crease or decrease, nor does it predict whether or not DoD will be able to achieve efficiencies in its operations. The DRM measures the budgetary impact of changes only in the number of forces, and consequently, the incremental impact on the budget of any change could be applied to any budget base with reasonable accuracy.

The cost projection has two parts--the computation of direct and indirect costs--and hinges on the resource allocations in DoD's five-year defense plan.

The DRM and the Five-Year Defense Plan. Understanding the DRM data base helps in understanding the model. The data base is a "roll-up" of program elements--the lowest level of aggregation in the budget structure of the five-year defense plan. Operation and investment costs are allocated to each program element when the budget is prepared. For example, separate program elements exist for major forces like B-52 bombers or frigates, and these program elements display the funds for direct operations and investment budgeted for these forces.

The DRM uses data at the level of program elements in the five-year defense plan to compute the direct costs for most major forces, but for other computations the DRM either disaggregates or aggregates these data. For example, aircraft carriers will have different operating costs depending on whether they are powered by a nuclear reactor or by conventional means. The program element contains all resources for the two types of carriers, so the data are disaggregated to give two DRM program elements. Similar disaggregations occur for submarines, cruisers, and Army divisions (for divisions, the relevant dimensions are type of division--for example, infantry or armored--and location--for example, stateside or overseas).

The program elements of the five-year defense plan are usually aggregated when they represent similar functions and can be combined to make the data base unclassified and more manageable. For example, about 465 program elements pertaining to research and development are combined to yield about 20 aggregated elements in the DRM. About 790 program elements that relate to central support functions are aggregated to yield about 60 aggregated elements in the DRM. Overall, the five-year defense plan has about 2,500 program elements and the DRM has about 340 aggregated elements that are grouped into the categories shown in Table A-1.

Direct Costs. Strategic forces and tactical and mobility forces are the two categories with major forces, and hence the only two categories for which the DRM computes direct costs of force changes. Major forces include Army divisions; Army separate brigades and regiments; land-based intercontinental ballistic missiles; bomber, fighter, attack, and airlift aircraft; and ships. Direct costs include such items as fuel and spare parts, and pay for the military personnel assigned to the force unit.

The number of major forces is related to direct costs that the DRM assumes are allocated to a program element of the five-year defense plan, and consequently to an aggregated element. Roughly 35 percent of DoD's total O&S budget is allocated to this cost category. The DRM divides the number of forces--for example, frigates--allocated to the relevant aggregated elements into the funds budgeted for operations, thereby computing a cost factor for the direct annual costs of the force element. The DRM assumes that these cost factors per unit are constant in real terms throughout the period for which costs are projected; that is, the DRM does not assume that operating tempos and policies change, or that resources are used any more or less efficiently.

When calculating the cost of a change in forces for the first year, the DRM assumes the change occurs during the middle of the year and so raises or reduces costs by half the annual amount. For example, the DRM would project that the savings from retiring one wing of 72 Air Force F-4 aircraft would be about $85 million of direct costs in the year the change is made and about $170 million annually thereafter.

Indirect Costs. The DRM also computes the indirect costs of force changes. Indirect costs are sometimes called the support "tail" and include such functions as training, medical care, logistics, and base operations. The computations assume that O&S funds in the support tail have a linear relationship to O&S funds in the force programs. Similarly, they assume that O&S funds in the broader categories of support--for example, medical and personnel support--have a linear relationship to O&S funds in the force programs and narrower categories of support--for example, training.

to be related to capital stock. Funds for medical care or base operations fall in this category.

Notwithstanding these intuitive conclusions, empirical analysis shows that total O&S spending was related to the value of DoD's capital stock for the period since 1975. Accordingly, this study uses the Capital Stock Model (CSM) as one of its methods for estimating O&S costs.

Estimating Capital Stock. Capital stock in DoD could be measured in many different ways.[2] In practice, a number of different measures of capital stock were considered in this analysis, each implying a different view of what determines O&S costs. The measures also differed in terms of how comprehensively they accounted for the services' capital assets.

