DEFENSE WEAPONS ACQUISITION: A SYSTEMS STUDY

by

Thomas D. Clark, Jr., DBA
Air Force Institute of Technology

Edward L. Whitenberg, MS
Air Force Technical Evaluation Center

Alan H. Woodruff, MS
Joint Cruise Missile Program Office

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DEFENSE WEAPONS ACQUISITION: A POLICY STUDY

During the latter stages of the administration of Jimmy Carter and the beginning of the Reagan administration, there has been an increasing emphasis on developing the United States' defense capability. The motivation for this has been a perceived imbalance between Soviet-Eastern European military capability and that of the United States and its allies. The key to an effective and appropriate buildup in military capability is the management and procurement system used to identify those weapons truly required, purchase them, and bring them to effective operational status.

A great deal has been written about the Department of Defense system designed to accomplish acquisiton (8,9,14). The majority of the material has been descriptive with occasional prescriptive, intuitive analysis. The popular press contains continual reports of the debates about various acquisition policies. A number of alternative acquisition policies have, in fact, been tried in the last two decades.

During this period, three major policy revisions have been introduced. In the 1960's then Secretary of Defense Robert MacNemara introduced a new organizational structure to centralize the decision making process for acquisition (7:3). Included in the structure was the Planning, Programming, Budgeting System (PPBS) and a strong systems analysis group within the Department of Defense (7:94). In 1971, then Deputy Secretary Vance Packard introduced ten major policy elements to

begin decentralization of responsibility and authority for acquisition management, and to reform the acquisition process (4:2). Secretary Packard established the Defense Systems Acquisition Review Council (DSARC) and directed publication of DoD Directive 5000.1 to codify the DSARC system and new acquisition guidelines (4:2).

The 1981 Acquisition Improvement Initiatives, directed by Deputy Secretary of Defense Frank Carlucci, provide for "controlled decentralization" of program management decisions, closer ties between DSARC and PPBS, and reduction of acquisition cost and time through a number of initiatives including Multiyear Procurement, and Preplanned Product Improvement (3). DoD policies provide guidance, in the aggregate, for acquisition system operation and the decision structure to be used by acquisiton managers, from the Defense Acquisition Executive to individual element managers, in managing acquisition programs. Each policy revision changed large parts of the existing structure and were designed to control more effectively the acquisition system under the conditions then existing. The frequent major changes in acquisition policy highlight a continuing need for policy makers to be able to study the effects of a policy before implementation, and to study the effects of a changing defense environment on the system.

The tools characteristically available to the policy maker have been judgment, intuition, experience, and analytical analysis of segments of the acquisition system. The acquisition system, however, is large and complex, containing myriad interrelationships between its components. This complexity makes it difficult for a policy maker to visualize and understand the complete system. In addition to direct relationships, a complex information feedback system has been created which provides second and higher order feedback effects throughout the acquisition system.

Forrester and others have shown the value of dynamic policy models of complex systems in providing a method to amplify intuition, judgment and experience, and to augment and direct analytical study (5;12). A valid policy model of the DoD acquisition system did not exist prior to development and implementation of the three major policy initiatives previously discussed. Such a model of the system's decision, information, and policy structures will enable senior DoD executives to study the effects of policy and of environmental changes on the system over time. A policy model also will provide a vehicle for executives and politicians to use in analyzing the dynamic nature of the acquisition process.

The research reported in this paper was directed toward understanding and modeling acquisition policy within the DoD. The acquisition model presented was developed at the departmental level and primarily is intended to portray the strategic policy structure of the acquisition system. Lower levels of aggregation were used only where the detail involved was required to capture a major concept. The model parameters and outputs were designated to show what trends would be associated with the implementation of various policy

alternatives.

Emphasis was placed on the dynamic nature of the relationships within the acquisition system and how they are affected by policies and external pressures. Exogenous factors input to the model include broad representations of the United States and Soviet economic conditions. The Soviet threat, so key to many of the political battles surrounding weapon acquisition, is generated in the model as a response to the threat perceived by them, subject to economic and political constraints. Incorporation of these and other key relationships was controlled through careful application of a design methodology.

RESEARCH METHODOLOGY

The research strategy used in the study involved an "iterative" process of conceptualization, analysis and measurement, and modeling. This process generally is known as the systems science paradigm (13). Each iteration increases confidence in the model as a useful policy analysis tool. Application of the paradigm in this study involved seven specific steps.

First, a broad-based conceptual structure using information available in the literature was developed. Then, participants at various executive levels in the acquisition system were interviewed. These interviews were used to evaluate the initial conceptual structure and to acquire specific information for use in formulating a parametric model.

The third step involved revising the conceptual structure and dividing the system into sectors for detailed analysis and measurement. In the fourth step, the sectors were mathematically modeled, each part tested, and integrated into a single model of the system. In the fifth step, a second series of interviews with executives and other system participants was performed. These were directed toward evaluation of the model's specific mathematical structure and formulation.

Based on the second round of interviews and further analysis of the parametric data gathered, the model was revised. Then, confidence building tests outlined by Forrester and Senge were performed (6). These verification and validation tests will be discussed specifically in a later section. The seventh step was performance of policy experimentation to illustrate how the model can be used. The remainder of the paper contains discussion of the results of the application of the methodology.

SYSTEM STRUCTURE

The DoD acquisition system has several major components or dimensions with a series of complex interactions between these components. The causal diagram of Figure 1 depicts the major components identified through literature research and in executive interviews as the key factors or sectors in the acquisition system. The diagram, drawn at a very high level of resolution, is interpreted by stating the hypothesized relationship between two variables: as variable "x" increases variable "y" increases/decreases. Increases are indicated by a positive sign (+) and decreases by a negative sign (-). This initial view was developed in greater detail in successive

iterations of the modeling process (19). The diagram was developed by first identifying the key process to be studied, and then identifying the primary forces or elements in the process that impact the operation of the system. The five sectors shown, Research & Development, Threat, Technology, Production, and Financial, correspond to the key processes in the acquisition system. Each will be discussed.

Place Figure 1 about here

Any system study requires careful definition of the purpose or goal against which system accomplishments are measured. This is particularly difficult in a complex, multilevel system like the one here. At the national level, the goal of the system is to provide the weapons necessary for the defense of the United States and for a deterrent against aggression by enemy forces. The necessity for weapons is the continually debated issue that drives acquisition and is related primarily to the perception of threat, particularly from the Soviet Union. This goal and the resulting forces for its accomplishment are embodied in the "pressure for acquisition" variable shown in Figure 1. Operationalizing the goal involves the dynamics required to maintain the parity in an aggregate measure of capability between United States and enemy forces. The Soviet Union was used as the enemy force for comparison of capability in the model, since the Soviets are the most frequently cited threat when total force comparisons are made (18: Ch II).

Capability is a somewhat abstract concept that can have many definitions and units of measurement. Measuring such an abstract concept for incorporation into a mathematical model required that the measure apply to a broad range of weapon systems (have commonality) in given areas, have conceptual relevance for both the United States and enemy forces, and possess a quantitative relevance for management. A measure of capability also should reflect the resource expenditures necessary to achieve a given level of that capability. The measure chosen to represent capability was the accumulated capital investment in the acquisition and modification of weapon systems. In addition to meeting the requirements and considerations discussed, the accumulated capital investment is a measure available for both the United States and Soviet forces, and is used for relative comparison of capability by decision makers (1:7; 10:15; 17:2; 18:II-4). Use of this measurement for capability in aggregate force comparison was discussed in the second round of executive interviews and confirmed to be an acceptable representation. These measures of United States and Soviet capability provide the primary contribution to the pressure for acquisition shown in Figure 1 and provide as a result, the actual goal that drives the defense acquisition process.

The variables, "research and development (R&D) progress" and "production," represent the physical processes and attendant decision structures for the acquisition system. Research and development includes the acquisition process from program initiation to production start. Pressures and resources from

the other sectors are used in R&D to control the flow of programs in accordance with the policies or decision criteria established by defense executives. Although not shown explicitly in Figure 1, information from the R&D sector is transmitted to the technology and financial sectors. For example, the DoD budget request for R&D is transmitted to the financial sector. Programs completing R&D enter production.

The variable "production" represents the creation of capability by either producing new weapon systems or modifying existing weapons. Inputs to production from research and development result in new capability. Weapon system modification is extensive in the current system and is included in the model as an alternative to developing new weapons. The progress of R&D programs and the number of R&D programs are increased as the pressure for acquisition increases.

The pressure for acquisition is developed by comparing the long and short term forecasts of relative United States and Soviet capability and the requirement to maintain a sound defense industrial base. The calculation of enemy capability and enemy response to United States acquisition is contained in the threat sector. The enemy's capability grows to meet both the threat posed by the United States and the desire for increased influence in the world. The desire for area domination by the Soviet Union was identified in several interviews as a base pressure that will maintain force buildup even when the Soviets possess a capability advantage. The pressures created act directly on the acquisition process and indirectly affect it by impacting the amount of resources available for acquisition. These resources are developed in the variable "acquisition funds available" in the financial sector.

