# RESOURCE ANALYSIS IN MILITARY LONG-RANGE PLANNING

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Program budgeting, cost effectiveness and cost analysis are three terms used repeatedly in descriptions of new military programs. They are part of the new decision-making process introduced by the Office of the Secretary of Defense in 1961. The nature of this change was well described by ex-Deputy Secretary Gilpatric in these words:

> In the past, the Defense Department has often developed its force structure by starting with a budget and sending it off in search of a program. Our new system of program packaging has reversed this procedure, by first determining our over-all strategy, then fitting the hardware and the manpower to those objectives.**

Since this process and these concepts have only recently come into fairly wide use, illumination of them may facilitate communication between the Department of Defense, the military departments, military contractors and the business community.

## PROGRAM BUDGETING

The fundamental feature of program budgeting in the Department of Defense is that it aligns or arrays the work statement in terms of each major objective as opposed to the functional or input requirements

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**Roswell L. Gilpatric, "Defense -- How Much Will It Cost?" California Management Review, Vol. V, No. 2, p. 53.

for accomplishing the total undertaking.* Thus, instead of the traditional U.S. Government military budget programs -- procurement, military construction and military personnel -- resource requirements are presented in terms of weapon systems or, at a higher level of aggregation, in terms of a total mission -- strategic retaliatory forces, continental defense forces, airlift and sealift, and the like.

The prime objective of program budgeting is to provide the Secretary of Defense and his advisors with a better basis for making program decisions. Major program decisions are those pertaining to important choices with regard to alternative weapon or support systems, force structures and their principal modes of employment amd deployment. In broad problems the most feasible solutions are often mixes of different systems and forces. It has become increasingly apparent that the selection of the most desirable mix should realistically involve cost as a major element. Mr. Charles J. Hitch, Assistant Secretary of Defense (Comptroller), has explained the importance of cost in these words:**

> Furthermore, there has long been a tendency in the Defense Department to state military requirements in absolute terms without reference to their costs. But the military effectiveness or military worth of any given weapon system cannot logically be considered in isolation. It must be considered in relation to its cost -- and in a world in which resources are limited, to the alternative uses to which the resources can be put. Military requirements are meaningful only in terms of benefits to be gained in relation to their cost. Thus, resource costs and military worth have to be scrutinized together.

The relevance of program budgeting to long-range planning is threefold. First, it implies an orderly process of planning and programming. In planning, one seeks a continual review of objectives

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*See also D. Novick, Efficiency and Economy in Government through New Budgeting and Accounting Procedures, The RAND Corporation, R-254, February 1, 1954; Which Program Do We Mean in "Programs Budgeting"?, The RAND Corporation, P-530, May 12, 1954; and New Approach to the Military Budget, The RAND Corporation, RM-1795, June 12, 1956.

**Testimony in Systems Development and Management (Part 2), Hearings before a Subcommittee of the Committee on Government Operations, House of Representatives, 87th Congress, 2d Session, U.S. Government Printing Office, Washington, 1962, p. 515.

and the means for their attainment. The preferred alternative remains preferred only as long as additional knowledge of program prospects in relation to competitive systems continues to support that choice. The concern is with weighing and evaluating and applying all of one's knowledge in the process. In the cost-effectiveness analyses used in planning, detailed cost estimates, which are characteristic of operating budgets, are not required. In programming, attention is concentrated on translating preferred alternatives into forces, manpower, and dollar costs, and these are projected over a five-year period. More precise costing is now in order since one must be able to anticipate the budgetary consequence of approved programs.

It is important to note the difference between programming as frequently performed in the military in the past and programming as used here. In the former, cost may not be taken into account at all -- a program can remain essentially a schedule of the physical activities required to accomplish a certain objective or plan. That kind of programming, however, often results in a mismatch between program and budget. Under the program budgeting concept the translation into dollars must be made up with the schedule, for a program decision is a budget decision and a budget decision is a program decision. Obviously, good cost estimates permit a more effective program budgeting decision.

The second implication that program budgeting as practiced in the Office of the Secretary of Defense has for long-range planning is that in projecting force structures out into the 1970's, one service, e.g., the Air Force, cannot ignore certain Army and Navy capabilities. Planning in terms of missions rather than standard appropriation categories tends to diminish the relevance of military service boundaries to the major programs such as continental defense or limited warfare. Today, a major program is no longer the exclusive province of an individual military service but rather, in varying degrees, is the province of all the services. Decisions pertaining to the force size of weapon systems where these systems are complementary and not in the same military department -- Minuteman (Air Force) and Polaris (Navy), for example -- must be viewed in the context of the total strategic picture. The additional considerations in doing force structure planning in this broader context complicate the job, but the results should be more realistic and of more real benefit to each service.