One estimate of the dollar value of DoD's capital stock included only *major weapons*--inventories of items such as ships, planes and tanks that DoD viewed as sufficiently important to count individually and for which historical inventory data exist. Another--*total weapons*--added to the stock of major weapons an estimate of the dollar value of diverse DoD items for which historical inventory data do not exist. Examples of such items include tactical air-to-air and air-to-ground missiles. Estimates of the value of these diverse items in the total weapons estimate were made using a perpetual inventory estimating technique. In the perpetual inventory method, funds in an account, for example, weapons procurement that buys tactical missiles, are assumed to behave as inventories. The method assumes a standard procurement lag, attrition rate, and retirement age. Since by definition these accounts buy a variety of systems, this assumption of standardization calls the accuracy of the estimates into question. This difficulty is particularly striking with accounts like "other procurement" that buy items as diverse as trucks and satellites.[3]

2. Annual estimates of the Department of Defense's capital value are also constructed by the Bureau of Economic Analysis of the Department of Commerce.

3. For an example of a perpetual inventory capital stock series, see Charles R. Roll, Jr., "Potential for Capital-Labor Substitution," (paper given to the Conference on the Economics of National Security sponsored by the United States Air Force Academy and the RAND Corporation, August 15-18, 1979).

Yet a third measure--*total DoD assets*--added to the total weapons capital stock the estimated value of DoD's real property (buildings and facilities). This third level of aggregation, total DoD assets, compounds the problems associated with perpetual inventory estimation by adding the estimate for total weapons to values for real property that may not have been adequately corrected for inflation and for which assumptions about the kinds of data to include may not have been the same in all the services. Major weapons represent about 50 percent of total DoD capital stock and total weapons about 70 percent.

All three of these capital stock values have been proportional to O&S costs during the years since 1975.[4] Figure A-1 shows the historical ratios (expressed as a percentage) of O&S funding to the various levels of capital values estimated. (All estimates are in constant 1988 dollars.) As the figure shows, the ratios have been fairly constant for the past 12 years, varying by a maximum of four percentage points.