The financial sector provides the funds for R&D and production. The difference between funds requested for acquisition and those provided is the primary constraint on the arms race. This point will be discussed more fully in a later section. The acquisition funds available are determined from the budget request submitted by the Defense Department and the pressures which are applied to Congress that impact the appropriation of funds.

The pressures applied to the Congress reflect the nature of the political, economic, and threat environments in which the acquisition system exists. Measures for the economic and political pressures may be developed by considering the DoD budget request as a fraction of the gross national product (GNP) and the demand for non-DoD funds created by the health of the economy. The DoD budget request is determined by the estimated cost of the perceived amount of capability necessary to meet the threat. In addition to the threat and resource availability, technology was identified in interviews as a key factor impacting the progress and output of the acquisition process.

Technology here is defined as the amount of capability that can be obtained from one production unit (for example, one airplane or one tank). The units for measuring technology are capability per production unit. For a research and development program to be completed and advanced to production, the

technology being used in the program must be developed, tested and incorporated into a manufacturing design. A standard measure of the technology for a program is developed. Then, the technology advancement or the lack of it will impact the time and cost required for program R&D. Technology advancement impacts production in two ways. First, as the technology applies to weapon system advances, more capability is obtained from each production unit. Second, as the technology advances, a need will develop to modify existing forces to maintain a given capability. As shown in Figure 1, the advancement of technology has a positive impact when increased and a negative impact when reduced.

KEY SYSTEM STRUCTURES

The portion of the causal diagram shown in Figure 2 is a positive or growth reinforcing structure that depicts how arms competition would result in a rapid expansion of forces and an expenditure of forces if external constraints (outside the loop shown) were not present to restrict this growth. Constraints are imposed by the availability of resources (dollars). The constraints represent the political realities of how much a government can spend on acquisition and stimulation of research and development (7).

Place Figure 2 about here

A second key feedback structure is the goal-seeking or negative loop shown in Figure 1 by pressure for acquisition, research and development progress, production, and then back to pressure for acquisition. This loop represents a smaller and shorter-term picture of acquisition. The forces represented tend to dampen weapons buildup as the forecasts of capability begin to compare favorably with that of the enemy. A problem can develop when the comparison is with a current picture of United States force growth and a delayed picture of enemy growth that does not adequately reflect the connection between the United States production and the pressure for enemy expansion. This will be discussed more fully in a later section.

The acquisition process is composed of the four major phases shown in Figure 3: Concept Exploration, Demonstration and Validation, Full Scale Development, and Production (15:17-3; 16:4). The first three phases constitute research and development and are measured as levels of programs with the decision points between them controlling the flow of programs. Production is modeled as a pipeline delay, with the delay duration dependent upon the rate of defense capability production and the amount of capability to be obtained from each program. The concept of a program employed in the actual model is based on an aggregate representation of defense capability. The use of an average program allows all programs in the model to be treated equally, and as policies are changed, the net effect on the acquisition system recorded. The model can, however, be tailored to specific programs by manipulation of the structural parameters and equations.

Place Figure 3 about here

The rate at which programs progress to the next stage of development is contingent upon the concepts of affordability and work completion. The decision processes related to these concepts are shown in Figure 4. Affordability and work accomplishment provide a maximum rate at which programs may flow into the next phase shown in Figure 3. Only the number of programs that can be completed in the current phase and are affordable may progress.

Place Figure 4 about here

Work accomplishment is measured through the calculation of an expected time the program would take for completion if the desired level of funding is available. Accomplishment is then adjusted to reflect the actual funding available. If the funds available for research and development do not match the requirements for progression in the expected time, program schedules are stretched or contracted to make the funds required equal the funds available. These are short-run program changes that reflect the bias for program acceleration when more funds than were planned for become available and that reflect the legal requirement to not spend more money than authorized for given programs.

The affordability concept combines two key ideas: how much need exists for programs (how great is the threat) and the funding availability for the remainder of the weapon system's life. The requirement for funding availability is modeled by considering the number of programs that will be completed or cancelled in the next acquisition phase and adjusting that value to reflect the DoD desired response to the enemy threat. There is an increase in programs when there is a threat that is currently not being met or a program reduction if the forecast of United States capability is higher than required. If funding availability is projected for the next several years, then funds may be included in the Five-Year Defense Plan (FYDP) and Extended Planning Annex (EPA) for the out years. The use of information about the program flow out of one phase to influence the flow from the previous phase creates a feedback relationship between the phases that is self-regulating in nature. The system will tend toward an equilibrium flow of programs to meet the threat and funding expectations of the system. When more programs can be completed in a phase than are affordable, two alternatives are available.

The first is to stretch the programs to a "window" where they become affordable, and the second is to cancel nonaffordable programs. The alternative most often used in the system and thus primarily applied in the model is to stretch programs. The result has been eventually to increase the rate at which programs are cancelled, to spend more on the programs in the interim, and to lengthen the acquisition life cycle. This is because as acquisition time for a program extends, there is "frequently a shift in the perception of priorities, attitudes, and appreciation of the external threat," resulting in an increase in the probability of cancellation (3:60 Fig.11). This will be discussed further when model behavior is

addressed.

This section has provided a brief description of the conceptual structure of the acquisition system, two of its key feedback structures, and the approach used to model the process. The following sections contain discussions of model behavior and an example of a typical policy experiment.

MODEL BEHAVIOR

The system dynamics methodology (5; 12) and the DYNAMO language (11) were used to develop a mathematical model (Appendix A) of the DoD acquisition structure described in the last section. The model was extensively tested during its development using the procedures prescribed by Forrester and Senge (6) as a guide. All of the core tests, as well as several others, were conducted (6:226). The results establish confidence in the model as a policy analysis tool. A discussion of the results of the symptom-generation tests, which demonstrated that the model could reproduce the problem symptoms, which motivated this research, is contained in this section.

Two major symptoms which the DoD acquisition system has exhibited over the past two decades were primary motivators for this research. The first was the steady increase in the cost and time required to acquire weapon systems (18:I-4), and the second was a steadily worsening situation in the comparison between Soviet and United States military capability (18:II-5). In order to test whether the model recreates these symptoms, it was initialized to simulate the time beginning in 1970, when the

United States was considered to be twenty-five percent ahead of the Soviet Union in cumulative military investment (18:II-8). Again, cumulative investment is used as a measure of capability in the system and so was employed in the model.

To observe the behavior of the cost and time required to acquire weapon systems, two variables were defined for model output: program cost and acquisition cycle length. Program cost was defined as the average total cost of a program from start through completion of production, in base-year dollars. The base year for calculation was time zero in the model, in this case 1970. The acquisition cycle length was defined as the time required from the start of a program through delivery of the first production item. This measure approximates the time to reach initial operational capability (IOC), which is a key measure of the performance of the acquisition system, according to several interviewees. The measure in the model for comparing United States and Soviet capability is the "raw pressure for acquisition." This is the ratio between cumulative Soviet and United States military investment.

The behavior of the acquisition cycle length and program cost are shown in Figure 5. While both variables increased through the 1970's, the model shows this trend being reversed in the middle to late 1980's. To an observer of the system who only sees empirical data from the recent past, there may be a tendency to believe that the system is growing without bound and to postulate the positive feedback loop in Figure 6 as the cause of the observed behavior. In fact, Gansler (9:94) points to a

feedback system similar to this as a cause of the cost and schedule growth which have occurred in the recent past. The output for the longer term, however, indicates that there is a control mechanism actually in operation which may reverse the currently observed trends.

Place Figures 5 and 6 about here

Observation of this behavior indicates a negative rather than the positive feedback loop of Figure 6 affects long-term cost and schedule growth. As shown in Figure 7, the interaction among several negative loops is responsible for the observed behavior. At the beginning of the model run, the United States was well ahead of the Soviet Union in capability. The projection of the long run threat, however, had already begun to forecast a deficiency in United States capability. As a result, the rate of new program starts increased early in the decade while the production affordability remained low because of the observed short term threat. This resulted in a backlog of programs in research and development, causing the duration of the programs to stretch while the programs waited for a "window" in which they would become affordable.

Place Figure 7 about here

This growth in the total number of programs in progress caused the long-term threat to begin to decline by the end of the 1970's. By that time, the short term-threat had reached significant proportions, allowing the backlog of the programs to begin entering production, slowing the growth in acquisition cycle length and, in fact, causing it to be reduced in the late 1980's and 1990's. When the short-term threat improves, the cycle which started at the beginning of the model run repeats itself.

This same mechanism seems to have occurred in the actual system in the 1970's, as a 1977 Defense Science Board study found that:

> The "bow wave" effect created by too many programs in full scale development at any given time in relation to the available production funds results in an acquisition cycle for the typical defense system which is in excess of the optimum length of time and is more costly than planned or estimated (3:1).

The same study concluded that:

> The time it takes therefore to get military equipment into the hands of forces in the field is dependent almost entirely on when the money becomes available to it. It is only loosely dependent, if at all, on when the development program started, on how much gold platting there is in the decision process, or on who happens to be sitting in the Pentagon. We can change our priorities and buy one thing before another, but the average procurement rate is fixed so long as we try to buy the same number of systems (3:36).

