# EXTENDED PLANNING IN THE NAVY AND THE RESOURCE DYNAMICS PROJECT

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ABSTRACT

The U.S. Navy's need for better long-range planning is discussed in light of recent dynamic increases to force plans. The difficulties embedded in the current planning and programming process, and the problems they cause in developing valid approaches are reviewed. The ongoing "Navy Resource Dynamics" project at The George Washington University is then presented as a means of overcoming the difficulties, and providing a timely planning model. The basis of the model is a lagged feedback analysis linking budget "flows" over time to weapon system asset "stocks." The trade-off between naval force levels and the cost of owning the forces is emphasized with force readiness being a relevant measure.

## Introduction

Naval long-range planning and its role in the planning, programming, budgeting process (PPBS) will be discussed in three sections. First, its relevance is explored; second, its difficulties and requirements are outlined. Third, an existing, developing approach toward extended planning is discussed. A summary of the views presented is that upcoming fiscal dynamics make better planning essential, and that the inevitable difficulties can be overcome to a large degree by the method proposed. The military resource allocation process is inherently a complex closed system--with feedbacks rife from initial fiscal formulation right through the "end game" where final changes are made--



but these feedbacks have been largely ignored because the PPBS process has been treated as a simple open system without adequate feedbacks. The approach discussed is a dynamic method allowing for the feedback implications.

## Is Extended Planning Necessary?

In a truly stable world, there is no overriding need for long-range planning. Fiscal targets and resource allocations, if either unchanging or changing in a "steady state" manner, can be tracked and predicted using thumb rules easily understood and implemented by the human mind. Under stable growth, the Navy budgets for aircraft spare parts, for example, may be safely assumed to require some 25 percent of the new aircraft procurement budget, which in turn is about 30 percent of total procurement, which averages 40 percent of the total budget.

If such conditions remain the same year after year their resource allocation dynamics are relatively uneventful. There are no severe lagged effects to imbalance the trends. But, suppose that procurement lags (between budgeting for units and their delivery) are four to six years, while for ownership--maintenance, operating, manning--the lags are less than a year. Then a major increase in force levels has lagged effects on resource allocation trends. For ownership costs will not need to rise until the four to six years when the newly procured units join the active forces. As the fleet units do arrive, the lagged but accelerated growth in requirements for ownership funds will occur. That could coincide with efforts to reduce defense after a long (four year) growth period--about the average time an administration lasts. Reductions in overall defense spending just as ownership needs accelerate will mean severe reductions in procurements, for ownership funds are difficult to deny once the systems and manpower are in place. A dynamic fiscal roller coaster evolves.

Extended planning clearly takes on importance when fiscal trends are dynamic...and actual defense spending plans call for such dynamics. Consider Figure 1. The historical balance between procurement and ownership is not to continue. The administration's planned real growth in defense budgets is unprecedented in recent peacetime planning, and dynamics are inevitable.

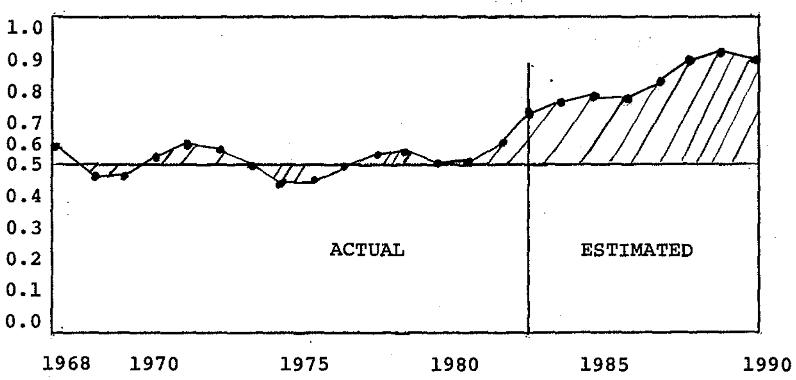



Figure 1. Funding Dynamics, U.S. Navy: Procurement ÷ Non-procurement (3 Yr Moving Ave)



It is hypothesized that the current PPBS process does not provide a realistic projection of the long-range planning period. For perspective, even when planned budget growth from 1972 to 1981 was relatively stable, procurement budgets projected one year beyond the immediate budget year were revised downward by about 15 percent when they became the actual budget one year later. Ownership budgets, on the other hand, were revised upward about five percent. Clearly, the procurement versus ownership planning process, even under stable budget growth, could stand improvement.