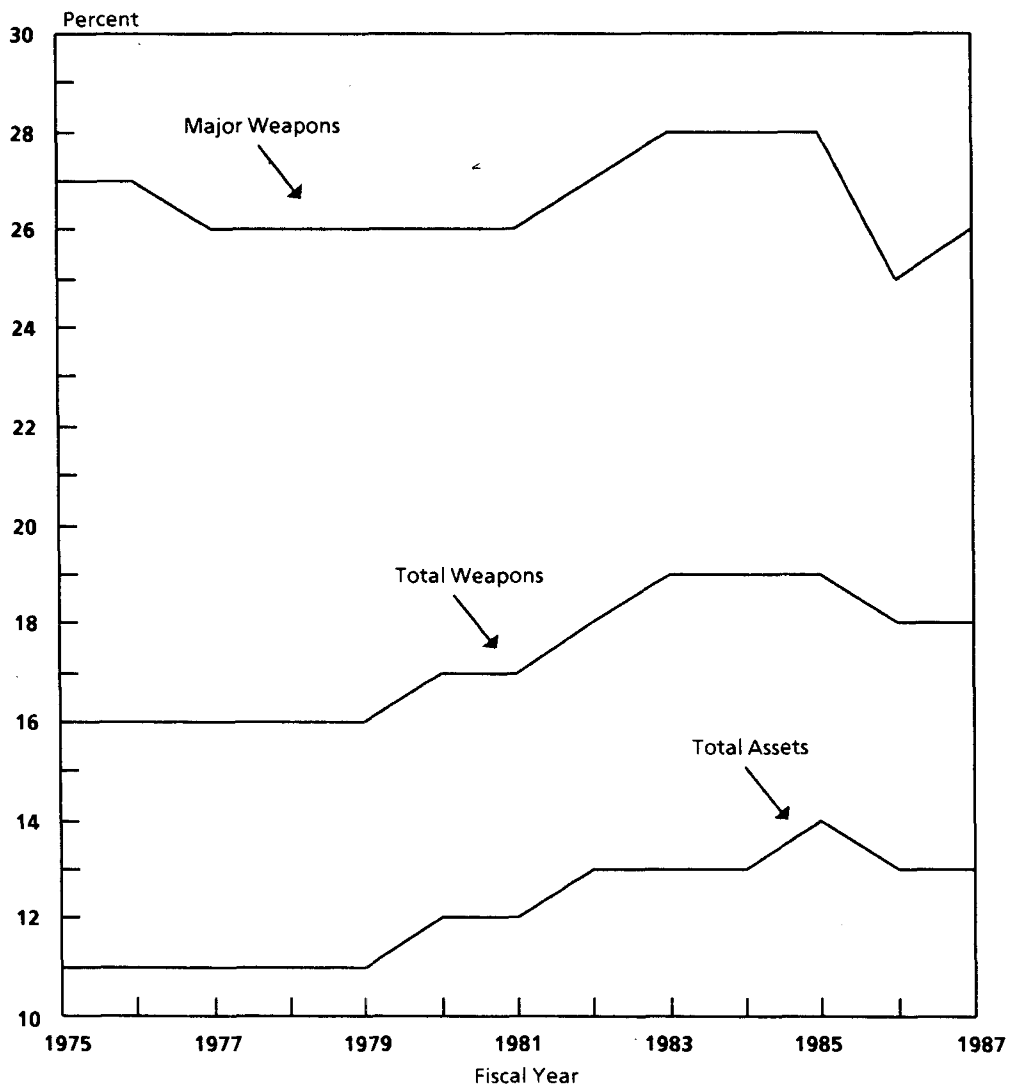
The major weapons capital value was chosen in this analysis because it offers several advantages over the values for total weapons or total DoD assets. The first advantage is ease of calculation, an important consideration in a model that will probably be run repeatedly in a variety of budgetary conditions. The second advantage is confidence that the data used to estimate major weapons capital stock are more accurate than the data used in the perpetual inventory technique (for total weapons) and the data on the value of DoD real property (for total DoD assets). Finally, it is plausible that major weapons purchases, with their pervasive influence on the rest of the defense budget, might have the greatest and most direct effect on O&S costs.

The capital stock of major weapons was constructed using historical counts of ships, planes, tanks, and helicopters that were in the DoD inventory. To convert the number of items to a dollar value, a unit cost for each item of equipment (expressed in constant 1988 dollars) was multiplied by the inventory of that kind of equipment. Unit procurement costs were used for all ships and major weapons systems in

4. The period from 1975 to 1987 represents existing data. Before 1975, some service inventory data were not available. There is little reason to attempt to construct a much earlier time series, since the intent of estimating peacetime operating costs might preclude using data from the Vietnam War era. In wartime, the ratio of operating costs to capital stock would presumably be much higher than in peacetime.

the Army; these unit costs equal total procurement costs divided by the number of items procured. Historical cost data for fixed-wing aircraft were available only at the "flyaway" level, which excludes some procurement costs (such as special ground support equipment) and is

