DEFENSE RESOURCE DYNAMICS

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ABSTRACT

Models based on a logic relating military ownership costs to active force assets were developed. Historical budget analyses provided relationships to tailor the models to each military service. The models, validated through projection of the 1980-85 defense growth period, were then used to predict 1986 to 1995 appropriations using top line fiscal levels as inputs. The models can explore policy options such as reduced fiscal growth, altered readiness policy, and changed inactivation plans.

INTRODUCTION

One of the major policy decisions in military planning is how to allocate future fiscal resources into two major categories: system acquisition and system operating/support (O/S). (Acquisition includes research and development of new systems and also procurement of operational systems, while O/S includes operating and maintaining, and manning active systems). Historically, the military services have overestimated the availability of acquisition funds, and underestimated requirements for operating/support. This annual perturbation in plans causes production inefficiency, raises unit prices, and is generally disruptive. The perturbation is considered unnecessary. The basic premise of this paper is that operating/support costs are highly predictable and must be given priority in the allocation process. This means that if planned budget limits are known, then acquisition, if treated as a residual account (budget minus O/S), becomes much more predictable, and stability in the acquisition process can evolve.

In the 1983 International System Dynamics conference a comprehensive system dynamic model of the U.S. Navy's resource allocation process was reported. (Clark, et al, 1983). Based on those insights gained through modeling the navy, a simplified SD model has been programmed in Micro-Dynamo and run for the 1980-1990 period for each of the military services. The 1980-85 period, being historical, was used for model validation purposes. The fiscal allocation in that period was, beginning with 1979, predicted with surprising accuracy, confirming the basic model logic and providing some confidence in the ability to predict future budget needs.

THE DYNAMICS

The service models developed are based on a simple relationship between asset value (stocks) and their associated ownership funding requirements (flows). The basic stock/flow model is shown in figure 1.

