COWLES FOUNDATION FOR RESEARCH IN ECONOMICS

AT YALE UNIVERSITY

Box 2125, Yale Station
New Haven, Connecticut 06520

COWLES FOUNDATION DISCUSSION PAPER NO: 627

NAVAL PROCUREMENT PROBLEMS:

THEORY AND PRACTICE

Zvi Livne and Martin Shubik

NAVAL PROCUREMENT PROBLEMS: THEORY AND PRACTICE*

by

Martin Shubik and Zvi Livne

1. INTRODUCTION

In the past 25 years there has been a considerable growth in literature both in the theory and applications of bidding (see bibliography of Stark and Rothkopf, 1979). There has also been a parallel, independent growth, in the literature on acquisition, incentive contracting, and on principal-agent relationship (Shavell, 1979; Holmstrom, 1979); as well as an upsurge in studies in industrial organization (e.g., Williamson, 1975).

For a number of social, political, legal, and economic reasons some form of bidding process is regarded as being desirable for the allocation of governmental contracts. In a private enterprise economy where there is an innate suspicion of large bureaucracies, the letting of contracts by an open public sealed bid is an attractive way of conforming to our ideas of competition and economic opportunity. The sealed bid

---

*This work relates to Department of the Navy Contract N00014-77-C-0518 issued by the Office of Naval Research under Contract Authority NR 047-006. However, the content does not necessarily reflect the position or the policy of the Department of the Navy or the Government, and no official endorsement should be inferred.

or its equivalent, the Dutch auction, and its near relation, the open auction, have been used with considerable success in selling commodities, art and antiques, assets from bankrupt firms, oil leases, land, and many other items. But the sale of items where direct and final transfer of ownership or rights to use can take place immediately is fundamentally different from sales involving contractual relationships to produce or deliver services over many years. Thus, it is not obvious that a mechanism that is economically efficient and fair when used to sell the tobacco crop is necessarily the best to decide upon the allocation of shipbuilding contracts for naval ships.

It is a truism that in economics, operations research, and other so-called decision sciences the gap between theory and practice is large. Pure theorists, consultants, and members of private or public operating bureaucracies who actually let or bid on contracts tend to operate with considerable different views of time horizons, contexts, and constraints. In particular, socio-political constraints are frequently understressed by theorists and overstressed by those with operating responsibility, while the consultants vary in their perceptions.

Those with operating responsibility must deal with ad hoc problems. Detail must be dealt with. The realities of placing an order for a specific ship or class of planes are invariably here and now and more or less specific. Underlying the welter of special considerations there needs to be a clear, but sophisticated, perception of what are the key problems in the design of optimal mechanisms to promote an efficient allocation of contracts.

The belief expressed in this paper is that results from the theories of bidding and contracting have practical implications and can be of benefit both to the improvement of operating decisions and to the development

of more interesting theory.

This paper stresses modeling. Far more questions are raised than are answered here. But this is done in the belief that a common understanding of what is the question provides a much needed link between those with specific problems and those with a general methodology which may be applicable to the problem at hand.

1.1. On the Distribution of Resources

There are around a dozen methods used in various societies to distribute resources. They are competitive markets, bargaining, contracting, auctions, sealed bids, voting, bureaucratic and legal fiat, custom, chance, force, fraud, and deceit (Shubik, 1970).

Economic theory has concentrated on the properties of competitive markets and has considered the difficulties encountered with competition among the few or oligopoly and oligopsony. Modern concern has turned to bargaining, contracting, auctions, and bidding. But in the public sector especially, the actions which set up the key preliminaries to procurement are not primarily economic but political. Budgets prepared by large administrative bureaucracies and are then voted upon by political agencies. Committee decision and voting plays a major political role in the supply and use of funds.