But, even when total budgets remain constant and procurements retain stable fractions of the total, policymakers may want to consider major changes in force mix--for example to an all Vertical/Short Take-off Landing (VSTOL) tactical air force, or to smaller ships, or to a nuclear Navy, to a draft augmented manpower force, etc. Or economic explorations may be necessary--what if compensation growth must exceed inflation? What if GNP growth is less than planned? What if the inflation norm exceeds expectations? What if cost estimates are optimistic? What if defense industries lose efficiency?

Such questions have dynamic implications through the resource allocation structure. Shifting to a VSTOL fleet causes increases in aircraft maintenance and fuel costs. These increased maintenance and fuel costs detract, if budgets are constrained, from procurement funds. Also, the smaller aircraft carriers required mean more carriers could, over time, be accumulated, but smaller ships are less fuel efficient and less manpower efficient (on a per ton basis) so associated fuel and manpower budgets need to rise accordingly. On the other hand, the increased manpower intensity at sea means that savings in manpower ashore can occur as more maintenance can be done underway. Such dynamics do not lend themselves well to "thumb rules."

Under conditions where overall force growth is anticipated and force mix changes are to be explored, not only must the dynamics be captured, but methods to rapidly alter the dynamics are essential. The current system cannot provide that capability. A system that responds automatically in all necessary dimensions is needed...one that is constructed to increase the budgets for leasing commercial logistic ships, say, when the ratio of Navy combatant to Navy support ships becomes too high, and that automatically increases the mean skill levels of manpower when units become more complex, and that alters maintenance needs if fleet age changes due to altered procurement amounts, etc. Such dynamics can either be reviewed in detail when each policy alternative is considered, or they can be built into a (computerized) model that can be used almost instantaneously as the inputs are changed. The latter obviously has practical appeal.

Some planning factors are more than simply complex. Political factors, and simple human biases, can have major imbalancing



impacts. For example, political determination that the economy will improve faster than is reasonable can lead to underestimation of inflation, which can cause the real funding available to be far less than that planned. Or, the natural optimism of project managers may result in underestimating the planned costs (procurement or ownership) of their systems. On the other hand, several years of underestimation of costs and inflation can cause cost estimators to bias their estimates upward, sometimes to the point where they exceed logical expectations.

Given such complexities, and such potentials for bias, the answer to the question "is extended planning necessary?" must be a strong affirmative.

## Problems and Difficulties in Planning

The current PPBS entails, in essence, obtaining information on hundreds of program elements and their associated costs, adding them together, and then "adjusting" the sum to fit fiscal limits. That, in itself, is a huge task, involving hundreds of people from project offices, from resource sponsors, from budget and analysis shops, from computer centers, etc. The inputs to such a process are filtered through numerous briefings and presentations in the management chain. The information has been influenced by biases, by errors, and by political factors. Data are misinterpreted through misunderstandings of, for example, how inflation was used or was supposed to be used.

Cost factors can be based on the wrong learning curves, or be calculated in the wrong year's dollars. The hundreds of telephone calls between the various echelons of the managerial chain, from the secretariats, through the service chiefs' staffs, to the material commands are not all consistent. The resulting costs, the quantity projections, the escalation funding needed, can be in error, or misunderstood, or both.

This data gathering process is not a one-time event even for a given year. Changes to guidance and to programs occur even before information requested on previous guidance is received. Data, when received, may be based on different guidance than that now assumed by the requestor.

Perhaps most significantly for present purposes, however, is that as these myriad details come together in the PPBS process, the budgets and plans they form run up against the annual budget submission deadline. In a matter of a few days near the end of the programming cycle, the resulting program must be made to fit within fiscal limits, and also to satisfy, as much as possible, the requirements of the sponsors who participate in the final reviewing process. At this point (the "end game"), large changes to cumulative appropriation categories and program allocations may be made. Such changes impact the assumptions underlying the detailed "gathering" process, which means the costs and budgets provided lose validity. But there is scarcely time to do another iteration of the hundreds of phone calls, briefings, and compilations required to obtain valid inputs... and far more than one iteration would be required. So, the changes are made at an aggregate level, using intuitive logic, and seat-of-the-pants policy. Subsequently, as budget and plans become reality, the acquisition and support processes must adjust to the unrealistic plans. Program cutbacks and stretch-outs occur, and the mismanagement label is once again reinforced by critics of defense.