Finally, since the Department of Defense now does its planning in program budget terms, it means that each proposal must indicate clearly the objective sought, the time dimensions and the commitments required. Basic and applied research and facilities for these activities are one kind of commitment. Advanced development or technical feasibility is a quite different one. Developing, producing, deploying and operating a system are orders of magnitude different from either advanced development or basic research.

Weapon or support system proposals must be in terms of total system costs and make clear whether the capability sought is entirely new or an upgrading of one now available in existing equipments. In either case the extent of the resource commitment required at each stage of action must be indicated; for example, development, production, deployment and operation. Full exploration of technical and operational alternatives, and the translation of these into complete statements of step-by-step resource and time commitments, save time and effort at each level of decision-making.

COST EFFECTIVENESS

Cost effectiveness is, today, a rather widely used phrase and probably is as little understood by most people as any new bit of language. As explained by Mr. Hitch in the testimony referred to above, in cost-effectiveness studies it is necessary to:

(a) Define objectives

(b) Lay out alternative ways of accomplishing the objective

(c) Calculate how effectively each alternative accomplishes the objective

(d) Calculate how much each alternative costs.

In making the cost-effectiveness calculation it is commonplace to want to minimize cost and maximize effectiveness. Obviously, this is impossible. We can specify effectiveness and then price out the resource requirement to attain that level of effectiveness (the fixed requirements case). Or, conversely, we can introduce a resource or budget limitation and then determine the extent to which we can obtain specified levels of effectiveness for these resource levels (the fixed budget case). The interest here is not in military requirements studies in the traditional military sense or cost studies in the traditional budget sense. Rather what is sought is military-economic studies that compare alternative ways of accomplishing national security objectives and ones that try to determine the means for accomplishing the most for a given cost or achieving a given objective at least cost.

A typical example of such a study would be one in which the objective is to neutralize a given set of targets. The effectiveness analyst has by far the most difficult part of the job. He must determine the size of the weapons to be used, the number to be delivered on target, the force in-being required to assure delivery of the weapons, the measures to be taken to assure the weapons are delivered, the measures to be taken to assure survival of a sufficient part of the force, and so on. He is forced to deal in kill probabilities, reaction times, reliability numbers, CEP's, and a host of similar considerations which when piled up one upon another tend to demonstrate an aggregate uncertainty that makes cost analysts feel that their estimates are relatively solid.

System designers, systems analysts and war gamers deal with the effectiveness calculation. The cost analysts make the resource translations. It is important in undertaking such studies to recognize this division of labor in cost and effectiveness work and, particularly, in the analytical effort to recognize that one set of analyses relates to the jobs to be done and the other to the appropriate resource translations. The cost analyst does not define the development program, the systems, or the forces; rather he takes given descriptions and costs them out (although he may, and frequently does, challenge the feasibility of the proposals). In this respect it is important to remember that the cost analyst can only price what is described -- the system, good or bad, will always be the responsibility of the engineers, scientists, and system designers.

In the real world this clear-cut delineation seldom works out that way. There is a great deal of interaction between the two groups in which cost analysts attempt to obtain the detailed information needed for costing purposes. When the system designers are unable to provide the required data, the cost analysts are forced to draw upon their own experience in pricing out analogous systems. While this may be expedient, it is not always desirable. It seems appropriate to describe what cost analysis should involve and what kinds of information cost analysts expect from capability analysts in order to come up with weapon system and total force cost estimates.

## COST ANALYSIS

In comparing the costs of military systems, "cost analysis" rather than "cost estimation" is the preferred reference because the analytical breakdown of many complex interrelated activities and equipments is so important a part of the method. Total weapon system cost is viewed as the aggregate of a number of separate functional activities -- installations, personnel, major equipment, associated equipment and the like. By arraying the cost of each activity for a variety of alternative system configurations the planner can get an appreciation of the trade-offs available to him as well as the possible range of system cost.

Help in choosing among alternative systems is not the only area in which weapon systems cost analysis can be useful. Other uses may involve choices among alternative courses of action in an R&D program, or after a system is phased into the operational inventory, choices among possible hardware modification programs. An example of one of the applications of cost analysis that may be useful in this connection is a RAND study of several years ago. The problem was to determine the size of the crew compartment in a nuclear-powered aircraft. There were three "givens" in this problem: (1) a crew size of five men, (2) each aircraft had to be capable of remaining in the air continuously for five days, and (3) the total force had to be capable of maintaining one million pounds of payload aloft continuously. The volume of the crew compartment had been tentatively established at 500 cubic feet after looking at various trade-offs between payload, aircraft gross weight and the weight of shielding required to protect the crew from nuclear radiation.