Of more concern to social psychologists and sociologists than to economists and operations researchers until recently has been the allocation of resources by bureaucratic and legal fiat, by custom and by chance. The growing interest in the behavioral theory of the firm (Cyert and March, 1963; Nelson and Winter, 1982) together with a new concern in industrial organization (Williamson, 1975), has marked a change in the thinking of many economists, and the recognition that the nature of

the internal bureaucracy of major corporations or government agencies does much to shape their economic behavior.

In contrast with the relatively straightforward conditions faced by the commercial firm as a buyer, Naval procurement is directly influenced by economic, bureaucratic and political conditions over significant time spans. All of these need to be acknowledged explicitly in the design of the procurement system. Whether an efficient procurement system should involve bidding, auctions, contracting or other methods is the question of direct concern here.

1.2. A Comparison of Alternative Mechanisms

Tables 1a and 1b[1] display a comparison of the six major economic structures for procuring equipment that a firm or government faces. The elements in the titles of the rows are the factors which are of importance in differentiating the efficiency and desirability of the different mechanisms.

The various virtues often attributed to the competitive markets by the popular press call for conditions that are frequently not present in naval procurement and, for that matter, in much of our economic activity.

For competition to be present, it is necessary that there be at least two competitors. This number, however may not, be sufficient. Communication (implicit or explicit) among few firms is relatively easy and implicit cooperation can be achieved in many instances. The cost or ease of communication among competitors varies with industries and market mechanisms. Even auctions with many buyers are susceptible to "rings."

---

[1]For the reader to whom some of the row titles may not appear to be self-evident, an explanation follows the tables.

TABLE 1A

		Auctions	Sealed Bid	Contract (olig./ oligopsony)	Competitive Market	Oligopoly or Oligopsony	Self Supply
1	Number of buyers/sellers	many to 1 or 1 to many	few or many to 1 or 1 to few or many	1 or few with 1 or few	many to many	many to few	internal bureaucracy
2	Bidding preparation costs	low	moderate to high	moderate to high	low	low	incentive & audit problems
3	Bid preparation time	short	moderate to long	moderate to long	short	short	depends upon internal routines
4	Delivery time of product	instant	short to very long	medium to very long	short	short to medium	medium to very long
5	Estimation and evaluation problems	few, well defined and can be handled fast	may be critical time consuming & hard to define & handle	may be critical time consuming & hard to define & handle	few	few	in general hard with the added difficulty of self-audit
6	Production & distribution	second hand goods or existing commodities for direct disposal	major liquidation special manufacturing	special production items and turnkey systems	mass markets mass production	mass markets, mass production sometimes with increasing return to scale	special production items internal security considerations
7	Importance of modifications & learning	none	little to high	little to high	none	some	little to high
8	Socio political constraints on process	essentially minor	frequently highly important	frequently highly important	essentially minor	anti-trust but frequently minor	bureaucratic & political can both be high
9	Importance of indivisibilities and/or uniqueness	sometimes	frequently	almost always	never	slight	almost always

TABLE 1B

		Auctions	Sealed Bid	Contract (olig./ oligopsony)	Competitive Market	Oligopoly	Self Supply
10	Capacity & investment problems	usually irrelevant	implicitly important & differentiating	implicitly important & differentiating	taken care of by smooth free market adjustment	oligopolistic adjustment needs anti trust superveillance	a bureaucratic estimation process
11	Well defined goals for sellers	profit	profit	profit but modified by joint problem solving	profit	profit	seller & buyer are one--often with a hard to quantify or qualify goal--& with a need for self criticism & perception
12	Well defined goal for buyers	usual—resale or personal consumption	often hard to qualify or quantify "National Defense" security protection	often hard to qualify or quantify "National Defense" security protection	resale profit or personal consumption	resale profit or personal consumption	
13	Risk & profit	only immediate risk of overbid	long run risk until delivery often special considerations	long run risk until delivery special contract clauses important	expected profit or some measure of risk aversion	expected profit or some measure of risk aversion	bureaucratic risk, promotion an unclear incentive system
14	Special importance of information & expertise	experts vs. amateurs	difference in perceptions of participants may cause considerable divergence in bid	differences in perceptions of participants may be reconciled by the contract	generally not important	generally not important	critically important to have high morale inhouse expertise

REMARKS ON ROW TITLES IN TABLES 1A and 1B

5. Estimation and evaluation problems: Refer to the difficulties encountered in estimating or evaluating the items being sold by either the sellers or buyers. An expert buyer at an auction generally needs only a quick inspection of the goods. The buyer and seller of a new as yet unbuilt submarine hardly know what difficulties they will encounter in building it. Estimation and evaluation is central to their actions.