Secretary Weinberger's annual report to Congress for fiscal year 1983 (18) compares United States and Soviet military investment accumulated over a twenty-year lifetime, which is the same as the measure of capability in the model. As shown in Figure 8, a steady increase of five percent per year in military investments, while the Soviets do the same will result in a permanent United States deficiency. On the other hand, if the United States increase is fourteen percent per year, while the Soviet increase is five percent, the present adverse trend will

be reversed and the gap will be closed in the 1990's. The behavior of the Raw Pressure for Acquisition variable in the model, as shown in Figure 9, matches the historical behavior almost perfectly, and projects future behavior somewhere between the extremes given in the Wienberger report.

Place Figures 8 and 9 about here

The reason for this behavior lies in the goal-seeking nature of the system and several negative biases that are a part of its structure. The first, and perhaps most obvious of the biases, is that Congress almost never appropriates as much money for the DoD as the President requests. This by itself would almost certainly prevent the DoD from increasing its investment spending by fourteen percent per year for the next twenty years, since even if the GNP grew at an annual rate of five percent a year, the military investment as a fraction of GNP would have to increase five fold.

A second bias is created by the duration of the programs almost always being longer than planned. As a result, more programs are cancelled than forecast, resulting in a consistent over estimation of United States capability. This estimation error causes fewer programs to be started than are needed to actually achieve parity with the Soviets. A third bias stems from the reactive nature of the acquisition system (18:I-11). The stated goal is for the United States capability to be equal to the Soviet capabilty, but as the Soviet capability grows, the reactive nature of the system results in a tendency to lag behind the objective. The final reason for the behavior observed in Figure 9 is the phenomenon of the arms race. Whenever the United States attempts to close a perceived gap in capability, an increasing threat will be perceived by the Soviet Union causing an increase in its spending and so forth. Of the four sources of negative feedback and bias, only one is within the control of defense acquisition executives: the length of the acquisition cycle and the cancellation rate for programs. To remove the other sources of bias would require a change in the structure of the current system or a modification of policy objectives. Such changes would have long-term effects which will be discussed later.

POLICY EXPERIMENTATION

An objective of all policy models is to provide a valid device for experimenting with alternatives that are intended to produce desired behavior in the referent system. In the acquistion system model, a number of policies can be tested to demonstrate its usefulness as an investigative device. For example, major questions revolve around the use of modification versus new procurement strategy, and the role of the Department of Defense in posturing the defense industrial base. Addressing such issues is beyond the immediate scope of this paper. There are, however, other questions that can be addressed meaningfully.

The previous section contained a discussion of how increasing costs of acquiring weapons resulted from a lengthening of the acquisition cycle, and how the length of the acquisition cycle played a role in the seeming inability to achieve the stated goal of parity in cumulative military investment with the Soviet Union. In attempting, therefore, to improve the behavior of the system, gaining control of the length of the acquisition cycle would appear to offer promise. To gain this control requires investigation into the causes of the acquisition cycle length. As discussed earlier, the dominant cause of the growth in cycle length was a negative feedback structure related to long-term affordability. While a negative feedback structure is goal-seeking and should therefore be self regulating, this particular structure oscillates over a fairly broad range and has a period of oscillation of three decades or more. As a result, a policy aimed at controlling the range of the oscillation of this negative feedback structure would be appropriate.

During the upswing of the acquisition cycle length, the major mechanism for causing schedule growth is that more programs are in progress than the DoD can afford to complete. The nonaffordable programs are allowed to remain in the present phase until an opportunity arises for them to continue to the next phase, creating a backlog of nonaffordable programs. The policy alternative that is most simply applied to alleviate this problem is to cancel those programs that are not affordable. The DoD Acquisition Improvement Program addresses this issue in the initiative to integrate the Defense Systems Acquisition Review Council with the Planning, Programming, and Budgeting System processes. The alternative selected for implementation provides that:

> ...programs reviewed by the DSARC will be accompanied by assurances that sufficient agreed-to resources are in the FYDP and EPA or can be reprogrammed to execute the program as recommended. DSARC review would certify the program as ready to proceed to the next acquisition stage. Affordability in the aggregate would be a function of the PPBS process (2:34).

During interviews with acquisition executives, it was found that the combination of this initiative with the initiative to increase program stability (2:4) leads to a policy of cancelling programs that are nonaffordable.

An absolute policy of cancelling all programs that do not appear to be affordable would be impossible to implement because of political constraints. A more realistic implementation would be to phase in, over some period of time, a policy of cancelling some fraction of the nonaffordable programs. Equations were structured in the model to selectively cancel programs beginning in 1982 with the model initialized to 1970.

As expected, the cancellation of programs that were not affordable had a positive effect on the system. The backlog of full-scale development and validation programs was reduced and the acquisition cycle length and program cost reduced. Figure 10 contains the model response to cancelling eighty percent of the nonaffordable programs over a period of twenty-four months.

The dashed lines show the original model behavior for comparison. The delays in the response of the acquisition cycle length and the program cost are caused by measuring both of them for programs which are being completed at the present time. Thus, for several years after the new policy is fully implemented, the programs being measured are those which spent a large part of their life cycle operating under the old policies.

Place Figure 10 about here

The experiment was repeated using ranges of other options to determine the sensitivity of the results to changes in the fraction and implementation period. The more quickly the policy is implemented, the more dramatic the resulting reductions in acquisition cycle length and program cost. Also, the larger the proportion of the nonaffordable programs cancelled, the more dramatic the results. Even a relatively modest policy of cancelling half of the nonaffordable programs, phased in over a period of four years had noticeable results. It would appear, therefore, that any effort in the indicated direction would be helpful in controlling the acquisition length and program cost.

CONCLUSIONS

A validated policy model of the DoD acquisition system has been developed and discussed. The use of the model for testing a specific policy alternative was demonstrated. As a policy analysis tool, the model can provide additional information for a policy maker to use in conjunction with intuition, experience, and judgement to evaluate the effects of proposed policy changes and the effectiveness of existing policy. The model also is a useful aid in understanding the complex interactions in the DoD acquisition system. Perhaps the most important conclusion that can be drawn from this phase of the research is that dynamic policy modelling appears to have considerable value in developing policies to more effectively control the process of acquiring weapons for the defense of the nation. The model is available for more extensive studies of initiatives to improve the acquisition process.

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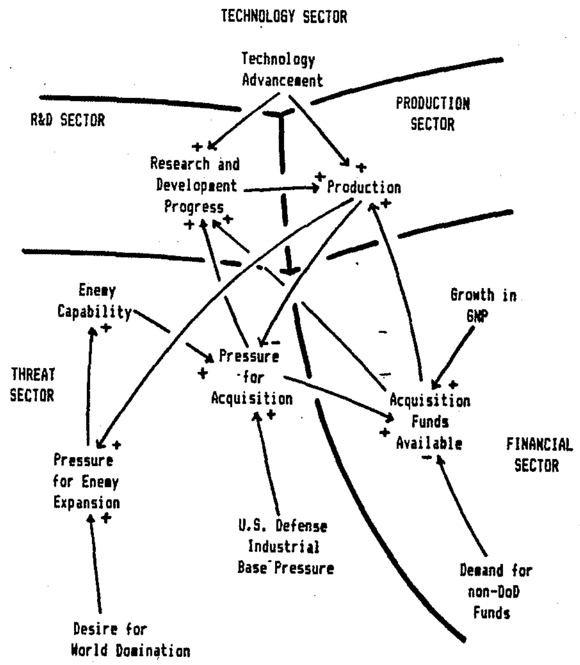