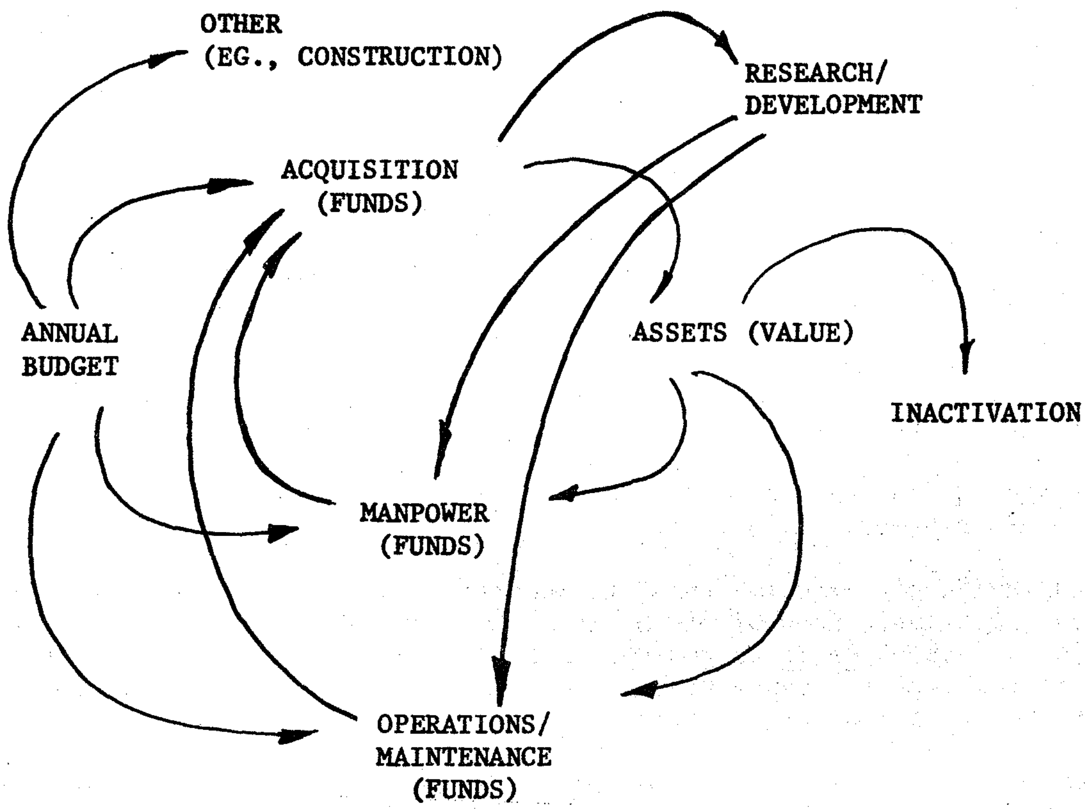

Figure 1. **BASIC DYNAMIC MODEL**

"Assets" refer to the accumulated value of major systems acquired over time--the inventory of weapon systems. The three major flows are the annual budgets for acquisition, manpower, and operations/maintenance. The basic model logic assumes that manpower and O/M funding are determined by the assets held in the inventory, and that acquisition funding is the residual left over after manpower and O/M are funded (and a small amount for "other" is set aside, usually one percent to three percent depending on the service). If manpower and O/M are underfunded (the "decremented readiness" case), then more funds are available for acquisition--and of course more future assets will accumulate, causing deferred ownership demands. Inactivation--referring to assets being retired--of course effect the asset value and the ownership demands. Rapid inactivation can reduce ownership budget demands quickly, while reduced procurements will effect ownership only after the several years' lag from contract to delivery.

Given the initial conditions for asset values and budgets, and the model relationships, the models determine each budget category for one annual budget cycle. Changes to assets are made for the next year, fiscal growth is incorporated, and the following years' budgets are determined, simulating the fund flows over time.

In the simplest sense, the results of these dynamics have much to do with accelerators: If a driver wishes to accelerate rapidly from 50 to 60 mph, he must step on the gas, and then ease back once 60 is reached. The same is true of force growth. To have 500 ships, a navy must procure an average 17 ships a year. To accelerate to 600 ships an extra 10 ships per year for a decade must be procured. Once 600 is reached, procurements can decline again to 17 (until the new 100 ships begin to inactivate 30 years later). Changes to inactivation plans can be made to alter this arithmetic in the short term, but the fact remains that a period of rapid fiscal growth should typically be followed by a period of decline in fiscal needs. That is the accelerator principle.

This growth-followed-by-decline accelerator is reinforced if, during the growth period, various readiness-related shortfalls are corrected. Funding may accelerate to reduce overhaul backlogs, spare parts shortages, or fuel inventory shortfalls. Once such readiness problems have been corrected, the accelerated operating and maintenance budgets can decelerate along with procurement budgets. (Clark, 1984).

The conclusion can be drawn that, in general, a period of rapid fiscal growth such as that experienced by the military in the 1980s', should be followed by a period of actual negative growth. This has not been widely recognized. In fact, virtually all defense fiscal plans call for rapid growth followed by slower, but still positive growth.

Some crude perspective can be provided. The 1989 defense appropriation is twice as large in constant dollars as the 1980 budget. Yet the military has far from doubled in that period. Such growth in budgets is justified during growth periods, but not after stabilization at the higher force levels. The Navy's growth to 600 ships, for example, represents about a 50 percent increase in the value of assets since 1980 (though only about a 15 percent increase in units). At the same time, manpower has increased 20 percent.

There are related dynamic aspects to acknowledge in analyzing defense fiscal needs. First, there are direct relationships between a military service's assets, the life span of those assets, and the annual funding (procurements) of new assets. The rudiments of these relationships can be expressed by the following example:

Assume systems last, on average, 20 years. Assume also that two-thirds of the procurement budget buys new systems -- the rest being used on initial spares, on support systems, on modifications, on "other procurements," etc. To buy $1.00 of systems then requires $1.50 in procurement. To replenish the systems inactivated each year, about one twentieth of the assets must be replaced. If assets are worth $100B, then $5B need replacement annually, and a $7.5B procurement budget is necessary just to maintain stocks.