The adjustments made to force the total budget authorizations to fit into fiscal constraints are impacted from another direction--expenditures. Economic pressures to reduce or control government spending are usually concentrated on the short term. This means procurement accounts are impacted differently from ownership accounts. Budget authorizations for ships and aircraft, say, are expended only as systems are built. This means authorized budgets for procurement are outlayed (expended) over several years; less than five percent of the authorization for a new aircraft carrier is actually spent in the budget year, the rest over an eight-year period beyond. But the budget authorizations for operating and maintenance are almost entirely expended in the first and second years of the plan. The process of reducing the planned authorizations of next year's budget, when combined with the politically important goal of reducing near term outlays (expenditures) therefore means the operating and maintenance plans are the ones most likely to be cut. Planning imbalance will result unless such effects are anticipated.

The combined unlikelihood of 1) obtaining the correct inputs in the gathering process, 2) obtaining those inputs without the biases of the information providers and without the biases of those providing the guidance, and 3) avoiding end game changes that would alter the inputs if the necessary feedback effects were reflected, lead to suggesting the PPBS process be at least supplemented by another system.

An "analytic" planning approach is proposed. Vital information embedded in the detailed planning inputs must be translated into analytic models more easily used in conducting the necessary explorations required by policy analysts. The necessary compilation of data and statistical relationships, and the production of useful output, must rely on efficient, modern computing capabilities.

The System Dynamics Approach

Fortunately, system dynamics provides a well-established framework which can be applied toward policy analyses in military long-range planning.[1] At The George Washington University a system dynamics approach is applied to the U.S. Navy's resource allocation problem. The project is called Navy Resource Dynamics (NAVRESDYN).

[1]References [1] and [2] are descriptive for those not familiar with system dynamics.



NAVRESDYN is a computer-based analytic model, which interrelates important variables through parametric relationships. The model is truly dynamic, meaning that the feedbacks are such that not only are the model parameters time dependent, but the parameters change as the policy variables themselves change. Thus, the maintenance parameters, for example, change as the fleet age changes, and fleet age is affected by maintenance as well.

In the current NAVRESDYN model, allocation must be made, in the broadest sense, between acquisition and ownership. Ownership involves operating and supporting the Navy's weapon assets. Yet the cost of ownership of Navy systems cannot be treated independently of the cost of acquisition, of naval readiness, or of operating/maintenance/manning policies. All these aspects must be included in the planning trade-offs.

The NAVRESDYN approach involves determining a historic relationship between overall Navy ownership budgets (or fund flows) and the stock of weapon assets in the inventory demanding those flows. These historical relationships can help predict future ownership needs, and this can be accomplished independently of detailed project-by-project summation.

Any budget plan can be separated into two major categories--funds that are committed and those not committed. Broadly defined, committed resources are those required to "own" existing forces--personnel compensation, fleet maintenance, fuel costs, are examples. To estimate the committed resources in future budgets, one must understand the relationships between the committed portions of the budget and the force levels requiring the commitments. This starting point can be defined as "determining the cost of ownership," as it acknowledges the need to operate and maintain existing systems at some reasonable level of readiness. Determining and predicting such ownership cost is not a trivial task. It requires developing an understanding for the total Navy resource allocation process, including the effects of changes in assets, support of those assets and the resulting readiness, operating, maintenance, and manpower policies and their impact on costs and readiness.

The basic premises for the Resource Dynamics approach are 1) that funding available over the planning horizon must be allocated toward research and development (R&D), toward procurement, or toward ownership; 2) that accumulated assets determine required ownership costs; 3) that required ownership costs can be influenced through R&D funded designed improvements, (e.g., decreased failure rates, increased fuel efficiencies); 4) that new acquisitions depend on the residual annual fundings remaining after necessary ownership costs are funded; and 5) that force readiness deteriorates if required ownership costs are not fully funded.