Figure A-1.
O&S Costs as a Percentage of Three Capital Value Measures

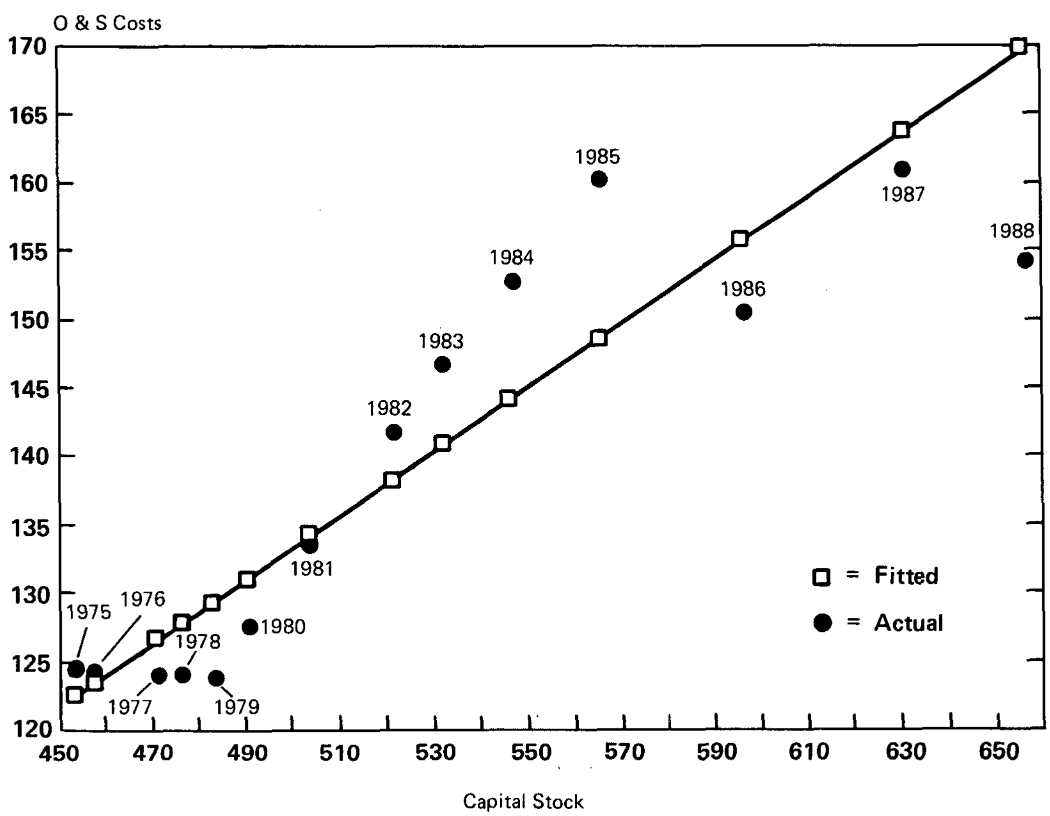


SOURCE: Congressional Budget Office estimates.

frequently assumed to be two-thirds of total procurement funding. The analysis used this factor of two-thirds to estimate procurement unit costs from the flyaway cost. (Weapons values were estimated using only flyaway cost estimates for aircraft and results are comparable to the ones shown here.)

Relating O&S to Capital Stock. Two methods of estimating the relationship of O&S to capital stock were used: a simple ratio calculation and a statistical regression analysis. Given the constancy of the ratio over time, the simple average of the annual ratios could be used to project O&S funding. The ratios for the period from 1975 to 1988

Figure A-2.
O & S Costs and Capital Stock: Fitted Values Compared with Actuals, Fiscal Years 1975-1988 (In billions of 1988 dollars)



SOURCE: Congressional Budget Office estimates based on Department of Defense data.

vary by only five percentage points, with the lowest ratio in 1988 and the highest in 1985. The average ratio over the period from 1975 to 1988, 26 percent, was used to project real growth of 5.5 percent per year. Alternatively, the 1988 ratio might be considered a more realistic estimate for future spending. Hence, that value was used for a second projection, that O&S funding would grow at a rate of 3 percent per year.

The statistical regression equation can also be used to project O&S costs. The equation incorporated data for the period from 1975 to 1987. Data from 1988 were omitted from the equation because, as Figure A-2 on the preceding page shows, they differ dramatically from other data points.[5] The baseline estimates in the text use data from the current period to adjust projections downward by the amount the equation overpredicts the 1989 budget request.