If, as can be demonstrated, the relationships between asset values and ownership needs (operating, maintaining, and manning) is direct--i.e., as assets grow, ownership costs grow proportionately--then large growth in overall budgets will multiply the growth in procurement availability. As a rough example, if procurement is a third of the total budget, then a five percent annual real increase in budgets will mean a 15 percent increase in procurement budgets, for the ownership demands do not change until new procurements arrive some years later. So accelerated budget growth translate into multiplied procurement growth. The 1980 to 1985 period has seen such multiples in procurement for each service. Of course, budget reductions will impact the opposite way -- a five percent budget decrease will tend to cause a 15 percent reduction in procurement availability.

The models developed and the resulting output are based on such dynamics, with refinements for changes in activation plans, manning differences, and miscellaneous other adjustments. Deliberate readiness changes to effect funding can be modeled by underfunding either maintenance, operations, or manpower factors to levels below 100 percent. Typical model equations are provided.

SOME VALIDATION COMMENTS

The above dynamic considerations are based on logic, but the models must be shown to be valid. Several steps toward model development and validation were made. First, using detailed experience gain in analysis of Navy Department assets, characteristics, budgets, and policies, analogous Army and Air Force models were developed. This analogous model building process is discussed below.

It was then considered essential to test the basic model logic by seeing how well each model would predict the allocation of available funding into the major appropriation categories of acquisition (procurement plus R&D), operations and maintenance, and manpower.

Starting with 1980 values for appropriations and asset values, and using historical 1970-1980 budget data to derive the model equations, the projections for 1981-1985 were compared with actual budgets for those years. In the initial models, the largest prediction error was five percent, and the average error for 45 different budget projections was two percent.

After the initial results were obtained, some further analysis was done to "fine tune" the models, by accounting for empirical differences in services. The fine tuning resulted in a maximum error of 3.2 percent. The average error was less than one percent for 45 separate predicted appropriations from 1980 to 1985.

These results are considered very encouraging because while budgets and forces were stable from 1970 to 1980, the 1980-85 period was characterized by large growth in budgets and forces. Most models will predict well during stable periods. But when massive dynamics are occurring, even dynamic models are often inadequate. That seemed not to be the case here, and gave considerable credence to the models developed.

For a comparison, had a static logic been used, wherein budget flows are related to other budget flows, much larger errors would have resulted. Without the stocks versus flows logic, a review of the 1970 to 1980 data would indicate that Air Force operating and maintenance accounts absorb a stable 31 percent of the budget. That would have lead to a 35 percent overestimate of the actual Air Force O&M account in 1985.

OBJECTIVES

There were two objectives of this analysis. First, to indicate how available defense budgets would be allocated by the services into major appropriation categories and how changes to fiscal plans would effect those allocations. Second, and more important, to provide a set of uncomplicated, yet reasonably comprehensive models, which could allow policy analysts to quickly determine the approximate impacts of policy options on funding allocations--"policy options" including changes to inactivation plans, changes to funding levels, changes to readiness policies, etc.

For example, the dynamic aspect of fiscal reductions below planned levels is indicated in figures 2 and 3, which show the predicted relative effects on major appropriation categories when readiness is not underfunded, for the Navy Department and the Army.

The differences in the figure 2 and 3 dynamics are important. While both services receive the same reductions (3 percent and 0 percent growth instead of 6 percent), the Army's reallocation process is initially more severe, but reaches steady state sooner than the Navy's. The Army's acquisition must drop considerably faster than the Navy's through 1990 primarily because the Army acquisition budget is a smaller fraction of the Army budget--and with readiness funded fully, acquisition must absorb most of the initial reductions. (If a procurement budget is 33 percent of the total, a one percent reduction in the total translates into a three percent drop in procurement. If procurement is 50 percent of the total, the one percent drop means only a two percent drop in procurement). Army systems have shorter life spans and shorter procurement-to-delivery lags, so force turnover is more rapid, causing equilibrium to occur sooner. Navy systems, on the other hand, take 25 years or so before an equilibrium can be reached.