Stated another way (and referring to Figure 2) quantity



and quality of asset stocks determine ownership fund flow requirements. Quantity depends largely on buys and on retirements, while quality can be influenced by R&D expenditures. Given fiscal constraints, ownership costs (plus research and development) when deducted from the fiscal level provided, determine the procurement residuals that can augment the asset stocks. Procurements, as they accumulate, lead to asset levels which determine ownership requirements, which in turn lead to future procurements, given future fiscal constraints. This circularity can be broken in one of two ways: 1) more funding is provided so that both acquisition and support can increase, or 2) support can be under-funded so that acquisition can accelerate--but this latter leads to reduced readiness of the required forces, to larger force levels, and, therefore, greater ownership requirements downstream. The circularity is illustrated in the diagram.

Counterintuitive results often occur when such feedbacks are properly modeled. Attempts to increase the fleet size by allocating more procurement funds toward buying smaller units can backfire. The reduced efficiencies and shorter life spans of smaller units can lead to more rapid turnover and large delayed needs for fuel and manpower. Consequently, Policy-makers benefit in two ways when the entire feedback structure is developed. First, they are forced to make explicit the assumptions made. Second, they can see the impacts of changes to those assumptions.

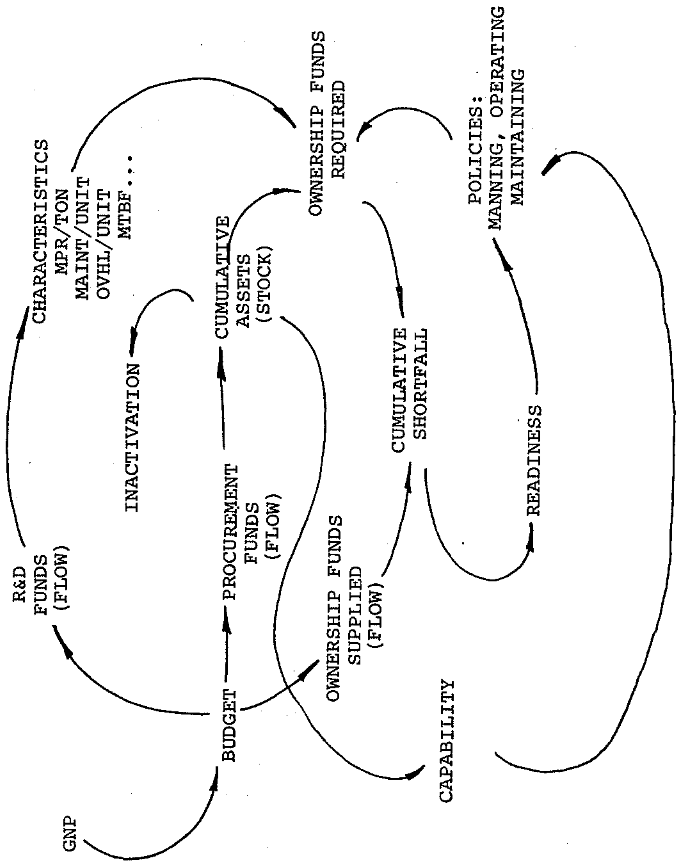



Figure 2. Simplified Resource Dynamics Structure



The "stocks-flows" logic embedded in Figure 2 is fundamental to the study of systems, and the Navy's resource allocation system is no exception. The figure shows one (annual) iteration which can be described through a system of (difference) equations wherein the system states, controls, and outputs at one point in time (t), are dependent only on 1) its states one time period earlier (t-1), 2) the controls (budgets) applied between the two time points, 3) the parameters (or constraints) of the system. In the figure the "states" of the system are the asset stock and the cumulated ownership shortfall; the "controls" are the inactivation rate and the budget flows (which evolve from the operating/maintenance/manning policies); the "parameters" are the force characteristics plus all the constants used in the relationships between variables (for each arrow in the figure can represent several relationships which must be derived statistically). The "force characteristics" are determined by numerous ownership costs, such as maintenance costs per unit, manpower requirements per ton, fuel use per ton per hour, overhaul costs per unit, etc., most of which can be affected through proper design improvements, meaning increased R&D expenditures. Finally, the "outputs" shown are the number of ships, and the readiness decay measure, though any variable can be printed as an "output"--certainly budgets flows are all candidates.

The model is, in essence, the set of difference equations representing a single time period, and the computer then iterates the model through as many time periods as required, calculating the value of all states, controls, parameters and outputs at the first time point, then the second, etc., until the entire time horizon is "simulated."

