft and 2587 helicopters in the Viet Nam War [1]. As a result of the attrition rates in Southeast Asia, the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) was established in the 1970's. The JTCG is chartered to coordinate the non-nuclear survivability research and development effort within the three services (the Army, the Navy, and the Air Force) of the Department of Defense.

This year the Virginia Polytechnic Institute and State University was awarded a research grant to develop and implement a survivability management model for use by advanced program planners. The model is to detail the essential survivability management parameters and their causal relationships throughout the life cycle of aircraft systems, and demonstrate the feasibility of obtaining a desired level of functional capability through a given approach and the connection between current needs and future returns. Other aspects will include the forecasting of macro-behavior, predicting consequences of proposed actions and failure to act, and the conducting of sensitivity analyses to establish research and data gathering priorities, as well as providing aids to communication among those concerned with survivability issues and in their understanding.

Aircraft combat survivability is defined by the United States Department of Defense as "the capability of an aircraft to avoid or withstand a man-made hostile environment without sustaining an impairment of its ability to accomplish its designated mission" [2]. From this definition, the broad scope of the concept of survivability is evident leading the JTCG 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 military services and industry, as well as within the services.

This research effort is organized into three phases of which this paper, the development of a pilot model, covers a significant portion of the first phase. This phase is being accomplished using information available in unclassified material and through discussions with key personnel in the survivability community. Emphasis during Phase 1 will be on the content and structure of the model rather than on calibration. Phase 1, then, is directed to demonstrating the usefulness of the approach.

Based on insights obtained during Phase 1, insights into the problem on the part of the contractor and insights into the methodology on the part of the sponsor, the detailed requirements of the final model will be determined for completion during Phase 2. Phase 3 will address itself to implementation of the research by placing the package on a computer designated by the JTCG and the scheduling of a series of workshops and short courses in the use of the model for the benefit of personnel throughout the survivability community. By the end of Phase 3, the JTCG Survivability Design Laboratory will be fully operational. It is estimated that the total three phase research effort will require three years.

OVERVIEW OF THE MODEL

Fig. 1 is a conceptualization of the JTCG Aircraft Survivability Model that is being developed in 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 are used to communicate the underlying structure of the survivability phenomenon. In Fig. 1 a few of the key parameters are identified and the interactions between the parameters displayed using arrows (solid or dashed) and signs (plus or minus). Since arrows denote the direction of causality, the two basic types of parameters--constants and variables--are easily distinguished. A parameter with only arrows emanating from it is a constant. Three types of variables used in system dynamics are also apparent. Level or state variables appear at the heads of solid arrows. Rate or change variables appear at the tails of solid arrows. Other variables are auxiliary variables. The signs on solid arrows tell whether the rate adds to or subtracts from the level variable. Signs on the dashed lines tell whether the parameters at each end of the arrow vary directly or inversely.

Starting in the upper left corner of Fig. 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". Relationships between parameters depicted in the causal diagram greatly facilitate writing the equations for the mathematical version of the computer model. Thus, "Federal Government Budget" must either be the sum or product of "Gross

National Product" and "Fraction of GNP to Government Budget". Dimensional analysis rules out the former.

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 "Sortic 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. 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. airpower, 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. 1 are treated individually and in more detail.

THE DEFENSE ECONOMY

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 the 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) [5]. 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 than air transportation) [6] [7].

DEFENSE MANAGEMENT

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 [17].

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

NATURE OF DEFENSE PROCUREMENT

Military decisions may be classified by kind as well as by level. It is useful to distinguish: operations decisions (strategy and tactics), procurement or force composition decisions, and research and development decisions. The basic difference among these kinds of decisions, from the point of view of analysis, is the time at which the decision affects the capability of the military forces concerned. An operations decision can affect capability almost immediately. A decision to procure something, on the other hand, cannot affect capability until the thing procured has been produced and fitted into operational forces. Finally, decisions to develop something based on researching it tend to affect capabilities at an even later date--after the system has been developed, procured and fitted into

operational forces. In this section we shall consider the procurement function.

Basically the inventory of each of 23 combat 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.