The regression equation was statistically significant, with signs that seemed intuitively logical, and explained 86 percent of the variance in O&S spending. The equation for the relationship used in the text is:

$$\text{O\&S} = \underset{(0.57)}{17{,}214} + \underset{(4.10)}{0.232}\,(\text{capital stock value})$$

Standard error = 5499
R bar squared = 0.86
Durbin Watson = 1.82

where figures in parentheses are t-statistics. When data for 1988 and for the 1989 proposed budget are included in the equation, the statistical relationship becomes much less clear. The equation is:

$$\text{O\&S} = \underset{(1.13)}{101{,}360} + \underset{(0.58)}{0.080}\,(\text{capital stock value})$$

Standard error = 5946
R bar squared = 0.83
Durbin Watson = 2.27

where figures in parentheses are t-statistics.

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5. In statistical terminology, the 1988 data point meets the criteria that would cause it to be characterized as an "outlier" and thus to be excluded from the analysis. Economic time-series analysis often excludes data points for particular years, such as World War II or the Great Depression, on the grounds that economic conditions in those years do not provide a basis for extrapolation. While the conceptual reasons for excluding 1988 from the equation are less clear than either of these two examples, the articles discussed earlier provide evidence that the Department of Defense may be concerned about the level of funding for that year.

Figure A-2 is a visual representation of how well the regression equation compares with historical data. The line in Figure A-2 shows the values of O&S costs projected by the equation (the so-called "fitted values"), given the historical values of capital stock in each year. The actual O&S values in these years are shown as points scattered about the line.

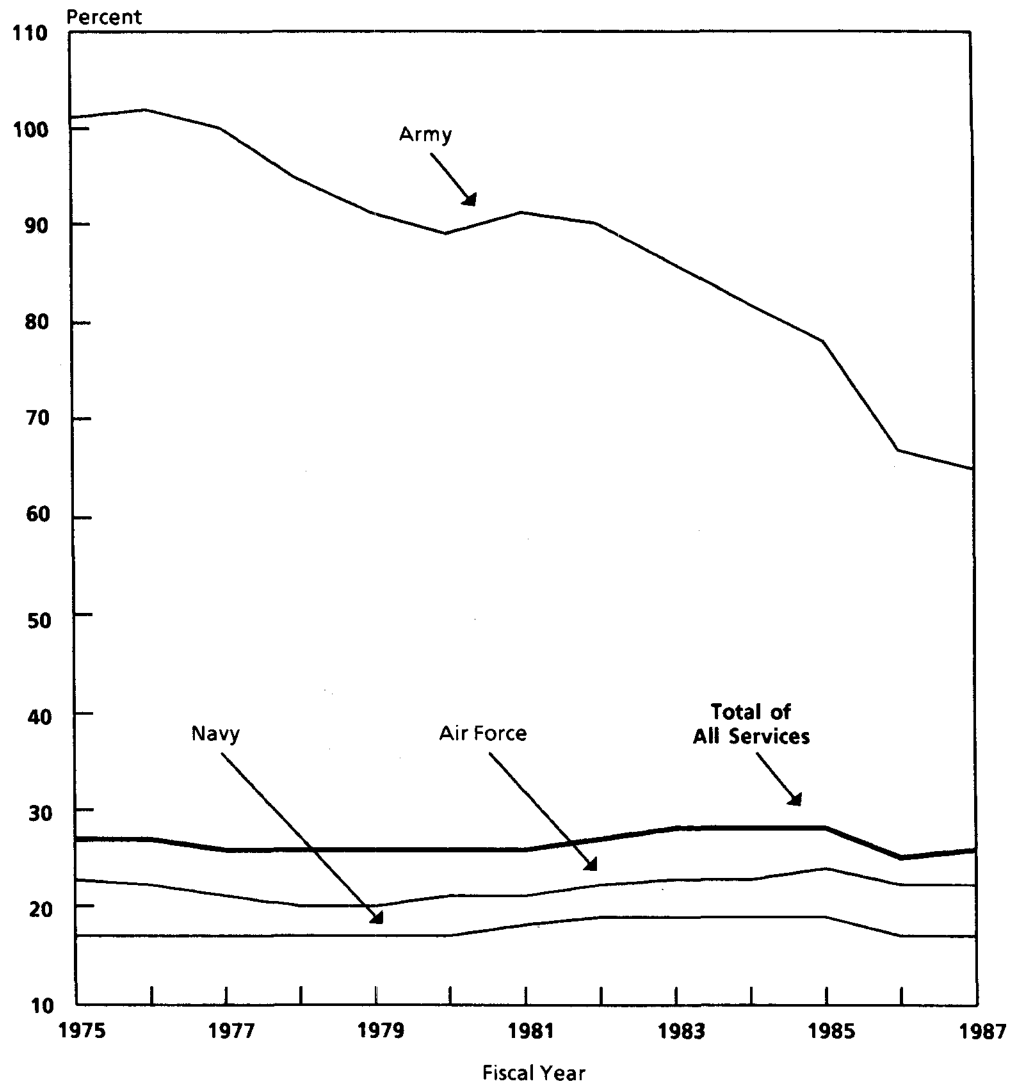
The figure reveals a pattern in the differences (the "residuals") between fitted and actual values.[6] For the 1970s, fitted values exceed actual values and thus the residuals are negative, indicating that the model would have projected higher O&S spending than actually occurred during a period when readiness was widely perceived as being at a low ebb. From 1982 through 1985, residuals are positive, indicating that the model would have projected less O&S spending than the actual amount. Perceptions about readiness were generally positive during these years.