Of course, Figure 2 gives an oversimplified look at the model. For example, "Assets" are, even in the simplest form of NAVRESDYN, split into ships and aircraft assets, and each of those is disaggregated by age category--30-year old ships, 29-year old, etc. The "ownership" flow shown is made up of ship maintenance, ship operations, ship manpower, and ten or so miscellaneous accounts--similarly for aircraft.

A note on the "readiness" direction of the research is appropriate. Readiness measures are considered in the form of readiness "indicators"--overhaul backlogs, spare parts shortfalls, manpower skill and quantity factors, steaming hours per ship etc. Policymakers involved in budget allocations can influence success in combat basically through control of resources affecting such indicators. A task group commander must ultimately ensure his forces are "ready" in the more traditional sense of operation or unit readiness, but he will have an easier time if policy level resource sponsors have provided adequate levels of spares, training time, manpower, maintenance, etc., to the task group in the first place. The hypothesis is that the fleet will have higher material readiness, personnel readiness, mission readiness, operational readiness,

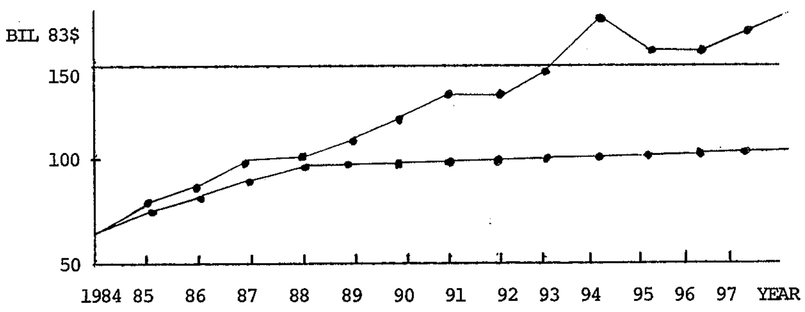


and less casualties, if resource allocators have monitored the "readiness indicators," and allocated intelligently toward those areas they can affect. Of course such allocations detract from procurement funds, and numerous trade-offs between force levels, and force readiness, can be explored by policymakers if the proper planning tools exist.

Having a model incorporating such considerations, one can execute a program using base case assumptions. Figure 3 provides a comparison of two modes: a fiscally constrained mode as has been described, and a "force level" mode wherein the types of ships and aircraft to be acquired are specified without fiscal constraints. The fiscal case determines how many ships and aircraft can be procured within prescribed budgets after first paying the ownership costs, while the force level case determines how much it will cost to buy and own the units planned.

Given a base case, one can conduct various "what if" exercises. These come in various categories, for example, budget changes, price inflation changes, changes to ship and aircraft characteristics, changes to production efficiencies, changes in the force mix.

By way of demonstration, Figure 4 provides a hypothetical fiscally constrained case in graphical form. The base case shows ship, aircraft, fleet value (ships and aircraft valued




| MODE | YEAR | BUDGET | SHIPS | ACFT | MANPOWER |
|---|---|---|---|---|---|
| FORCE LEVEL | 1984 | $69B | 548 | 6070 | 551 (THOU) |
| | 1989 | 110 | 560 | 7100 | 586 |
| | 1993 | 143 | 550 | 7700 | 620 |
| | 1998 | 171 | 580 | 7850 | 719 |
| FISCAL CONSTRAINT | 1984 | 73 | 548 | 6070 | 551 |
| | 1989 | 96 | 568 | 4600 | 530 |
| | 1993 | 100 | 548 | 5400 | 580 |
| | 1998 | 105 | 537 | 5500 | 616 |