Having treated budgets for acquisition and modification of aircraft, it remains to consider costs. The positive side of technological substitution--lower casualty rates and a more efficient military--has not come cheaply. U.S. tactical air power is perhaps the purest example of this trade-off. The extent of the problem is easily illustrated. During the peak procurement year of World War II (1943) the Army Air Corps committed $2.5 billion to purchase tactical aircraft: fighters and light and medium bombers of a dozen popular types. For fiscal year 1975 the Air Force requested $1.1 billion to buy modern airplanes for the same tactical purposes. The difference is that in 1943 the Air Corps got 25,000 planes for its money; in 1975 the Air Force got 100. The average cost of a tactical warplane procured increased from $100,000 in 1943 to $11,000,000 in 1975 [22]. Recent comparisons are no more heartening. Cost data on the 55 major weapons systems being produced by DOD in 1980 showed them to be 45% higher than the original estimate. New tactical fighters for the air force and navy will run from a low of about $11 million per plane for the F-16 to a high of about $24 million per unit for the F-14A. Even the navy's "low cost" fighter, the A/F-18, will cost over $17 million a piece.

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 [23].

Therefore, as we have stressed before, analysis focused on procurement decisions, of necessity, will have to consider technological developments and design alternatives on the one hand and operations--the strategy and tactics with which each aircraft will be used when it is deployed--on the other. In the modeling effort this is accomplished by tieing the Procurement Submodel 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. As to the Procurement-Attrition interaction, referring to Fig. 1, we see they are merely different aspects of the aircraft inventory adjustment process. Attrition is considered in the next section.

TACTICAL AIR POWER

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 [2][3]. 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.

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 Submodel S-1 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. Again 23 aircraft types have been chosen. The U.S. aircraft and the U.S.S.R. aircraft were selected to cover a variety of missions for the different services [24]. The demands of air combat tend to force distinct designs on aircraft intended for differing tactical roles. Basically, tactical airpower can be dedivided 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 long- and short-range component.

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. Surface-to-surface interchanges, while important, are beyond the scope of this research.

SURVIVABILITY ENHANCEMENT TRADE-OFFS

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. 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, 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 [28]. 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. 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.

The basic vulnerability reduction concepts incorporated into the model 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" [2]. 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".

In the previous section we alluded to the relative fragileness of ground air defense weapons. The ability of combat aircraft to protect themselves is referred to in the literature as "self-defense systems" [2]. 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.

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.

MANAGING TECHNOLOGICAL SUBSTITUTION

One of the great ironies of the civil efficiency/military effectivenesses mismatch is the contradictory ways in which new technology is viewed in different environments. Applied in industry it is referred to as progress; employed in the military it is called "gold plating". American defense planners have long assumed, properly, that U.S. weaponry must be technologically superior to the Soviet Union's. Spending on technology makes sense in our military, just as in the private sector, because it is typically a substitute for people, and in our society people is a more valuable resource than capital. Some economy-minded defense reformers have failed to see the weapons-evolution phenomenon for what it really is--the same technological substitution trend that is taking place across society.

Waging war is no different in principle from any resource transformation process, and improvements should be pursued just as vigorously as for farming, mining, manufacturing and construction. If anything, automation within the military makes even more sense than in other sectors where human labor is consumed only figuratively.

PURPOSE OF THE MODEL

How well is the JTCG/AS responding to its Charter? Fundamentally, the JTCG/AS is a coordinating group with the responsibility of external coordination within the Services and among the Services and industry. Equally important is internal coordination between its Subgroups, to insure mutual support in the overall goal of survivability advancement and standardization of methodology to evaluate overall effectiveness of survivability alternatives for various aircraft systems and aircraft missions, as required by decision-makers. Even though it is known that the JTCG/AS program has resulted in direct cost savings during peacetime operations in addition to the obvious benefits to be realized during a war, there still does not exist one commonly accepted way of measuring the impact of all survivability efforts during wartime. It is impossible to compare quantitatively alternative projects, efforts, and benefits of resource allocations, making strategic planning more arbitrary and less rational than is desirable.

There exists a need to develop a coordinating instrumentality, detailing interrelationships for use by the various organizations in the survivability community in their deliberations on future activities. This modeling effort is directed to the fulfillment of this need.