Figure 1. Causal Structure of The Acquisition System

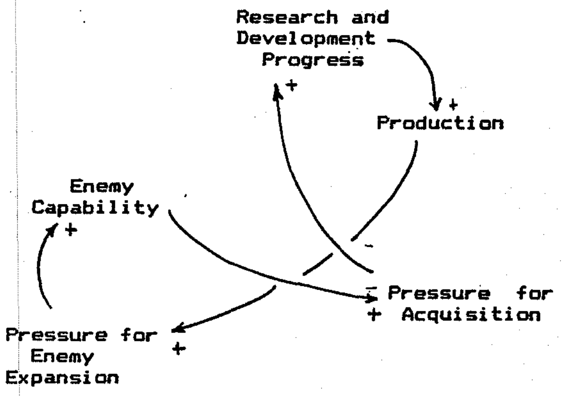

Figure 2. The Arms Race

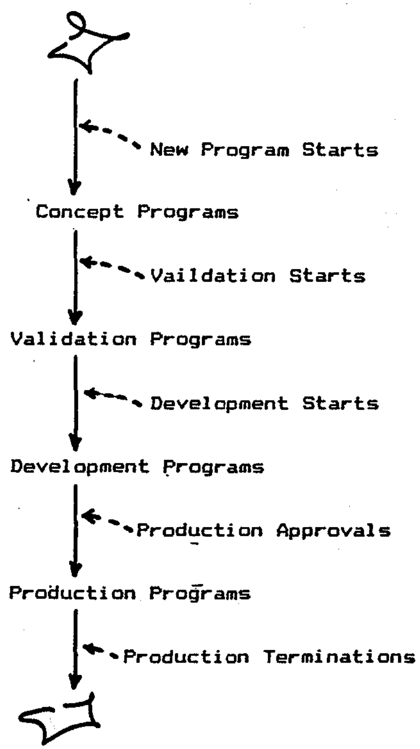

Figure 3. The Acquisition Process

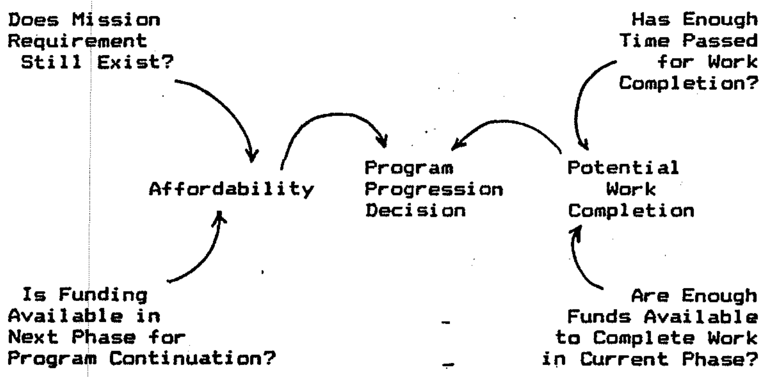

Figure 4. Program Progression Decision

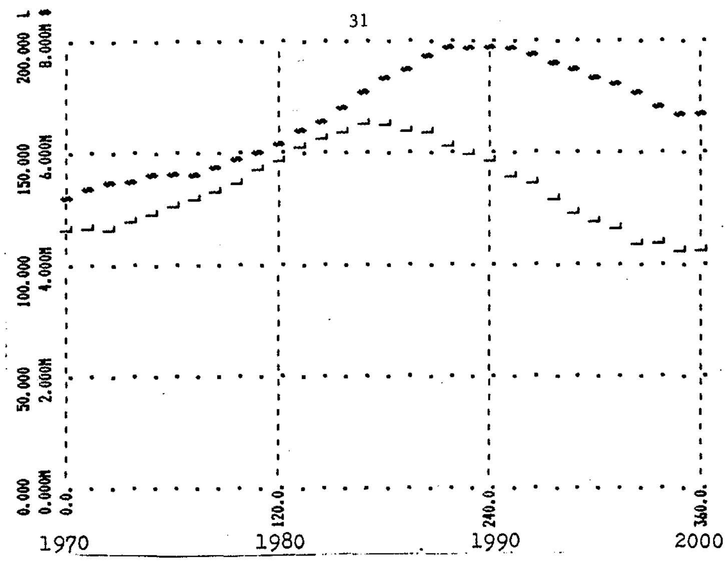

Figure 5. Model Output of Program Cost ($) and Acquisition Cycle Length (L)

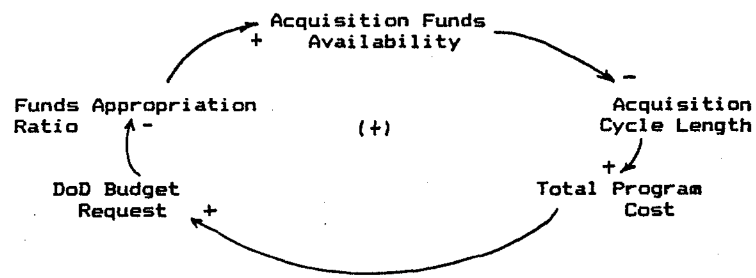

Figure 6. Cost and Schedule Growth (+)

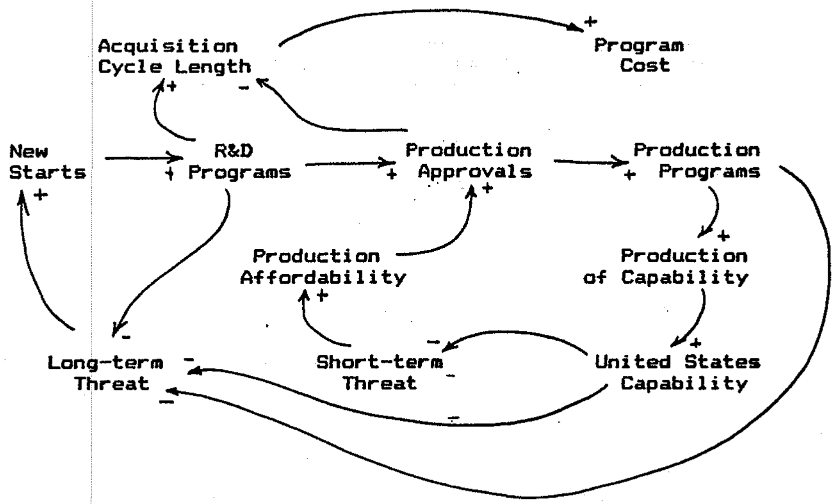

Figure 7. Causal Structure of the Cyclical Behavior of Acquisition Cycle Length & Program Cost

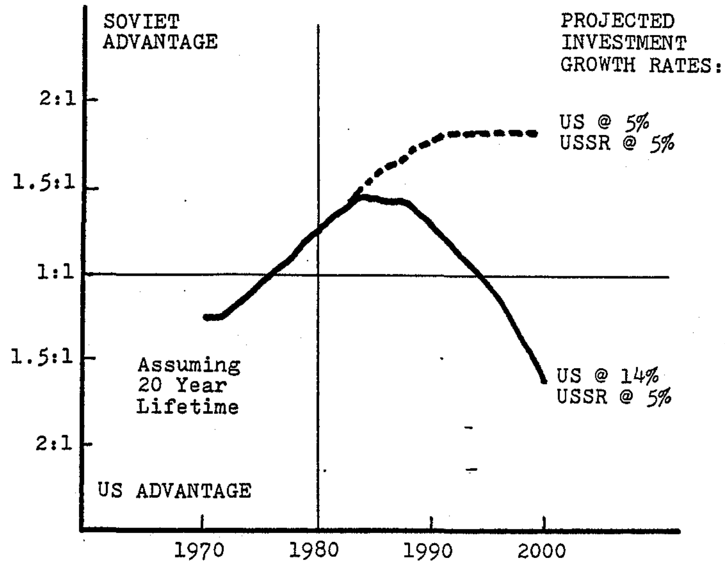

Figure 8. Ratio of Accumulated Military Investments (18:Chart II-A.2)

Figure 9. Model Output of Acquisition Pressure (S)

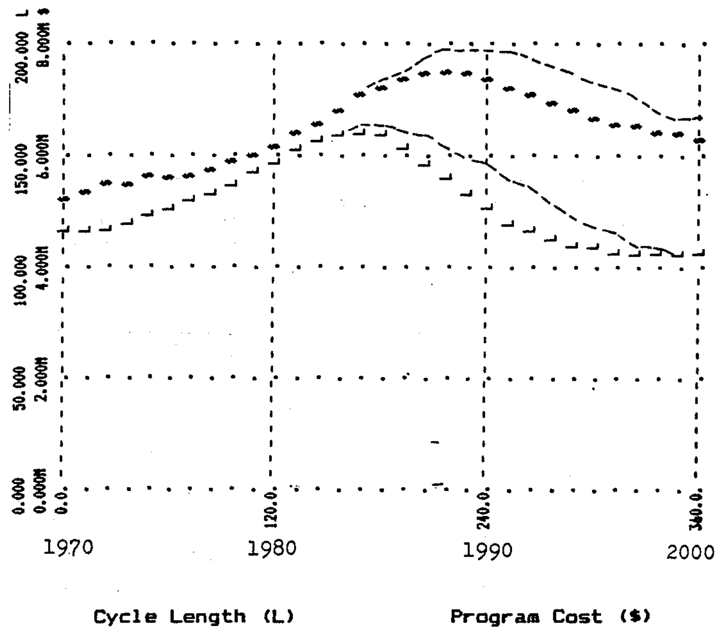

Figure 10. Policy Experimentation Results

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                      RESEARCH AND DEVELOPMENT SECTOR
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                   ********** CONCEPT PHASE **********

R  NS.KL=((PRD.K-1)*2+1)*SMOOTH(PT.JK,12)*OPF.K*SMOOTH(RDFAF.K,12)    RD1
N     NS=9.67
A      OPF.K=1+CCF.K*CDUR+VCF.K*EVDUR.K+DCF.K*EDDUR.K                 RD2
R    CCNX.KL=CP.K*CCF.K+CLIP(0,CPC.K-VAFD.K,VAFD.K,CPC.K)             RD3
N       VAFD=9.64
A      CCF.K=TABLE(CNX,CDUR,12,240,12)/12                             RD4
T       CNX=.003,.025,.035,.046,.033,.036,.052,.065,
X        .071,.075,.077,.08,.083,.086,.089,.092,.095,.098,
X        .101,.104                                                    RD5
R    VS.KL=MIN(VAFD.K,CPC.K)                                          RD6
A      CPC.K=CP.K/CDUR                                                RD7
C      CDUR=12                                                        RD8
A      VAFD.K=PRD.K*SMOOTH(VCNX.JK+DS.JK,12)                          RD9
L  CP.K=CP.J+DT*(NS.JK-(CCNX.JK+VS.JK))                               RD10
N      CP=116