It is obvious that as the volume of the crew compartment is increased, the requirements for shielding increase and with them the gross weight of the aircraft. If gross weight is held constant when the weight of the crew compartment increases, payload weight decreases and more aircraft will be required to complete the system's mission. More mission aircraft require more flight crews, more maintenance facilities, more personnel, etc. The question was one of obtaining some quantitative measure of what happened to the cost of the entire weapon system when the crew compartment size was varied from the 500 cubic foot size. It was only by placing the problem in a total system environment that the effect on system cost of variations in a key specification could be observed. A decision made simply on the basis of how much it would cost in terms of a single item of hardware, thereby neglecting all of the interdependent cost factors in other parts of the system, could have been greatly in error.

As indicated earlier, a cost estimate is tied to a description furnished by someone other than a cost analyst. It is axiomatic that the estimate cannot be better than the statement of requirements on which it is based; yet these statements as they reach the cost people sometimes reflect their creator's own particular interest and very little else. An airframe designer may provide speed, range, altitude, and weight data, but nothing on electronics, and electronics may represent as much as 50 per cent of the cost of the total aircraft. An advocate of solid propellant rockets for some task may have only the vaguest idea of the type of thrust vector control that will be employed, or whether the casing will be made of steel, fiberglass or titanium. Yet this is the kind of information essential to the estimate.

To illustrate this point further, let us look at examples of some of the worksheets now used at The RAND Corporation to accumulate the information needed to estimate research and development costs. Chart 1 shows the desired inputs and cost elements needed to estimate costs of

## Worksheet

## AIRFRAME SUBSYSTEM DESIGN AND DEVELOPMENT COST ESTIMATE

Project ____________ Date ______________

Stage Designation ______________ Vehicle Designation ______________________________

### Design Parameters and Characteristics

Type of Material ____________________________ Airframe Length __________________ ft

Type of Construction ____________________________ Airframe Diameter ________________ ft

Propellant Combination __________________________ Density ____________________ lb/ft$^3$

Propellant Weight, $W_p$ _______________________ lb Volume __________________________ ft$^3$

Airframe Weight, $W_a$ _______________________ lb Ratio, $W_a/W_p$ _____________________

Propulsion System Designation _________________ Manufacturer _____________________

Number of Engines per Propulsion System _______ Thrust per Engine ________________ lb

Other: ____________________________________________________________________________

### Major Milestones

Program Approval ___________ Contract Award ________ Prel Design Complete __________

First Test, Battleship ___________ Static _________________ Flight _________________

Other: ____________________________________________________________________________

### Major Assumptions ____________________________________________________________

__________________________________________________________________________________

__________________________________________________________________________________

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

| Design and Development Costs | | (Millions of Dollars) |
|---|---|---|
| Preliminary Reseach and Design Studies | | ________ |
| Development Engineering and Hardware | | ________ |
| Airborne Equipment | ________ | |
| Ground Equipment | ________ | |
| Industrial Facilities | | ________ |
| Other (Captive Test ) | | ________ |
| (Propellant ) | | ________ |
| Total Design and Development Costs | | ________ |

Chart 1

developing liquid propellant airframes. Note that all the blanks above the dashed line must be filled in by a scientist or engineer or a person who in some cases would be termed a capability analyst. The kinds of inputs required to prepare a cost estimate naturally vary with the type of subsystem for which the estimate is being made. For solid rockets different characteristics would be emphasized. The design parameters and characteristics listed on the worksheets arise from RAND's estimating equations. In addition to these inputs the worksheets call for major milestones and major assumptions. Schedule information is necessary for the task of distributing dollar estimates over time. The major assumptions must be spelled out to make clear exactly what the costs stand for. Also this allows one to revise basic assumptions, hence estimates, as more becomes known about the development problems encountered. Following the cost estimates prepared for each individual subsystem, the costs of testing and evaluating the complete system are estimated and a final cost category, System Management and Technical Direction is added.

Most of these inputs are relatively straightforward; yet they assume we know what in fact we often really do not know -- the length of a development program, for example, and the amount of test-to-failure hardware, the number of flight tests and the number of engineering hours that will be required. We don't really know sometimes whether the system desired can be developed at all -- all of us can think of examples where millions of dollars have been spent and the design specifications never achieved (not only by the military but in commercial applications).

Minimum development time and minimum cost are both worthwhile objectives although mutually incompatible. The nation which is first in the field with an important new weapon may gain a decisive military advantage, while a weapon system which is too late will be unable to cope effectively with the newest enemy threats. These considerations, while important, are intangibles, and it is seldom possible to predict in advance when a difference of a year or two will be significant. Minimum cost, on the other hand, is a concept appreciated by almost everyone. Many costs reflect the scarcity of real resources and especially of talented engineers and scientists, competent managers and skilled production workers. The uneconomic use of resources in one weapon program deprives other military programs of resources they may require, or it prevents the advance of non-defense wants such as education, roads, housing, aid to underdeveloped nations, etc. We must therefore view any weapons proposal as operating within a resource constraint since the amount of resources available for weapons is never unlimited, either in time of peace or war.