6. Production and distribution: Mechanisms involving the distribution of existing goods differ considerably from those involving production. Auctions tend to be confined to the disposal of second hand goods, commodities or to liquidations. Bids and contracts usually involve production.

7. Importance of modifications and learning: Auctions tend to be instantaneous. There is nothing in particular to learn about the goods changing hands that is not known from the start. In contrast when construction is contracted for the product may be modified before delivery and new information of relevance to both parties may be learned en route.

8. Socio politico constraints on processes: Modern auctions rarely involve political considerations or public policy. Government procurement does. There are social and political constraints which must be considered in government bids and contracts which do not exist for business done in the private sector alone.

10. Capacity and investment problems: Auctions are here and now involving distribution of existing goods. Military procurement involves the buying of production for the future and keeping open options for future supplies. The economic capacity and health of suppliers matters.

14. Special importance of information and expertise: In auctions amateurs may be hurt but experts need little work to completely inform themselves. In contracting, experts are an absolute necessity, but expertise alone is not sufficient. There may be fundamental perceptual problems involving cost, worth and how to proceed.

For modern naval ship procurement the choices are sealed bid, contract, self supply, or monopsony oligopoly. The last (which does not appear in the tables) is when a single buyer faces few large suppliers.

Although oligopoly describes much of U.S. industrial structure, such as the automobile industry, tobacco, liquor or consumer durables, the characterizing feature of oligopoly is that although there are few sellers there are many buyers. For naval ships, there is, in essence, only one buyer.

In auctions, competitive markets, and most consumer good oligopolistic markets there is little hand tailoring of bids. When the items are large, new, expensive, and time consuming to produce, the time and complexity of the initial bid preparation becomes an important factor. Some firms may be eliminated from competition by inability to assemble the engineering talent to prepare a bid.

The auction and competitive markets are devices for moving existing goods with rapidity. When the items sold take three or four years or even longer to produce and technology and supply may be in doubt, the design of contractual conditions and/or special bidding procedures are the least that can be expected for any efficient process.

Intuitively the virtues of the competitive market, the auction, or sealed bid fit in well with the concepts of anonymity and fair treatment to all of a democratic society. Unfortunately, the economic and physical conditions required for the functioning of competitive market do not exist for most large item defense procurement.

The most attractive feasible alternative to the competitive market which is consistent with a free market ideology and offers the benefits of apparent impartiality and arms length dealing is the sealed bid. The

simple sealed bid where a group of competitors each submit a single number to perform a specific task has been studied extensively under many conditions (see Stark and Rothkopf, 1979, bibliography for many references). Unfortunately, the theoretical results are of extremely limited worth for situations where there has to be a continuing contractual relationship between the buyer and the successful seller. A low bid may be nothing more than a buy-in attempt to tie in a committed buyer to a protracted series of cost escalations and renegotiations.

The dynamics of independent bid preparation from at least two competitors, in spite of the many complications, is nevertheless attractive as a relatively simple process which satisfies social and political desiderata. Furthermore, the competitive bid on the surface offers fairly straightforward opportunities for auditing, control, and public disclosure.

It is our opinion that there is no such thing as "the optimal solution to the abstract problem of ship procurement." There is, however, the possibility of improving ship procurement by the U.S. Navy in the 1980s given the social, political and bureaucratic realities of the time. Judicious improvements in a process which involves a blend of competition for contracts and contract design might do this. The alternative of having the Navy build its own ships in some form or another (for example, actually build the ships; or own the shipyards and hire outside management) has not been firmly shown from an economic and technological point of view to be clearly better or worse than bidding and contracting.