  CONCEPT COSTING

L  CCOST.K=CCOST.J+DT*(INF.J*CCOST.J)                                 RD11
N    CCOST=4.17E+5

                    ******** VALIDATION ********

R    VCNX.KL=VP.K*VCF.K                                               RD12
A      VCF.K=TABLE(CNX,CDUR+VDUR.K,12,240,12)/12                      RD13
R    DS.KL=MIN(DAFD.K,PVCR.K)                                         RD14
A      DAFD.K=PRD.K*SMOOTH(DCNX.JK+PA.JK,12)                          RD15
A      EVSR.K=VP.K/EVDUR.K                                            RD16
A      EVDUR.K=DLINF3(TRDTG.K,12)                                     RD17
A      PVCR.K=EVSR.K/MAX(RDFF.K,CLIP(ARDFF.K,1,RDFAF.K,MRSF.K))       RD18
A      RDCS.K=CLIP(CSPRC,CSPRSO,RDFAF.K,1)                            RD19
A      RDFF.K=((1/RDCS.K)-1)/((RDFAF.K/RDCS.K)-1)                     RD20
A      RDCSA.K=CLIP(CSPRC,CSPRSO,ARDFAF.K,1)                          RD21
A      ARDFF.K=((1/RDCSA.K)-1)/((ARDFAF.K/RDCSA.K)-1)                 RD22
C       CSPRC=-.5                                                     RD23
C       CSPRSO=.5                                                     RD24
N       EVDUR=28
L  VP.K=VP.J+DT*(VS.JK-(DS.JK+VCNX.JK))                               RD25
N     VP=TABLE(TVP,TECHAR,6,14,4)
A      VDUR.K=VP.K/DS.JK                                              RD26
N      DS=8.44
N       VDUR=TABLE(TVDUR,TECHAR,6,14,4)
```



```
  VALIDATION COSTING

A      VCEF.K=VCM.K*VCOST.K                                           RD27
L  BVCOST.K=BVCOST.J+DT*(BVCOST.J*INF.J)                              RD28
A      VCOST.K=BVCOST.K*WSCF.K                                        RD29
A      VSLP.K=CLIP(CSPRSO,CSPRC,VDURR.K,1)                            RD30
A      VDURR.K=AVDUR.K/EVDUR.K                                        RD31
A      AVDUR.K=VP.K/PVCR.K
A      VCM.K=((VDURR.K-1)*VSLP.K+1)/VDURR.K                           RD32
N    BVCOST=8.93E+5

              ********** DEVELOPMENT PHASE ***********

N    DP=304
R    DCNX.KL=DP.K*DCF.K                                               RD33
A      DCF.K=TABLE(CNX,CDUR+VDUR.K+DDUR.K,12,240,12)/12               RD34
R    PA.KL=MIN(PAFD.K,PDCR.K)                                         RD35
N      PA=6.68
A      PAFD.K=SMOOTH(PT.JK,12)*DPFAQ.K                                RD36
A      EDCR.K=DP.K/EDDUR.K                                            RD37
A      EDDUR.K=BDDUR                                                  RD38
C      BDDUR=36                                                       RD39
A      PDCR.K=EDCR.K/MAX(RDFF.K,CLIP(ARDFF.K,1,RDFAF.K,MRSF.K))       RD40
L  DP.K=DP.J+DT*(DS.JK-(DCNX.JK+PA.JK))                               RD41
A      DDUR.K=DP.K/PA.JK                                              RD42

  DEVELOPMENT COSTING

A      DCEF.K=DCM.K*DCOST.K                                           RD43
L  BDCOST.K=BDCOST.J+DT*(BDCOST.J*INF.J)                              RD44
A      DCOST.K=BDCOST.K*WSCF.K                                        RD45
A      DSLP.K=CLIP(CSPRSO,CSPRC,DDURR.K,1)                            RD46
A      DDURR.K=ADDUR.K/EDDUR.K                                        RD47
A      ADDUR.K=DP.K/PDCR.K
A      DCM.K=((DDURR.K-1)*DSLP.K+1)/DDURR.K                           RD48
N    BDCOST=3.333E+6

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                        PRODUCTION SECTOR
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                ******* NEW SYSTEM PRODUCTION *******

R    PRODS.KL=PP.K*ROP.K*PTECH.K                                      P1
R  PCC.KL=DELAYP(PRODS.JK,PTIME,CAPIP.K)                              P2
C      PTIME=30                                                       P3
R    PROD.KL=PP.K*ROP.K                                               P4
R    NFC.KL=DELAYP(PROD.JK,PTIME,NIP.K)                               P5
N       NFC=1562.5
R    NOBS.KL=DELAYP(NFC.JK,OLTIME,SOF.K)                              P6
C      OLTIME=240                                                     P7
```

```
A      ROP.K=DROP.K*MIN(PFF.K,CLIP(APFF.K,1,PFAF.K,MRSF.K))         P8
A      PFF.K=TABLE(TPFF,PFAF.K,.2,2.0,.1)                           P9
A      APFF.K=TABLE(TPFF,APFAF.K,.2,2.0,.1)                         P10
T       TPFF=.07,.215,.295,.38,.48,.58,.69,.82,1.0,1.065,1.13,
X       1.19,1.25,1.305,1.36,1.41,1.46,1.51,1.56                    P11
A      DROP.K=SOB.K/EPD.K                                           P12
A      EPD.K=BPD                                                    P13
C       BPD=60                                                      P14
A      SOB.K=CPP/PTECH.K                                            P15
C       CPP=100                                                     P16
R    PT.KL=DELAYP(PA.JK,PDUR.K,PP.K)                                P17
N      PT=6.68
A      PDUR.K=SOB.K/ROP.K                                           P18
N      PDUR=60

     NEW SYSTEM PRODUCTION COSTING

L   PCOST.K=PCOST.J+DT*(PCOST.J*INF.J)                              P19
A      PECR.K=TABLE(TPECR,ROP.K/DROP.K,.1,1.6,.1)                   P20
T       TPECR=1.45,1.4,1.35,1.3,1.25,1.2,1.15,1.1,1.05,1.0,1.05,
X       1.1,1.15,1.2,1.25,1.3                                       P21
N       PCOST=3.5E+6

        ******** FORCE MODIFICATION CALCULATION *******

A      OPTECH.K=UCAP.K/SOF.K                                        P22
A      OTGAP.K=TECHAV.K-OPTECH.K                                    P23
C       MODTGF=.05                                                  P24
A      FMODT.K=NMODT.K/DPFAQ.K                                      P25
C       NMODT=240                                                   P26
A      DMODS.K=SOF.K*OTGAP.K*MODTGF/FMODT.K                         P27
R    MODS.KL=DMODS.K*MIN(PFAF.K,CLIP(APFAF.K,1,PFAF.K,MRSF.K))      P28
R    MODC.KL=DELAYP(MODS.JK,MTIME,MODIP.K)                          P29
N       MODS=62.5
N       DMODS=62.5
C      MTIME=24                                                     P30