One must then be convinced not only of the need and technical feasibility of a new program; one must be certain that the program is feasible in the way it is proposed. In other words, the Air Force, for example, may decide that a variable geometry wing is desirable and feasible, but before embarking on a development program it must have confidence in a particular design, not a general concept. Presumably, this is what a program definition phase will supply, and this will be reflected in estimates of weapon system R&D costs.

Up to now we have considered only the inputs a cost analyst requires for estimating R&D costs. Two very important areas remain -- initial investment and annual operating costs. These will not be discussed in detail. Instead, Chart 2 is used to illustrate a part of the kinds of information needed before a total weapon system cost estimate can be completed. The ballistic missile described is purely hypothetical, and under no circumstances should it be regarded as a new weapon system proposal.

One final comment. The detail shown in the exhibits may give an impression of exactitude, and no one is more aware of the inexactness of cost predictions than we in the business. Cost estimates can differ from the actual for any number of reasons -- design changes, unforeseen difficulties, omissions in the initial requirements, changes in the operational concept, program stretch-outs, or poor cost estimates. The important thing is not, however, that this uncertainty exists -- it is that we be constantly aware of its existence in doing advanced planning and take it into account. One procedure for doing this has come to be known as cost sensitivity analysis. Briefly, this is a systematic examination of how total system cost changes as key system characteristics

WORKSHEET

Operational and Organizational Data

| | |
|---|---|
| Force Size | 2000 missiles. |
| Activation rate | Buildup to 25 wings by end of Fy 67. First squadron operational during Fy 63. |
| Organization | 25 Missiles per squadron; 3 squadrons per wing. LCC controls all missiles in one squadron, has secondary capability of controlling all missiles in wing. |
| Support base | One support base per wing to house wing personnel and provide administrative and maintenance facilities. Support base will share or use existing SAC bases where possible. |
| Deployment | 1 Missile per silo; 1 LCC per squadron. A minimum of 10 n mi between silos. Each silo located within 0.5 mi of surfaced road capable of withstanding axle loads up to 20,000 lb. All silos located in remote areas of the continental U. S. |

Chart 2

are varied over a relevant range. In an R&D program, for example, the cost may be highly sensitive to the number of flight test vehicles. Since, admittedly, one cannot predict the exact number of flight tests required to prove out a new vehicle, it would appear prudent to look at a range of numbers to see what the possible range of costs is. Similarly, if the reliability of a piece of equipment in terms of mean time to failure has a significant effect on system cost, it is well to know what happens to cost if the reliability specifications are not met.

This brings us to what I think can be the major contribution of cost analysis to long-range planning -- that is, the development of sensitivity analyses which will treat of the projections of technology into future systems and force structures. The proposals for new activities will involve a wide range of uncertainties. By analyzing each of these in terms of major component activities it should be possible for the resource analysts to indicate to the designers the elements which are most significant in a resource sense. Then, by having the engineers introduce alternative ways for accomplishing the objective, the resource analyst can work with the engineers to determine the way in which the job can best be done in cost terms.

## CONCLUSION

Military planning in the Department of Defense is now administered through the program budget procedure. This arrays the national security objectives in terms of major missions -- strategic retaliatory, continental defense, airlift and sealift and the like -- and the major systems for accomplishing them, e.g., Minuteman, Polaris or B-52 for strategic retaliation. In this process a wide range of alternative equipments are considered as well as varying possibilities for deploying or operating them. Each possibility is translated in terms of not only military effectiveness but also the cost of obtaining and operating that capability.

In the past, there was a tendency to state military needs in terms of requirements only, that is, without reference to their costs. But military effectiveness or worth of any given weapon system must be considered in relation to its ~~cost, that is, cost~~ effectiveness relationships must be established and analyzed to provide the decision-makers with the appropriate illumination of the problems at each level of the program budget.

Cost analysis provides the resource translations of effectiveness estimates developed by systems designers who have made the calculations of the equipment and operating concepts required to perform a specific mission. However, cost analysis is not limited to the problem of choosing between alternative systems. It also can be used to assist in choices among alternative courses of action in an R&D program, or after a system is phased into the operational inventory, choices among possible hardware modification programs.

Cost analysis, cost effectiveness and program budgeting are each prime elements in the new decision-making process introduced in the Department of Defense by Secretary Robert F. McNamara in 1961.