In order to serve the JTCG/AS in the management of survivability related activities in the Department of Defense, the model is conceived, and is being developed, for several interrelated general purposes: technical evaluation, doctrinal evaluation, force-structure analysis, defense economy assessment, and for pedagogical uses--all based on survivability considerations and trade-offs. For the purpose of technical evaluation, the model is aimed at the weapons' level--both current and projected components and systems; analyses of doctrines and force structure are directed toward the impact of survivability decisions on tactics and strategy, the coordination of weapons systems, command, control and communication systems, and the structure of forces. At the technical level, we are interested in the relationship between susceptibility and vulnerability reduction and survivability enhancement. The effect on the number of aircraft required for different missions would be a typical question for doctrinal evaluation. Force structure evaluation issues for the model are concerned with problems

of "product mix"--how many of what aircraft types under survivability alternatives? All three of the above purposes assume given U.S. and U.S.S.R. military/economic environments; which, though "given", can still yield insights into the limits of the problem when ranges of conditions are selected to create optimistic and pessimistic alternatives for the future.

USES OF THE MODEL

In fulfilling the above objectives, the model is used to perform analysis, diagnosis, and operations. Three distinct levels of use may be identified conforming to the three levels of defense economics described earlier in the report. The first, for high-level, strategic decision making, is exemplified by the economic-political-military exercise. It is the part of the JTCG/AS Model contained in the Economy and Defense Budget Submodels that is generally accepted as providing the inputs and constraints to the survivability community. One tempted to question the need for modeling a level above the survivability decision making responsibilities should devote their attention to Fig. 1. It is evident that decisions made regarding survivability management affects relative U.S. and U.S.S.R. force structures and strengths which in time influence government and DOD budget allocations that determine survivability funding.

The second-level deals with decisions for which the survivability community has either complete responsibility or direct input to a higher echelon. In the model it is incorporated in the Procurement Submodel and Survivability Submodel. The third-level of model-use addresses itself to the bureaucratic, operational and scientific activities usually associated with survivability. It is at the interface of scientific and advisory functions with operations--often not concerned with immediate applications but with building a supply of basic knowledge. It is to be incorporated into the model by partitioning the Survivability Submodel into Susceptibility and Vulnerability Components, and developing these to a level of detail consistent with the state-of-the-art and management requirements.

Several figures-of-merits used to define the trade-offs associated with aircraft design or usage alternatives were discussed in the Survivability Enhancement Trade-offs Section. Two shortcomings of these parameters are the lack of a means for comparing relative strengths and failure to consider the time dimension. Some of the parameters such as "losses per target killed" and "number of sorties per aircraft lifetime" address themselves to overcoming these shortcomings but do not go far enough and are seldom used anyway because of the emphasis on cost-effectiveness figures-of-merit required to support or defeat the spending arithmetic of advocacy models.

Referring to Fig. 1, the "merit rating system" used to generate feedback response at the various decision making levels is "Relative Strengths of U.S.S.R./U.S. Air Power". Eventually this MRS parameter will combine several appropriate figures-of-merit, but at present it is limited to two: (1) "Time After D-Day when Sorties Per Day for U.S. Combat Aircraft Equals Sorties Per Day for U.S.S.R. Combat Aircraft" and (2) "Time After D-Day When Total Sorties Flown by U.S. Combat Aircraft Equals Total Sorties Flown by U.S.S.R. Combat Aircraft" (see Fig. 2). While these two figures-of-merit are based on the rather conventional sortie rate and sortie capability FOM's, they are superior because they consider Soviet air power and are time sensitive. What is depicted in Fig. 2, is an indication of how long,

for two different strategies tied to mission survivabilities of .977 and .984, that it would take the U.S. to achieve air superiority as measured by some weighted average of the two time parameters. Note that in both cases, the mission survivability probabilities for the average of all U.S. combat aircraft is higher than the mission survivability probability for the average of all U.S.S.R. combat aircraft, which is .954. In the next section the role of scenario generation in the use of the model as suggested in Fig. 2 will be discussed.

SCENARIO ANALYSIS

Aircraft combat survivability development, design and management is technological substitution in its purest form. The question is not, is it good or bad, but how much. We do not believe that this question can be properly answered using current survivability assessment techniques and evaluation methodologies. We think that it can be properly addressed using the JTCG/AS Management Model in one of its many uses.