Figure 3. Force Level vs. Fiscal Constraint Modes

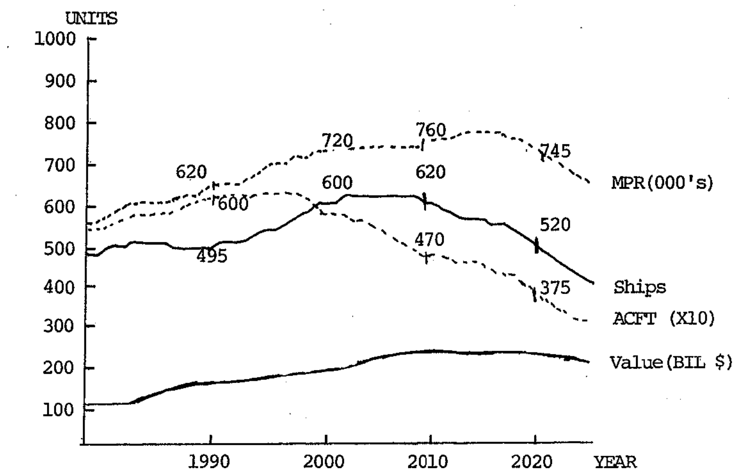



Figure 4. Ships, Aircraft, Manpower, and Asset Value, Base Case



at cost) and required manpower projections, under a fiscally constrained case. In this run, future ship and aircraft unit costs have been assumed to grow at historic rates (five to seven percent) and the Navy budget grows, in constant dollars, by seven percent per year for five years, then by one percent for the remainder of the planning horizon. Several factors are noteworthy. First, both ship and aircraft unit levels lag the budget growth. This is consistent with the lag in deliveries of aircraft (two-three years) and ships (three-eight years) beyond the budget year. Second, with ship and aircraft procurement costs growing at five percent to seven percent and budgets eventually growing only 1.0 percent, units must eventually decline. Note, however, that value continues to rise, as each unit is far more "valuable" than the unit being replaced and real budgets do grow. Third, aircraft units, lasting only 15 years or so, decline sooner than ships, which last 30 years. Fourth, the lag between budget growth decline and unit count decline is longer than the normal budget-to-delivery lag. This is because within the model, attempts to avoid fleet decline in numbers feeds back as a policy to retain units beyond their normal service life...but that ages the fleet and eventually leads to higher maintenance costs and accelerated declines later. Fifth, note that manpower continues to increase beyond the decline in fleet units, because fleet value continues to grow. Finally, the eventual manpower decline occurs because of manpower efficiencies associated with the more costly, but more automated units, and also because the increasing value of the fleet causes more of the budget to go toward ownership accounts, so fleet asset growth is slowed.

With this base case for reference, other excursions can be explored. Figure 5 asks "what if budgets grow one percent less, each year, than planned."

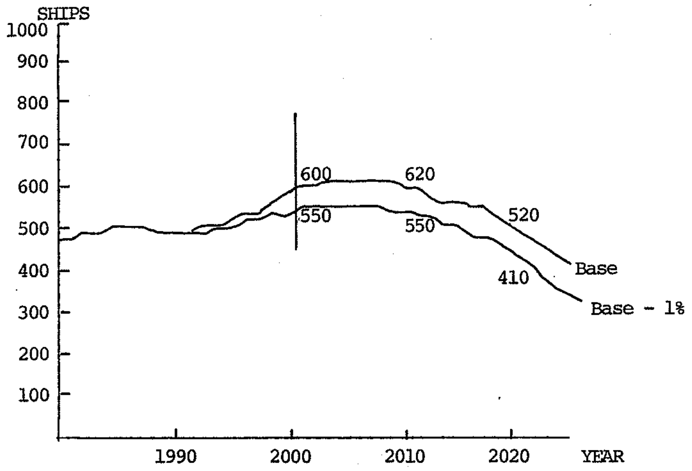



Figure 5. Ship Reductions Associated with Budgets 1% Less than Planned

Figure 6 shows the "what if the force mix is changed" example, where a total shift to a VSTOL (Vertical/Short Take Off Landing) tactical aircraft force is programmed. This case is interesting, for the VSTOL force allows smaller aircraft carriers, presumed to save money and therefore increase fleet



numbers. A counterintuitive decline in numbers occurs, however, for several reasons. First, VSTOL aircraft cost more per unit for equivalent capability, have higher attrition rates, and shorter service life. Second, their maintenance costs (compare the "aircraft maintenance" budgets) are considerably higher. Third, the smaller ships are less manpower and fuel efficient on a per ton basis, consequently proportionately more money is required for ownership. Further, VSTOL capable ships other than aircraft carriers are more expensive than their non-VSTOL capable predecessors. These types of results, natural in feedback models, are unlikely to be incorporated in a static (open system) approach to planning.