Such fiscal dynamics are difficult to explain verbally. Yet they are basic for understanding fiscal policy. Figures 2 and 3 offer the important message that future funding needs are highly dependent on short term budget policy changes; and therefore that long range planning is crucial to avoid annual perturbations in budget allocations--perturbations which cause inefficiency in system procurements when project plans must be changed. While some change is unavoidable, major biases in plans can amplify the changes unnecessarily. For example, from 1971 to 1981, the Navy's procurement budget each year was adjusted downward an average of seven percent compared to the overall budget, while the operating and support budgets were adjusted upward by eight percent. The instability in fund allocation caused by such biases are inefficient. Dynamic models of the type developed for this research are designed to avoid such bias by relating ownership costs to the predictable asset levels of the military services.

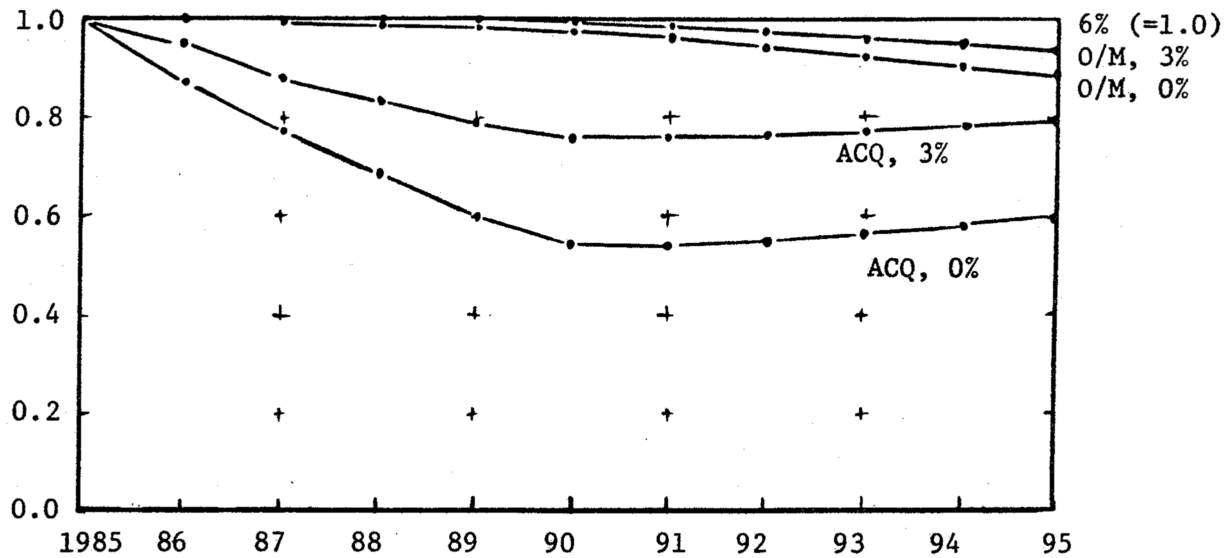

Figure 2. Navy Department -- Fractional reduction in Acquisition (ACQ) and Operations/Maintenance (O/M) budgets for 3% and 0% real growth (1985-1990), compared to 6% growth (6% = 1.0).