Both of the super powers are engaged in similar resource allocation problems in deciding how military spending should be apportioned to R&D, O&M, and procurement. The allocations are the decision variables used to influence the inevitable quality/quantity trade-offs in the acquisition and modernization of their weapons systems. Traditionally the U.S. has opted for quality and the Soviets, quantity--consistent with their relative technological capabilities and (some would say) their respective attitudes as to the importance of human life. However, even if the Soviet technological capability continues to lag that of the U.S. in the future, it is evident that the range of options available to each side will overlap. How, then, should each side, go about making its allocation?

In the context of the scenario generated in Fig. 2, we are not saying that average mission survivability for Soviet combat aircraft is and will remain .954, for example; we are saying that if it is, and if we choose a strategy that can be identified as one in which the average mission survivability of our combat aircraft is .977--a strategy assumed to be available to us--then we can expect the parameter values shown for the two figures-of-merit after D-Day. Several other simplifying but not necessarily unrealistic assumptions have been made in the scenario analyses summarized in Fig. 2. First of all, looking at the ordinate axis at time "present", one sees that the inventory of Soviet combat aircraft is one-and-one-half that of the U.S. Two U.S. strategies are investigated: Strategy 1 in which the U.S. strives to match Soviet production so as to maintain the status quo in numbers and in superior survivability (.977 to .954) and Strategy 2 in which the U.S. acquires less aircraft at an enhanced survivability of .989. At D-day, under strategy 1 the U.S. has two-thirds the combat aircraft of the Soviets; under Strategy 2, the U.S. has one-third the combat aircraft of the Soviets. In preparing for the D-Day showdown all resource inputs are the same--for the U.S.S.R. and the U.S. under either strategy. Only the resource allocations have been varied between procurement, O&M, and R&D so as to produce the relative aircraft quantities and qualities (survivability probabilities) shown.

What can we conclude from the two scenarios depicted in Fig. 2--Scenario 1 which pits U.S. Strategy 1 against the U.S.S.R. Strategy and Scenario 2 which matches U.S. Strategy 2 against the U.S.S.R. Strategy.

Assuming that both strategies are within American technological capabilities (a hardware consideration), which do we choose (a software consideration)? We believe that the answer to this depends on interpreting the results in the context of a value system that takes into account the theatre of operations and national security priorities. It requires extending our scenarios to include the environments in which these strategies are to operate.

The common denominator for the U.S. in responding to threats is control of the air. However, as seen in Fig. 2 the concept of air superiority is elusive. Consider U.S. Strategy 1, while after 17 days the number of sorties per day flown by each side is the same. It is not until the 48th day that the U.S. catches up to the U.S.S.R. in the total number of sorties flown--at which time the U.S. sortie rate is approximately twice the U.S.S.R. sortie rate. For strategy 2, the critical times are 32 days and 118 days with overwhelming air superiority by the latter date (assuming the availability of supplies). The ordinate scale in Fig. 2 has been normalized so that aircraft ratios rather than numbers can be used, making the relationships applicable to different theatre scenarios where numbers will differ. The point is: what penalty does the U.S. incur in the time it takes to achieve air superiority and what good does it do after it has? While the parameter values may be roughly the same in each theatre-scenario, the answers to these questions will depend upon what is at stake in each theatre.