| | BASE CASE | VSTOL CASE |
|---|---|---|
| SHIPS: | 600 | 550 |
| AIRCRAFT: | 5900 | 5500 |
| MANPOWER: | 720,000 | 680,000 |
| OWNERSHIP BUDGET: | $ 36.7B | $ 38.5B |
| SHIP OPERATIONS: | $ 4.0B | $ 3.9B |
| AIR OPERATIONS: | $ 4.1B | $ 4.2B |
| ACFT MAINTENANCE: | $ 4.0B | $ 5.7B |
| VALUE OF SHIPS: | $ 244B | $ 243B |
| VALUE OF ACFT: | $ 65B | $ 60.3B |
| AGE OF AVE SHIP: | 12.2 YRS | 12.5 YRS |
| AGE OF AVE ACFT: | 9.2 YRS | 9.5 YRS |
| AVE UNIT VALUE, SHIPS: | $ 410M | 450M |
| AVE UNIT VALUE, ACFT: | $ 16.0M | 15.8M |

Figure 6. VSTOL Case

## Statistical Analyses Supporting the Model

Model outputs are of course largely dependent on the accuracy of model parameters and the functional forms relating the variables. Of the numerous statistical explorations conducted to date, only a handful of examples are mentioned here. Typically, a crude statistical analysis is performed to obtain model relationships, and, after testing the model to the sensitivity of the relevant parameters, more detailed statistical studies are conducted on the most sensitive parameters. This allows developing the model without delaying until all detailed statistical analyses are performed, and also makes the statistical analysis plan more efficient by stressing the most sensitive parameters for exploration first.

In the area of fleet units and their characteristics, analyses on trends in size, in cost per ton, on trends in asset levels, on crew requirements per dollar of asset value, on generating capacity per unit, on propulsion power, and in carrying capacity per ton have been conducted. As examples, over the past 20 years ships have grown about three percent per year in size and 2.7 percent in cost per ton (constant dollars). Aircraft unit costs have grown about seven percent per year. Ship cost per ton has approximately matched the growth in generating capacity per ton. Afloat manpower per dollar of asset value has declined some three percent per year and, if one inspects budget trends, this has resulted in <u>lower</u> fractions going toward military pay--from 23 percent in 1972 to only 14 percent in 1982--quite contrary to popular opinion that military manpower costs are growing too fast.



An analysis of the last 1250 ships built shows some 25 percent of the units receive major conversions, and when converted, some 50 percent of their initial value must be added to accomplish the conversion. Such data is incorporated into the model to allow adjusting fleet age (units are renovated when converted) and also to allow changing manpower and complexity factors.

The ownership costs associated with the fleet units have been analyzed. Aircraft maintenance costs are about five percent of aircraft asset value overall but must be disaggregated into fixed wing, VSTOL, and rotary wing. Aircraft maintenance varies only slightly with the age of the aircraft series, largely because the aircraft modernization program keeps aircraft fairly near their new condition. Aircraft operating costs are determined as functions of aircraft weight and thrust/weight ratios. Ship maintenance is determined to require, overall, about four percent of ship value and, of course, varies from type to type. Ship fuel costs are determined to rise with horsepower, tonnage, and generating capacity, but a ten percent increase in each leads to only three percent, two percent, and one percent increases in fuel. Aircraft fuel use analysis required splitting aircraft into three categories. Manpower costs ashore are inversely related to those at sea, with 20 percent elasticity--meaning each 1000-man reduction at sea has been offset by a 200-man increase ashore, still a saving, however.

## Conclusion

The statistical analyses, when combined with the logic of stocks and flows in a feedback system model, provides one means of at least partly overcoming the political realistics and budget complexities of the PPBS process. A Resource Dynamics approach, with historical knowledge built into a computer model, allows making realistic projections of either the costs of a desired fleet, or projections of a likely fleet, given resource constraints. Rapid "what if" excursions around the resulting base cases make realistic "policy analysis" feasible, within available time frames and without involving too many people--a fact which makes it politically possible to explore even some sensitive options. Model disaggregation allows more accuracy and the incorporation of readiness decay as functions of shortfalls in manpower, maintenance, and operations funding, allows making policy trade-off between procurement and readiness. The modern computer, combined with statistical facts and managerial knowledge, thus, has allowed developing a naval policy tool within the System Dynamics framework.



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[2] Richardson, G. P., and A. L. Pugh, III (1981). Introduction to System Dynamics Modeling with Dynamo, MIT Press, Cambridge, MA.