           ****** US CAPABILITY COMPUTATION ******

R    UOR.KL=DELAYP(PCC.JK+MODC.JK,OLTIME,UCAP.K)                    P31
N     UOR=625
N     PCC=562.5
```



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                          FINANCIAL SECTOR
  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

              ****** FUNDING REQUIREMENTS ******

           R&D

A      CFR.K=CP.K*(1+((PRD.K-1)*(BDT+6)/CDUR.K))*
X       CCOST.K*12*(1+PINF.K)*MRF                                   F1
C      MRF=1.0                                                      F2
A      VFR.K=VP.K*(1+((PRD.K-1)*(BDT+6)/EVDUR.K))*
X       VCOST.K*12*(1+PINF.K)*MRF                                   F3
A      DFR.K=DP.K*(1+((PRD.K-1)*(BDT+6)/EDDUR.K))*
X       DCOST.K*12*(1+PINF.K)*MRF                                   F4
A      RDFR.K=CFR.K+VFR.K+DFR.K                                     F5
A      RDBR.K=DLINF3(RDFR.K,BDT)                                    F6
C      BDT=12                                                       F7

           PRODUCTION

A    PFR.K=((PP.K*(1+((DPFAQ.K-1)*(BDT+6)/EPD.K)))*PTECH.K*DROP.K
X       +SMOOTH(DMODS.K,STIME)*MODCF)*PCOST.K
X       *12*(1+PINF.K)*MRF                                          F8
C      MODCF=1.2                                                    F9
A      PBR.K=DLINF3(PFR.K,BDT)                                      F10

           O&S

A      OSFR.K=UCAP.K*CAPGF.K**(BDT+6)*OSCF.K*12*(1+PINF.K)          F11
A      CAPGF.K=1+SMOOTH(ICAPGF.K,STIME)                             F12
A      ICAPGF.K=(PCC.JK+MODC.JK-UOR.JK)/UCAP.K                      F13
A      OSBR.K=DLINF3(OSFR.K,BDT)                                    F14
L   OSCF.K=OSCF.J+DT*OSCIR.JK                                       F15
R     OSCIR.KL=OSCF.K*INF.K                                         F16
N      OSCF=2.08E+4

          ****** ECONOMIC AND POLITICAL FACTORS ******

A      FAR.K=TP.K*GNPP.K*FPP.K/PNDF.K                               F17
L   UGNP.K=UGNP.J+DT*UGNPGR.JK                                      F18
R     UGNPGR.KL=UGNP.K*UGNPGF.K                                     F19
A      UGNPGF.K=RGNPGF.K+INF.K                                      F20
A      RGNPGF.K=.0025+.0035*SIN(6.283*TIME.K/72)                    F21
A      INF.K=INFC                                                   F22
C       INFC=0.0                                                    F23
A      CPINF.K=.9*INF.K                                             F24
A      PINF.K=(1+.9*INF.K)**(BDT+6)-1                               F25
A      TP.K=TABLE(TTP,CPFAQ.K,.9,2.0,.1)                            F26
```

```
T        TTP=.93,.932,.936,.944,.96,.98,.99,.996,1.0,1.002,1.004,1.005  F27
A       DDBR.K=RDBR.K+PBR.K+OSBR.K                                       F28
A       DBGF.K=(DDBR.K+SUM(OSSUPR.K))/UGNP.K                             F29
A       GNPP.K=TABLE(TGNPP,DBGF.K,.03,.07,.01)                           F30
T        TGNPP=1.005,1.003,1.0,.99,.95                                   F31
A       FPP.K=TABLE(TFPP,RGNPGF.K,-.001,.007,.001)
X        +TABLE(TIEFP,INF.K,-.01,.02,.005)                               F32
T        TFPP=1.0,.994,.988,.984,.98,.976,.974,.972,.97                  F33
T        TIEFP=0,0,0,-.002,-.006,-.012,-.02                              F34
A       PNDF.K=TABLE(TPNDF,RGNPGF.K,-.001,.007,.001)                     F35
X        +TABLE(TIEND,INF.K,-.01,.02,.005)
T        TPNDF=1.0,.994,.988,.984,.98,.976,.974,.972,.97                 F36
T        TIEND=0,0,0,.02,.06,.012,.02                                    F37
```

****** APPROPRIATION AND EXPENDITURE ******

R&D

```
L    RDFA.K=RDFA.J+DT*(RDAR.JK-RDSR.JK)                                  F38
R      RDAR.KL=RDBR.K*FAR.K/DT*PULSE(1,12-DT,12)                         F39
R      RDSR.KL=CP.K*CCOST.K+VP.K*VCEF.K+DP.K*DCEF.K                      F40
A       RDFAF.K=RDFA.K/RDFRR.K                                           F41
A       ARDFAF.K=(RDFA.K-RDRR.K)/RDFRR.K                                 F42
A       RDFRR.K=(((CP.K*CGF.K**(TRFY.K/2)*CCOST.K
X        +VP.K*VGF.K**(TRFY.K/2)*VCOST.K
X        +DP.K*DGF.K**(TRFY.K/2)*DCOST.K)
X        *TRFY.K)*(1+CPINF.K)**(TRFY.K/2))                               F43
A       CGF.K=1+SMOOTH(((NS.JK-(CPC.K+CCNX.JK))/CP.K),STIME)             F44
A       VGF.K=1+SMOOTH(((CPC.K-(EVSR.K+VCNX.JK))/VP.K),STIME)            F45
A       DGF.K=1+SMOOTH(((EVSR.K-(EDCR.K+DCNX.JK))/DP.K),STIME)           F46
C         STIME=12                                                       F47
A       RDRR.K=RDFRR.K*(MRSF.K-1)                                        F48
A       MRSF.K=CLIP(MRF,1,TRFY.K,3)                                      F49
N       RDFAF=1
N       ARDFAF=1
L    TRFY.K=TRFY.J+PULSE(12,12-DT,12)-DT                                 F50
N       TRFY=12
```

PRODUCTION

```
L    PFA.K=PFA.J+DT*(PAR.JK-PSR.JK)                                      F51
R      PAR.KL=PBR.K*FAR.K/DT*PULSE(1,12-DT,12)                           F52
R      PSR.KL=PCOST.K*(PRODS.JK*PECR.K+MODS.JK*MODCF)                    F53
A        PFAF.K=PFA.K/PFRR.K                                             F54
N        PFAF=1
A        APFAF.K=(PFA.K-PRR.K)/PFRR.K                                    F55
A       PFRR.K=(((PP.K*PGF.K**(TRFY.K/2))
X        *DROP.K*PTECH.K+DMODS.JK*MODCF)*PCOST.K*TRFY.K
X        *(1+CPINF.K)**(TRFY.K/2))                                       F56
A       PGF.K=1+SMOOTH(((EDCR.K-PT.JK)/PP.K),STIME)                      F57
A       PRR.K=PFRR.K*(MRSF.K-1)                                          F58
```


O&S

```
L    OSFA.K=OSFA.J+DT*(OSAR.JK-OSSR.JK)                                  F59
R      OSAR.KL=OSBR.K*FAR.K/DT*PULSE(1,12-DT,12)+OSSA.K                  F60
R      OSSR.KL=OSFA.K/TRFY.K                                             F61
A        OSSA.K=SHIFTL(OSSUPR.K,1)*FAR.K                                 F62
L    OSSUPR.K(1)=CLIP(0,1,OSFAF.J,.99)*OSFS.J*PULSE(1,4-DT,12)           F63
C        M=7                                                             F64
FOR I=1,M                                                                F65
N        OSSUPR(I)=0                                                     F66
A        OSFS.K=(1-OSFAF.K)*OSFA.K                                       F67
A        OSFAF.K=(OSFA.K+SUMV(OSSUPR.K,2,M))/(UCAP.K*CAPGF.K**(TRFY.K/2)
X         *OSCF.K*TRFY.K*(1+CPINF.K)**(TRFY.K/2))                        F68
N        UGNP=2.0E+12
N        RDFA=TABLE(TRDFA,TECHAR,6,14,4)
N        PFA=31.2E+9
N        OSFA=37.4E+9
```

* *

TECHNOLOGY SECTOR

* *

```
L    TECHAV.K=TECHAV.J+DT*TDR.JK                                         TE1
R      TDR.KL=TECHAV.K*TECHGF.K                                          TE2
A        TECHGF.K=NTGF.K*FAR.K*(1-TGAPF.K)**2                            TE3
A        NTGF.K=(2**(1/TBTG.K))-1                                        TE4
A        TBTG.K=96                                                       TE5
A        TGAP.K=TECHAV.K-TECHAP.K                                        TE6
N         TECHAP=.8
N         TECHAV=1
A        TGAPF.K=TGAP.K/TECHAV.K                                         TE7
L    TECHAP.K=TECHAP.J+DT*TAR.JK                                         TE8
R      TAR.KL=TGAP.K/TABLE(TTAT,TECHAR,0,20,2)                           TE9
T         TTAT=72,60,48,36,30,24,21,18,16,14,12                          TE10
A        WSCF.K=1+LOGN(TECHAP.K)/LOGN(10)                                TE11
A        AVETGR.K=SMOOTH(TECHGF.K,VDUR.K)                                TE12
A        TRDTG.K=LOGN(DTG.K)/AVETGR.K                                    TE13
A        DTG.K=TABLE(TDTG,TECHAR,0,20,2)                                 TE14
T         TDTG=1.01,1.01,1.01,1.05,1.1,1.2,1.5,1.65,1.7,1.75,1.8         TE15
A        PTECH.K=SMOOTH(TECHAP.K,(PDUR.K/2))                             TE16
C      TECHAR=10                                                         TE17
```