Beginning in 1986, residuals once again are negative, and indeed there is a large negative residual for 1988. This relationship could indicate that O&S funding substantially below levels predicted by historical experience might again lead at least to perceptions that readiness levels are declining.

These observations about readiness suggest that the regression equation might be better specified statistically if it were possible to include readiness as an explicit variable. Using the terminology of economics, readiness might be thought of as produced by a combination of fixed inputs (capital stock) and variable inputs (military personnel and others represented by the activities included in the operation and maintenance accounts). Assuming that the efficient amounts of these inputs are used, such a "production function" for readiness can be rewritten as a cost function in which the variable costs of military personnel and operation and maintenance depend on the level of readiness (output) and the amount of capital stock.

6. This sort of a pattern also indicates a statistical problem related to the data. The problem is called autocorrelation and means that the observations for various periods are statistically related to each other. Methods for measuring autocorrelation--the Durbin-Watson test--and for adjusting the equations to correct for it--the Cochrane-Orcutt procedure--have been employed to adjust all equations for autocorrelation.

Figure A-3.
O&S Costs as a Percentage of
Major Weapons Values in the Services



SOURCE: Congressional Budget Office estimates.

Lacking a measure of readiness, this equation cannot be estimated. Instead, the CSM implicitly holds constant the level of readiness in estimating the relation between the sum of the costs of labor and other variable inputs on the one hand, and the cost of capital on the other. The observed pattern of residuals suggests the importance of the omitted variable, readiness, but as long as the level of readiness does not change in the future, the estimated equation can be used for purposes of projection.

Other Specifications. An issue in the construction of the model was whether it was appropriate to use the same capital stock measure for all of the services. Figure A-3 on the preceding page shows the ratios of O&S funding (expressed as percentages) in the three services to major weapons values for each service over the past 12 years. For two services--the Air Force and the Navy--the ratios are roughly constant, varying during the 1975-1987 period by only four percentage points for the Air Force and two percentage points for the Navy. For the Army, however, the ratio declines dramatically from a high of 102 percent in 1976 to 65 percent in 1987. This decline reflects rapid increases in the portion of the Army's capital stock in the major weapons category, from 37 percent of total weapons in 1975 to 51 percent by 1987. The increases occurred because the Army added major, expensive new weapons to its inventory, including the M-1 tank, the Bradley Fighting Vehicle, and the Apache helicopter.