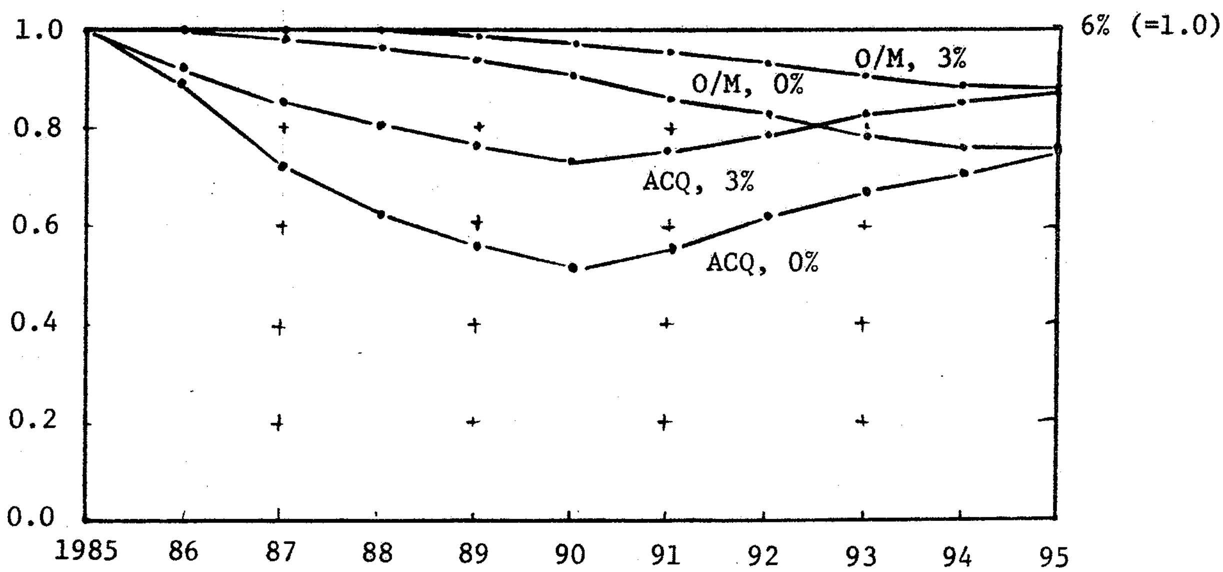

Figure 3. Army -- Fractional reduction in Acquisition (ACQ) and Operations/Maintenance (O/M) budgets for 3% and 0% real growth (1985-1990), compared to 6% growth (6% = 1.0).

BASIC MODEL RELATIONSHIPS AND ASSUMPTIONS

The following model logic has been applied to all the services. The generic logic is described first, then detailed parameters for each service are provided.

First, asset values are imputed to each service based on a review of historical procurements. Then, budget totals are assumed as input values for each year from 1980 to 1995. Average asset lifespan determines the "normal" annual loss of assets to inactivation -- 25 year assets life implies 1/25th of the assets inactivate each year. This inactivation rate can be slowed or accelerated. New assets added to asset stocks depend on lagged procurement funds.

The model simulations first determine operations/maintenance (O/M) budget needs and manpower budgets, each of which are fractions of asset value. Then, construction budgets and "miscellaneous" budgets are determined, each as fractions of the total budget available. Each of these four amounts can be decreased fractionally, to accommodate a policy of underfunding (O/M, manpower, and construction particularly) during periods of severely constrained fiscal growth. These four elements, when deducted from the annual budget, leave the acquisition residual. The acquisition residual is allocated to research/development (R&D) and procurement. A fractional part of procurement is set aside for spare parts, modernizations, and support equipments, and the remainder is available for procurement of systems. Of this remainder, another fraction is assumed to be non-asset enhancing (i.e., ripout costs, overhead, etc.), the rest is, after a procurement lag, added to the asset stock.

Refinements on the above include smoothing or delaying the effect of changes to manpower funding and R&D funding.

Initial asset values for the Navy were obtained from The George Washington University "Resource Dynamics" databases. There, each ship and aircraft in the active U.S. fleet is valued at cost in 1985 dollars, ship conversion values are included. Aircraft are valued at the 200th unit cost of each type/model/series of aircraft. The asset values obtained through that detailed counting process are divided by the sum of the last 25 years of procurements, (the expected average life of naval systems -- ships lasting 30 years, and aircraft about 15. This ratio is used to impute values of Army and Air Force Systems, as of 1980, by multiplying the sum of the previous fifteen years of procurements by this ratio (Army and Air Force systems lasting approximately 15 years). The initial values for Navy, Army, and Air Force assets obtained in this way were $210B, $105B, and $55B respectively. Analysis will show that the models are not overly sensitive to the exact value of the initial assets, for the stock/flow logic plus other model parameters will ensure that early budgets will match actual values.

However, if the asset values are too much in error, the simulation logic will soon drive predicted budgets away from their correct values. That is why the validation process for these models was important. The 1980 to 1985 validation, by being very much within the initial ten percent error range assumed, provided confidence that the imputed asset values were reasonably accurate.

The actual models used are written in the Dynamo simulation language, and are provided on the following pages. Detailed results of the models, showing approximate budget allocations of each service for 1975-1998, are not presented here, but are described elsewhere (Clark, Pisani, 1985). Summary predictions for 1986-1990 follow.