* *

THREAT SECTOR

* *

****** ENEMY CAPABILITY *******

```
L    EGNP.K=EGNP.J+DT*EGNPGR.JK                                          TH1
R      EGNPGR.KL=EGNP.K*EGNPGF.K                                         TH2
A        EGNPGF.K=EGP+INF.K                                              TH3
```

```
C     EGP=.004                                                     TH3A
N     EGNP=1.0E+12
A     EGNPFA.K=NGNPFA*PECG.K                                       TH4
C     NGNPFA=.05
A     PECG.K=TABHL(TPECG,RPECG.K,1.0,1.2,.2)                       TH5
T     TPECG=1.0/1.2                                                TH6
A     RPECG.K=(DLINF3(UCAP.K,EINT)-(ECAPGR.JK-EOR.JK)*EADJT)
X      *DLINF3(PRD.K,EINT)/ECAP.K                                  TH7
C     EADJT=120                                                    TH8
C     EINT=6                                                       TH8A
R    EOR.KL=DELAYP(ECAPGR.JK,ALES,ECAP.K)                          TH9
R    ECAPGR.KL=EGNP.K*EGNPFA.K/CPCU.K/12                           TH10
A     CPCU.K=(CCOST.K*CDUR+VCOST.K*EVDUR.K+DCOST.K*EDDUR.K)/
X      CPP+PCOST.K                                                 TH11
C     ALES=240                                                     TH11A

              ****** PRESSURE FOR NEW STARTS ******

A     PRD.K=MAX(DIBP,PRPRD.K)                                      TH12
C      DIBP=.9                                                     TH13
A     PRPRD.K=DLINF3(RPRD.K,TDPP)                                  TH14
A     RPRD.K=1+((FECAP.K-UCAP.K-FUSCC.K)/(CPP*PU.K))               TH15
A     PU.K=CP.K+VP.K+DP.K+PP.K                                     TH15A
A     FECAP.K=DLINF3(ECAP.K,UINT)*ECAPGF.K**PH.K                   TH16
A     ECAPGF.K=(DLINF3(ECAPGR.JK,UINT)-DLINF3(EOR.JK,UINT))/
X      DLINF3(ECAP.K,UINT)+1                                       TH17
A     FUSCC.K=(CP.K+VP.K+DP.K+PP.K)*CPP+
X       (MODC.JK-UOR.JK)*PH.K                                      TH18
A     PH.K=CDUR+EVDUR+EDDUR.K+EPD.K                                TH19

              *****  PRESSURE FOR ACQUISITION *****

A     RPFAQ.K=DLINF3(ECAP.K,UINT)/UCAP.K                           TH20
A     DPPFAQ.K=DLINF3(RPFAQ.K,TDPP)                                TH21
A     DPFAQ.K=MAX(DIBP,DPPFAQ.K)                                   TH22
N     DPFAQ=1
A     CPPFAQ.K=DLINF3(RPFAQ.K,TCPP)                                TH23
A     CPFAQ.K=MAX(DIBP,CPPFAQ.K)                                   TH24
C     TDPP=12                                                      TH25
C     TCPP=24                                                      TH26
C     UINT=6                                                       TH27
N     ECAPGR=500
N     PECG=1
N     PRD=1
**************************************************************************

       ****** INITIALIZATION CHANGES FOR TECHAR CHANGE ******

T  TVDUR=8.4,28,86
T  TVP=81,270,829
T  TRDFA=13.6E+9,15.6E+9,21.6E+9
```



```
****************************************
           CALCULATION OF OUTPUT VARIABLES

A  ACQLTH.K=CDUR+DLINF3(VDUR.K,(DDUR.K+PTIME))+
X    DLINF3(DDUR.K,PTIME)+PTIME
NOTE  ACQLTH = Time from program initiation to delivery of first
  production item. (months)  Measured for programs in production.
L  TECAGE.K=LOGN(TECHAV.J/OPTECH.J)/SMOOTH(TECHGF.J,TECAGE.J)
N    TECAGE=120
NOTE  TECAGE = Estimated months between the current production
  technology and when it was the 'state of the art.'
A  CC.K=DLINF3((CCOST.K*CDUR),VDUR.K+DDUR.K+PDUR.K)
A  VC.K=DLINF3((VCEF.K*VDUR.K),DDUR.K+PDUR.K)
A  DC.K=DLINF3((DCEF.K*DDUR.K),PDUR.K)
A  PC.K=PCOST.K*PECR.K*CPP.K
A  PROGC.K=(CC.K+VC.K+DC.K+PC.K)/CPP.K
NOTE  PROGC = Cost per capability unit for programs in production
A  CSTR.K=(CC.K+VC.K+DC.K)/PC.K
NOTE  CSTR = Cost ratio : R&D vs Production

****************************************

OPT RF
PLOT ACQLTH=L/PROGC=$/CSTR=R/TECAGE=T
PLOT ECAP=E,UCAP=U/RPRD=L,RPFAQ=S
SPEC DT=.5,LENGTH=360,PLTPER=12
RUN
```

R&D Sector Variables

Variable Name	Variable Description	Units of Measure
ADDUR	Adjusted Development Duration	months
ARDFAF	RDFAF Adjusted to include Mgmt. Res.	dimensionless
ARDFF	RDFF Adjusted to include Mgmt. Res.	dimensionless
AVDUR	Adjusted Validation Duration	months
BDCOST	Baseline Development Cost	$/program/ month
BDDUR	Baseline Development Duration	months
BVCOST	Baseline Validation Cost	$/program/ month
CCF	Concept Cancellation Factor	fraction/ month
CCNX	Concept Cancellation Rate	programs/month
CCOST	Concept Phase Cost Factor	$/program/ month
CDUR	Concept Duration	months
CNX	Table of R&D Cancellation Factors	fraction/ year
CP	Concept Programs	programs
CPC	Concept Program Completions	programs/month
CSPRC	Cost Slope for R&D Program Contraction	dimensionless
CSPRSO	Cost Slope for R&D Program Stretch-out	dimensionless
DAFD	Development Affordability	programs/month
DCEF	Development Cost Expenditure Factor	$/program
DCF	Development Cancellation Factor	fraction/month
DCM	Development Cost Multiplier	dimensionless

DCNX	Development Cancellation Rate	programs/month
DCOST	Development Cost	$/program/ month
DDUR	Development Duration	months
DDURR	Development Ratio of Current Duration to Expected Duration	dimensionless
DP	Programs in Development	programs
DPFAQ	DoD Pressure for Acquisition	dimensionless
DS	Development Starts	programs/month
DSLP	Development Cost Slope for the existing DDURR	dimensionless
EDCR	Expected Development Completion Rate	programs/month
EDDUR	Expected Development Duration	months
EVDUR	Expected Validation Duration	months
EVCR	Expected Validation Completion Rate	programs/month
INF	Inflation Factor	fraction/month
MRSF	Management Reserve Spending Factor	dimensionless
OPF	Overprogramming Factor	dimensionless
PA	Production Approvals	programs/month
PAFD	Production Approval Affordability Constraint	programs/month
PDCR	Potential Development Completion Rate	programs/month
PRD	Pressure for R&D	dimensionless
PT	Production Terminations	programs/month
RDCS	R&D Cost Slope for adjusting for funds available	dimensionless
RDCSA	R&D Cost Slope for adjusting for funds available with mgmt. res.	dimensionless
RDFAF	R&D Funds Availability Factor	dimensionless

RDFF	R&D Funds Factor	dimensionless
TECHAR	Technological Advancement Rating	dimensionless
TRDTG	Time Required for Desired Technology Growth	months
TVDUR	Table of Validation Durations for Initializations	months
TVP	Table of Validation Programs for Initializations	programs
VAFD	Validation Start Affordability Constraint	programs/month
VCEF	Validation Cost Expenditure Factor	$/program/ month
VCF	Validation Cancellation Factor	fraction/month
VCM	Validation Cost Multiplier	dimensionless
VCNX	Validation Cancellation Rate	programs/month
VCOST	Validation Cost	$/program/ month
VDUR	Validation Duration	months
VDURR	Validation Ratio of Duration to Expected Duration	dimensionless
VP	Validation Programs	programs
VS	Validation Starts	programs/month
VSLP	Validation Cost Slope for calculating cost of validation from VDUR	dimensionless
WSCF	Weapon System Complexity Factor	dimensionless

Production Sector Variables

Variable Name	Variable Description	Units of Measure
APFAF	PFAF Adjusted to include Mgmt. Res.	dimensionless
APFF	PFF Adjusted to include Mgmt. Res.	dimensionless
BPD	Baseline Production Duration	months
CAPIP	Capability in Production	capability
CPP	Capability per Program	capability
DMODS	Desired Modification Starts	capability/ month
DPFAQ	DoD Pressure for Acquisition	dimensionless
DROP	Desired Rate of Production	capability/ program/month
EPD	Expected Production Duration	months
FMODT	Force Modernization Time	months
INF	Inflation Fraction	fraction/month
MODC	Modification Completions	capability/ month
MODIP	Modifications in Progress	capability units
MODS	Modification Starts	capability/ month
MODTGF	Modification Technology Gap Fraction	dimensionless
MRSF	Management Reserve Spending Factor	dimensionless
MTIME	Modification Delay Time	months
NFC	Numerical Force Completion Rate	production units/month
NIP	Number of units in Production	production units
NMODT	Normal Modification Time	months

NOBS	Numerical Obsolescence Rate	production units/month
OLTIME	Operational Lifetime	months
OPTECH	Operational Technology	capability/ production unit
OTGAP	Operations Technology Gap	capability/ production unit
PA	Production Approvals	programs/month
PCC	Production Capability Completions	capability/ month
PCOST	Production Cost	$/capability
PDUR	Production Duration	months
PECR	Production Efficiency Cost Ratio	dimensionless
PFAF	Procurement Funds Availability Factor	dimensionless
PP	Programs in Production	programs
PROD	Production Rate	production units/month
PRODS	Production Starts	capability/ month
PT	Production Program Terminations	programs/month
PTECH	Technology Applied to Production	capability/ production unit
PTIME	Time for Production	months
ROP	Rate of Production	capability/ month
SOB	Size of the Buy	production units/program
SOF	Size of the Force	production units
TECHAV	Technology Available	technology units
TPECR	Table of Production Efficiency Cost Ratios	dimensionless