Thus, an alternative specification of the model that uses major weapons capital for the Navy and the Air Force and total weapons for the Army was considered. This version of the model, like the others, offered a good statistical relationship. But it yields a much higher estimate of annual real growth in O&S through 1993 than does the version using major weapons capital stock for the Army. One explanation for this high projection is that the Army has achieved economies in the cost of supporting its major weapons, economies that are ignored in this specification.

Two other alternative versions of the CSM--one fixing portions of O&S costs and another estimating operation and maintenance costs based on capital stock and military personnel--were also considered. Because of conceptual problems with the models, they are not discussed here or used in the study to project funding.

APPENDIX B

OTHER OPERATION AND SUPPORT MODELS

Many other models are used to estimate operation and support (O&S) needs. None provides estimates that cover the whole of the Department of Defense (DoD), and therefore these other models are not used in this study. Nonetheless, a brief discussion of five of the models may provide an understanding of alternative approaches to estimating O&S funding needs. This appendix also discusses two new models that are under development and offer the promise of improved estimating capability.

The CORE Model

The Air Force's Cost Oriented Resource Estimating (CORE) model calculates squadron operating costs for aircraft. Input to the model is based on historical expenditure data, some of which are derived from other Air Force models. In some cases (for example, squadron manning levels), data are estimates from the previous budget year. In other cases, such as depot maintenance costs, estimates are derived from historical expenditure data, adjusted statistically for a variety of reasons including the age and cost of the systems.[1]

CORE is sometimes described as a "cost factors" model--that is, a model that estimates the marginal cost factor of adding or deleting a squadron of a particular kind of plane and applies that factor to squadrons of those planes through the estimating period. The model is primarily used for "what if?" programming exercises and to provide independent cost estimates for the evaluation of systems development. Since the model does not estimate the total average costs of Air Force

1. CORE's depot maintenance cost estimates, for example, are the output of the Weapons System Cost Retrieval System, a data base run by the Air Force Logistics Command to collect actual costs of depot maintenance activities.

systems, it cannot be used to estimate total Air Force requirements for O&S funds.[2]

The NARM

The Navy Resource Model (NARM) is similar to the CORE model in that it estimates average marginal operating costs for a variety of Navy systems. It also uses historical expenditure data to project future systems costs. The Navy used the NARM to derive direct and indirect costs for its ships and planes only through 1980, and direct costs through 1982. Since then, the Navy has been developing a data base that may eventually lead to expenditure-based O&S cost estimates for all major Navy weapons systems.

The AFPCH

This *Army Force Planning Cost Handbook* (AFPCH) resembles the other cost factors approaches, except that most of the factors are expressed on a per capita basis rather than per system. The model produces estimates of one-time and recurring factors for direct O&S costs and support costs, all of which are reported in the *Army Force Planning Cost Handbook*. These cost factors vary depending upon the organizational equipment of each unit and its location. As with the other factors models, AFPCH is primarily intended to capture marginal costs associated with a force change.

In 1982, the Army became concerned about the quality of the historical data used by the AFPCH model and adopted a budget-based factors approach. This approach uses the costs associated with a system in the budget to project future costs for the system.

The *U.S. Army OMA & MPA Cost Factors Handbook*--using budgetary data--was last published in 1984. Since then, the Army has been updating these factors when they are required for specific esti-

2. CORE, which only estimates costs for active systems, is being replaced by a model called Systematic Approach to Better Long-range Estimating (SABLE). SABLE estimates O&S costs for Reserve and Guard squadrons as well as active squadrons. It is currently being used by the Air Staff and by some of the Air Force's major commands for budget exercises, though it also estimates only marginal costs.

mates. The Army plans to develop a model for O&S cost estimation to replace the AFPCH.