SUMMARIZED PREDICTIONS

The average annual real growth in military budgets over the next five years is six percent per year for the Army and Navy, and four percent for the Air Force. If the expected real growth rate of each services' fiscal limit is halved over the next five years, then the average annual funding available for acquisition of new systems would be reduced by $8.68 (or 16 percent of the acquisition budgets) for the Navy Department, by $5.5B (19 percent of acquisition) for the Army, and $5.5B (9.3 percent) for the Air Force.

If real growth is zeroed for each service, then the predicted average acquisition budgets for 1986 to 1990 would be reduced each year by $16.6B (or 31 percent) for the Navy Department, by $10.5B (or 36 percent) for the Army, and $10.8B (or 18 percent) for the Air Force.

These reductions assume no unit readiness decay. Consequently operations/maintenance and military personnel budgets would be reduced very little over the same period, for systems procured prior to 1986 would continue arriving, building up force levels even while the 1986 to 1990 acquisitions were reduced.

If some tolerance for readiness underfunding was allowed, the procurement reductions would be less severe, and manpower and operations/maintenance budgets would absorb much of the funding reductions.

Increased inactivations of older, active units would also reduce pressures on budgets by reducing manning and operations/maintenance demands.

Yet another option is to place units in reserve status, with reduced crews and limited operations to reduce ownership costs.

Table 1 shows a summary allocation of funds for the three service departments assuming Navy and Army real growth of six percent versus three percent, and Air Force real growth of four percent versus two percent. Some readiness decay to the 90-95 percent level is allowed with the three percent and two percent cases. The acquisition funds are those remaining after deducting O/M and manpower costs. (Column headings are: Budg = Budget, Mpr = Manpower budget, O/M = Operations/Maintenance budget, Acq = Acquisition Funding).

Department of Navy

	6% Real Growth				3% Real Growth			
	Budg	Mpr	O/M	Acq	Budg	Mpr	O/M	Acq
1986	95.2	16.9	28.1	46.4	92.6	16.7	26.7	45.5
87	100.9	17.2	29.7	49.9	95.3	16.7	28.2	46.7
88	107.0	17.5	31.3	53.8	98.2	16.8	29.8	47.7
89	113.4	17.8	33.1	58.0	101.1	17.0	31.4	48.7
90	120.2	18.0	34.7	62.7	104.2	17.1	32.9	50.1

Army

	6% Real Growth				3% Real Growth			
	Budg	Mpr	O/M	Acq	Budg	Mpr	O/M	Acq
1986	71.3	19.4	21.4	25.6	69.3	19.3	20.3	25.1
87	75.6	20.0	22.9	27.4	71.4	19.7	21.8	25.1
88	80.2	20.6	24.6	29.3	73.5	20.2	23.2	25.1
89	85.0	21.3	26.3	31.5	75.7	20.5	24.7	25.4
90	90.1	21.8	28.2	33.7	78.0	20.7	26.0	26.0

Air Force

	4% Real Growth				2% Real Growth			
	Budg	Mpr	O/M	Acq	Budg	Mpr	O/M	Acq
1986	97.0	14.3	23.8	56.9	95.1	14.1	22.6	56.6
87	100.8	15.0	25.9	57.9	97.0	14.6	24.6	56.0
88	104.9	15.6	28.1	59.0	98.9	15.0	26.7	55.3
89	109.1	16.2	30.3	60.4	100.9	15.4	28.6	55.0
90	113.4	16.6	32.4	62.1	102.9	15.7	30.4	54.9

Table 1. Predicted service budget appropriations for high (6 percent and 4 percent) and medium (3 percent and 2 percent) cases, with readiness decrements allowed. All predictions in constant 1985 budget year dollars.