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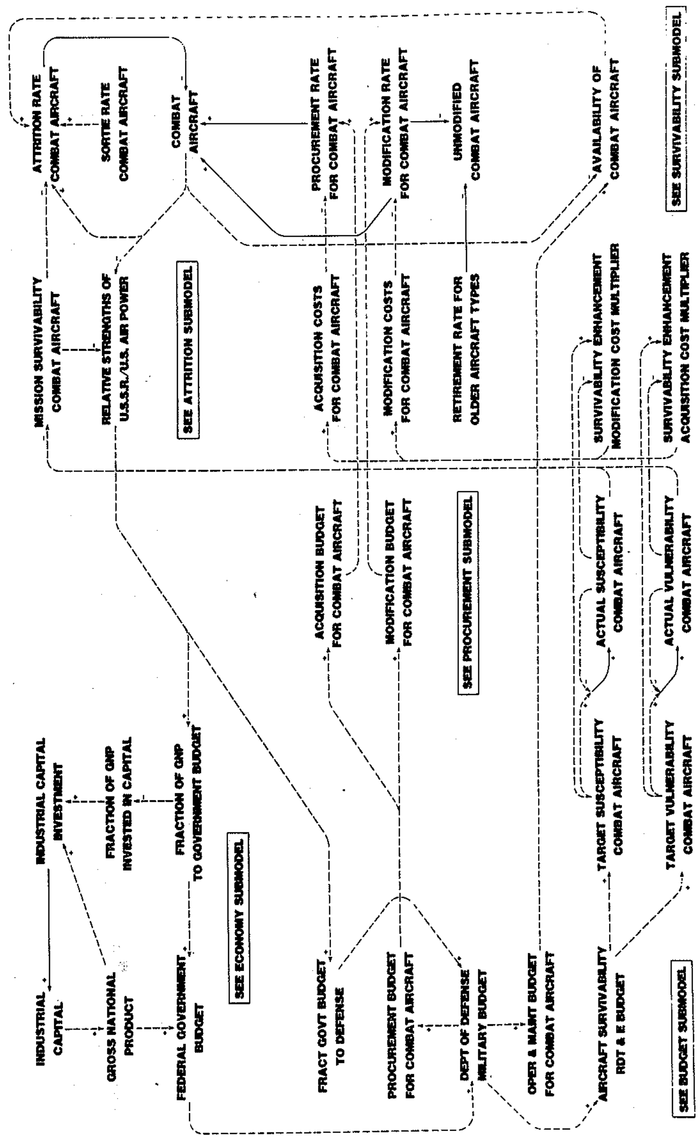
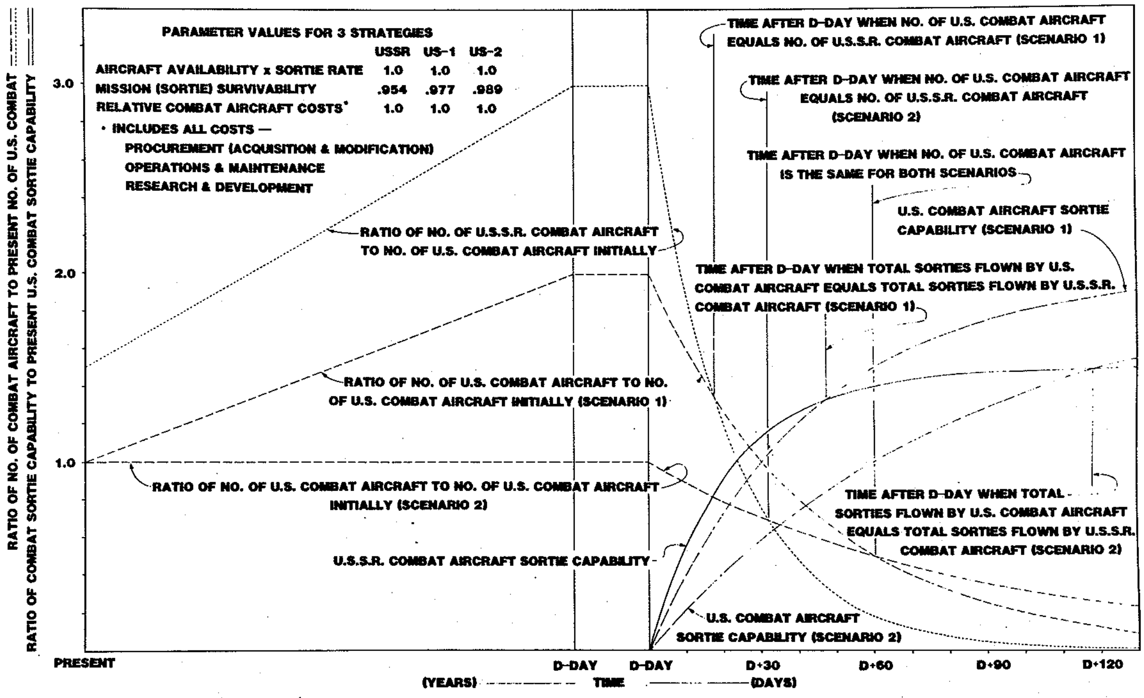


STRUCTURE OF JTCG AIRCRAFT SURVIVABILITY MODEL

FIG 1



COMBAT AIRCRAFT SURVIVABILITY ENHANCEMENT SCENARIOS

FIG 2

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