The Resource Dynamics Model

This model estimates total Navy O&S costs. While the model uses statistical regression techniques--chiefly to estimate maintenance costs--it also uses pro rata and fixed factors where regression relationships were not found. Input to the model includes force structure, system characteristics, asset value, and historical O&S data from the VAMOSC data base (discussed below).[3]

The Navy O&S Cost Model

The Navy O&S Cost Model estimates total Navy O&S costs. For input, the model uses historical cost data, a variety of systems characteristics, and asset values. The model estimates costs based on the best fits in regression equations for historical systems costs. Details of the model are classified.[4]

MODELS UNDER DEVELOPMENT

As the above discussion indicates, there is considerable room for improvement in the data and methods used to estimate O&S costs. For example, none of the models relates O&S costs to measures of readiness. Several efforts are underway in DoD to improve this situation. One, Visibility and Management of O&S Costs (VAMOSC), grows out of a long-term effort by the Office of the Secretary of Defense

3. For a description of the model's methodology, see Rolf Clark, "Navy Resource Dynamics: Planning Future Forces and Budget," in Hans W. Hofmann and Heinz Schelle, ed., *Kosten in der Verteidigungsplanung* (Munich: Verlag für Wehrwissenschaften, 1985). For a discussion of Navy O&S cost relationships, see Rolf Clark, "Operating and Support Costs of the U.S. Navy: Some Analytic Facts," in John C. Honig, ed., *Budgeting for Sustainability* (Baltimore: Operations Research Society of America, 1986).

4. This model was developed for the Office of the Secretary of Defense by the Institute for Defense Analyses. A description of the model is available in Jerome Bracken and others, *Navy Operating and Support Cost Model* (June 1985), IDA Report R-298, prepared for Office of Secretary of Defense, Director, Program Analysis and Evaluation, (Secret).

to build a base of historical expenditure data to support budgetary projections. Another Navy effort, the Resources to Readiness Model, shows some promise in relating expenditure data to one measure of readiness--mission capable rates.

The VAMOSC Data Base

The concept of VAMOSC (Visibility and Management of O&S Costs) has existed since the mid-1970s. It is envisioned as being a collection of expenditure data that would provide system-specific operating costs, using existing data-reporting systems. The CORE and AFPCH models, and the NARM are all examples of data collection efforts that VAMOSC would use as a source of information. Once sufficient historical data had been collected, VAMOSC could be used to estimate future costs.

Perhaps in part because of the requirement not to add to reporting efforts by the services, VAMOSC has to date enjoyed only limited success. Difficulties arise when the services' existing reporting systems collect information as "line items" rather than as data specific to different weapons systems. An example could be a radio that is used on many different kinds of aircraft. The depot that repairs those radios may know how many radios (as line items) are replaced or repaired, but may not know that radios are repaired every week for one type of plane but every two years for another.

Partly for this reason, the VAMOSC data are not consistently useful. The data base for Navy ships, specifically aircraft carriers, is widely viewed as being better than that for Navy aircraft, because the Navy accounts for many operating costs by carrier but not by plane or squadron. There may be hope for improvement in the system in the future, largely because of improvements in computer technology that may eventually enable the services to record the destination of a particular spare part and hence allocate its costs more accurately. The cost of establishing such computerized data bases, however, will be high, and it could be many years before all of the services are able to realize the full potential of VAMOSC.[5]

5. The Air Force is currently engaged in an effort to use computers for much of VAMOSC's data collection.

The Navy Resources to Readiness Model

This model, also currently in its beginning stages, promises some improvement in relating a variety of expenditure data to readiness ratings.[6] In particular, the model purports to be able to predict the time ships must spend out of operation for maintenance by using overhaul and expenditure data from VAMOSC. If such predictions can be made for ships, they may also be able to be calculated for other DoD weapons systems. Indeed, the contractor working on the ship model has also developed a Navy aircraft model that shows promise.[7]

6. Mathtech, Inc., "Navy Ships Resources-to-Readiness Model" (a briefing prepared for the Department of the Navy, September 30, 1987).

7. Mathtech, Inc., "Relating Logistics Resources and Flying Hours to Aviation Readiness" (a briefing prepared for the Department of the Navy, September 30, 1987).