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* MILITARY RESOURCE ALLOCATION--SAMPLE MODEL

L   ASSETS.K=ASSETS.J+DT*(NEWAST.J-OLDAST.J)         ASSETS
A   NEWAST.K=FAC1*FAC2*CLIP(NEWA2,NEWA1,
X          TIME.K,START+1.5)                          NEW ASSETS
C   FAC1=.7
NOTE      FRAC OF SYS PROC EFFECTIVE
C   FAC2=.8
NOTE      FRAC OF PROC BUYING SYSTEMS
A   NEWA1.K=TABHL(TNEWA1,T.K,0,1,1)                  NEWA1
A   NEWA2=SMOOTH(PROBUD.K,LAG)                        NEWA2
A   OLDAST.K=ASSETS.K/ALIFE                           OLD ASSETS
A   BUDGET.K=TABLE(TBUD.K,TIME.K,START,STOP,1)        BUDGET
N   TIME=START
A   RDBUD.K=SMOOTH(RDFDS.K,RDLAG)                     LAG RD
A   RDFDS.K=RDFRAC*BUDGET.K                           RD AVAIL
A   CONBUD.K=CONMUL.K*BUDGET.K*DECRC                  MILCON
A   CONMUL.K=TABHL(TCON.K,TIME.K,1982,1985.1)         MILCON MLTPLR
T   TCON=.02,.04,.04,.05
A   OMBUD.K=OMMULT*ASSETS.K*OMFAC.K*DECRO             O @ M
A   OMFAC.K=TABHL(tomfac.k,time.k,1980,1990,1)        OM FACTOR
T   TOMFAC=1/1.04/1.11/1.10/1.03/1/1/1/1/1/1
A   MPBUD.K=MPMULT.K*ASSETS.K*MFAC.K*SDECRM.K         MPR BUD
A   MPR.K=MPBUD.K/MCOST                               MANPOWER (1000'S)
C   MCOST=.0244
A   SDECRM.K=SMOOTH(DECRM.K,2)
A   DECRM.K=DECM
N   DECRM=.90
C   DECM=.90                                          MPR DECR
C   DECRC=.90                                         CONBUD DECR
C   DECRO=1.0                                         OM DECR
A   MFAC.K=TABHL(TMFAC.K,TIME.K,1980,1990,1)          MANNING FACTOR
T   TMFAC=1/1/1.05/1.06/1.04/1.0/1/1/1/1/1            ANNUAL GWTH YR
A   MPMULT.K=MPF*(1+(T.K*MPGRO))                      MP MULTPLYR
A   T.K=TIME.K-START                                  ELAPSED TIME
A   PROBUD.K=BUDGET.K-RDBUD.K-CONBUD.K-
X       OMBUD.K-MPBUD.K-MSCBUD.K                      PROCUREMENT
A   ACQBUD.K=BUDGET.K-CONBUD.K-OMBUD.K-MPBUD.K-
X       MSCBUD.K                                      ACQUISITION
A   MSCBUD.K=MSCFRA.K*BUDGET.K                        MISCELLANEOUS
A   MSCFRA.K=TABHL(TMSC.K,TIME.K,1982,1985,1)
T   TMSC=0/0.0/.02/.02
NOTE
NOTE
N   ASSETS=55
C   LAG=2,RDLAG=2,ALIFE=15,START=1980,STOP=1995,RDFRAC=.07
C   OMMULT=.283,MPF=.313,MPGRO=-.03
T   TNEWA1=9.02/9.27
T   TBUD=46.8/52.0/58.0/61.9/64.8/
X        67.3/71.3/75.6/80.15/85.0/90.1/91.0/91.9/92.8/93.7/94/7
N   RDBUD=3.8
SPEC DT=.5/LENGTH=1995/PRTPER=1/PLTPER=1
PRINT ASSETS,MPR,BUDGET,MPBUD,OMBUD,PROBUD,RDBUD,CONBUD,ACQBUD
RUN
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REFERENCES

Clark, R., S. Graves and K. Sheehan. "Extended Planning in the Navy and the Resource Dynamics Project," The 1983 International System Dynamics Conference July 27-30, 1983, Volume 1, p. 397.

Clark, R. "Operating and Support Costs of the U.S. Navy: Some Analytic Facts," Technical Paper T-492/84, Institute for Management Science and Engineering, The George Washington University, Washington, DC, 23 July 1984.

Clark, R. and A. Pisani. "Predicting Military Appropriations for 1986-1995," Technical Memorandum TM-55059, Institute for Management Science and Engineering, The George Washington University, Washington, DC, 3 January 1985.