TPFF	Table of Procurement Funds Factors	dimensionless
UCAP	US Capability	capability
UOR	U.S. Weapon System Obsolescence Rate	capability/ month

Financial Sector Variables

Variable Name	Variable Description	Units of Measure
APFAF	Production Funds Availability Factor Adjusted to include management reserve	dimensionless
ARDFAF	R&D Funds Availability Factor Adjusted to include management reserve	dimensionless
BDT	Budgetary Delay Time	months
CAPGF	Capability Growth Factor	dimensionless
CCNX	Concept Cancellation Rate	programs/month
CCOST	Concept Cost	$/program/ month
CDUR	Concept Duration	months
CFR	Concept Funds Required	$
CGF	Concept Phase Growth Factor	dimensionless
CP	Concept Programs	programs
CPC	Concept Program Completions	programs
CPFAQ	Congressional Pressure for Acquisition	dimensionless
CPINF	Current Year Projected Inflation	fraction/month
DBGF	Defense Budget as Fraction of GNP	dimensionless
DCEF	Effective Development Cost	$/program/ month
DCNX	Development Cancellation rate	programs/month
DCOST	Development Cost	$/program/ month
DDBR	DoD Budget Request	$
DFR	Development Funds Required	$
DGF	Development Growth Factor	dimensionless

DMODS	Desired Modification Starts	capability/ month
DP	Development Programs	programs
DPFAQ	Defense Pressure for Acquisition	dimensionless
DROP	Desired Rate of Production	production units/month
EDCR	Expected Development Completion Rate	programs/month
EDDUR	Expected Development Duration	months
EPD	Expected Production Duration	months
EVDUR	Expected Validation Duration	months
EVSR	Expected Validation Start Rate	programs/month
FAR	Funds Appropriation Ratio	dimensionless
FPP	Fiscal Policy Pressure on Appropriation	dimensionless
GNPP	GNP Pressure on Appropriations	dimensionless
ICAPGF	Instantaneous Capability Growth Fraction	fraction/month
INF	Actual Inflation Rate	fraction/month
MODC	Modification Completions	capability/ month
MODCF	Modification Cost Factor	dimensionless
MODS	Modification Starts	capability/ month
MRF	Management Reserve Factor	dimensionless
MRSF	Management Reserve Spending Factor	dimensionless
OSAR	Operations and Support (O&S) Appropriation Rate	$/month
OSBR	O&S Budget Request	$
OSCF	O&S Cost Factor	$/capability/ month

OSCIR	O&S Cost Inflation Rate	$/capability/ month/month
OSFA	O&S Funds Available	$
OSFAF	O&S Funds Availability Factor	dimensionless
OSFR	O&S Funds Required	$
OSFS	O&S Funds Shortage	$
OSSA	O&S Supplemental Appropriation	$/month
OSSR	O&S Spending Rate	$/month
OSSUPR	O&S Supplemental Request	$
PAR	Production Appropriation Rate	$/month
PBR	Production Budget Request	$
PCC	Production Completion Rate	capability/ month
PCOST	Production Cost	$/capability
PECR	Production level Efficiency Cost Ratio	dimensionless
PFA	Production Funds Available	$
PFAF	Production Funds Availability Factor	dimensionless
PFR	Production Funds Required	$
PFRR	Production Funds Required for Remainder of year	$
PGF	Production Growth Factor	dimensionless
PINF	Projected Inflation factor	dimensionless
PNDF	Pressure for Non-DoD Funds	dimensionless
PP	Production Programs	programs
PRD	Pressure for R&D	dimensionless
PRODS	Production Starts	capability/ month
PRR	Production Reserve Required	$

PSR	Production Spending Rate	$/month
PT	Production Terminations	programs/month
PTECH	Technology applied in Production	capability/ production unit
RDAR	R&D Appropriation Rate	$/month
RDBR	R&D Budget Request	$
RDFA	R&D Funds Available	$
RDFAF	R&D Funds Availability Factor	dimensionless
RDFR	R&D Funds Required in budget year	$
RDFRR	R&D Funds Required for Remainder of year	$
RDRR	R&D Required Reserve	$
RDSR	R&D Spending Rate	$/month
RGNPGF	"Real" GNP Growth Fraction	fraction/month
STIME	Smoothing Time for program growth factors	months
TECHAR	Technology Advancement Rating	dimensionless
TFPP	Table of Fiscal Policy Pressure	dimensionless
TGNPP	Table of GNP Pressure on Appropriations	dimensionless
TIEFP	Table of Inflation Effect on Fiscal Policy	dimensionless
TIEND	Table of Inflation Effect on Pressure for Non-Defense Funds	dimensionless
TP	Threat Pressure	dimensionless
TPNDF	Table of Pressure for Non-DoD Funds	dimensionless
TRFY	Time Remaining in Fiscal Year	months
TTP	Table of Threat Pressures	dimensionless
UCAP	US Capability	capability

UGNP	US GNP	$
UGNPGF	US GNP Growth Fraction	fraction/month
UGNPGR	US GNP Growth Rate	$/month
UOR	US Obsolescence Rate	capability/ month
VCEF	Validation Effective Cost Factor	$/program/ month
VCNX	Validation Cancellation rate	programs/month
VCOST	Validation Cost	$/program/ month
VFR	Validation Funds Required	$
VGF	Validation Growth Factor	dimensionless
VP	Validation Programs	programs

Technology Sector Variables

Variable Name	Variable Description	Units of Measure
AVETGR	Average Technology Growth Fraction	dimensionless
DTG	Desired Technology Growth factor	dimensionless
FAR	Funds Appropriation Ratio	dimensionless
NTGF	Normal Technology Growth Fraction	fraction/month
PDUR	Production Duration	months
PTECH	Technology Applied to Production	capability/ production unit
TAR	Technology Application Rate	technology units/month
TBTG	Time Between Technology Generations	months
TDR	Technology Discovery Rate	technology
TDTG	Table of Desired Technology Growth vs Technology Advancement Rating	dimensionless
TECHAP	Technology Applied	technology units
TECHAR	Technology Advance Rating	dimensionless
TECHAV	Technology Available	technology units
TECHGF	Technology Growth Fraction	fraction/month
TGAP	Technology Gap between Avail. & Applied	technology units
TGAPF	TGAP as Fraction of TECHAV	dimensionless
TRDTG	Time Required for Desired Technology Growth	months
TTAT	Table of Technology Application Time	months
VDUR	Validation Duration	months
WSCF	Weapon System Complexity Factor	dimensionless

Note: Units of technology correspond to units of capability obtained from a unit of production

Note: A generation of technology is a doubling of the capability obtained from a unit of production

Capability Sector Variables

Variable Name	Variable Description	Units of Measure
ALES	Average Life of Enemy Systems	months
CCOST	Concept Cost	$/program/ month
CDUR	Concept Duration	months
CP	Concept Programs	programs
CPCU	Cost Per Capability Unit for Enemy	$/capability
CPFAQ	Congressional Pressure for Acquisition	dimensionless
CPP	Capability per Program	capability
CPPFAQ	Congressional Perceived Pressure for Acquisition	dimensionless
DCOST	Development Cost	$/program/ month
DIBP	Defense Industrial Base Pressure	dimensionless
DP	Development Programs	programs
DPFAQ	DoD Pressure for Acquisition	dimensionless
DPPFAQ	DoD Perceived Pressure for Acquisition	dimensionless
EADJT	Enemy Capability Adjustment Time	months
ECAP	Enemy Capability	capability units
ECAPGF	Enemy Capability Growth Factor	factor/month
ECAPGR	Enemy Capability Growth Rate	capability units
EDDUR	Expected Development Duration	months
EGNP	Enemy GNP	$
EGNPFA	Enemy GNP Fraction for Acquisition	dimensionless

EGNPGF	Enemy GNP Growth Fraction	fraction/month
EGNPGR	Enemy GNP Growth Rate	$/month
EINT	Enemy Intelligence Delay Time	months
EPD	Expected Production Duration	months
EVDUR	Expected Validation Duration	months
FECAP	Forecast Enemy Capability	capability
FUSCC	Forecast US Capability Completions	capability
INF	Inflation fraction	fraction/ month
MODC	Modification Completions	capability/ month
NGNPFA	"Normal" Enemy GNP Fraction for Acquisition	dimensionless
PCOST	Production Cost	$/capability unit
PECG	Pressure for Enemy Capability Growth	dimensionless
PH	Planning Horizon	months
PP	Production Programs	programs
PRD	Pressure for R&D	dimensionless
PRPRD	Perceived Raw Pressure for R&D	dimensionless
RPECG	Raw Pressure for Enemy Capability Growth	dimensionless
RPFAQ	Raw Pressure for Acquisition	dimensionless
RPRD	Raw Pressure for R&D	dimensionless
TCPP	Time for Congress to Perceive Threat	months
TDPP	Time for DoD to Perceive Threat	months
TPECG	Table of Pressure for Enemy Capability Growth	dimensionless
UCAP	US Capability	capability

UINT	US Intelligence delay time	months
UOR	US Obsolescence Rate	capability units/month
VCOST	Validation Cost	$/program unit/month
VP	Validation Programs	programs