In a forthcoming separate paper we suggest that there has been work in agency problems and contracting and more sophisticated bidding mechanisms which at least indicate new possibilities and suggest that bidding procedures involving several strategic variables might be

administratively feasible, fair, not too complicated, and better than the single bid. We return to this point in Section 6.

2. THE CURRENT U.S. AND SOVIET NAVIES

2.1. U.S. and S.U. Navies

A brief summary sketch of the U.S. and Soviet naval forces is given merely to portray the order of magnitude of the naval procurement problem. It is important to keep in mind that the purposes and missions of the U.S. and Soviet navies are different; hence, comparisons based upon a concern which confuses parity and symmetry may be misleading.

The statistics used here are based upon the extensive study of John Collins (1980, p. 37).

TABLE 2

U.S. AND SOVIET NAVAL POWER 1960

	U.S.	S.U.
Aircraft carriers	23	0
Cruisers	13	23
Destroyers	226	124
Frigates/other escorts	41	13
Attack submarines	111	404
Amphibious ships	113	0

TABLE 3

U.S. AND SOVIET NAVAL POWER 1970, 1979

	U.S.		S.U.	
	1970	1979	1970	1979
Carriers Attack	1	3	0	0
Carriers Oil	14	10	0	0
Carriers ASW	4	0	0	0
Carriers Helicopters	7	11	2	2
Carriers Guided Missile VTOL	0	0	0	2
Cruisers	27	27	24	35
Destroyers	187	95	77	71
Frigates	53	67	114	169
Attack Subs	105	80	297	266
Strategic Nuclear Subs	41	41	20	69
Strategic Diesel Subs	0	0	20	16
Amphibious Ships	97	63	10	26

A brief glance at Tables 2 and 3 show a considerable change in the relative size of the U.S. and Soviet navies and also shows a considerable difference in composition of the fleets. The age of the ships is also of importance as changes in technology may obsolete vessels long before they reach their originally planned life span.

2.2. U.S. Budgets

Table 4 gives a brief sketch of the U.S. defense budget (SAUS, 1980, p. 366) and naval procurement.

TABLE 4

Unit: Billions	Constant dollar (1972) defense budget	Current dollar defense budget	Defense % of GNP	Naval procurement in current dollars
1960	73.8	45.2	9.1	---
1970	90.3	78.6	8.2	7.0
1976	65.6	89.4	5.5	8.0
1977	66.5	97.5	5.3	8.5
1978	66.6	105.2	4.8	9.2
1979	69.3	117.7	5.1	11.8
1980	70.7	130.4	5.2	12.6

U.S. budgetary figures are in the public domain. The information in this document can be gleaned with relative ease from public resources. A broad description of what is being built, where it is being built, what it costs, when funding is approved can be obtained from open public documents, corporate reports, 10K filings, newspapers, and publicly available books.

In contrast, Soviet information is buried in secrecy. In particular, the true costs, process, and size of Soviet procurement are extremely hard to come by. In the past few years the CIA estimates of the percentage of Soviet GNP spent on defense have been revised upwards by a factor of 100% (e.g. Gansler, 1980; Rosefielde, 1982). A forthcoming book on the

estimation of Soviet defense expenditures suggests that these new estimates may still be significantly too low (Rosefielde, 1982).

The mere fact that the Soviet Union, spending somewhere between 5-15% of its GNP (depending upon who is counting and interpreting) has been able to challenge or exceed U.S. military superiority should indicate that although open markets and competition appear to be nice, attractive, and efficient for many reasons, they are not the only form of socio-economic organization that can achieve the desired results.

Alexander (1973) has provided several studies of Soviet procurement and Gansler (1980, p. 254) suggested that the lessons to be learned from the Soviet system include (1) Make R&D profitable on its own and independent from production, (2) Combine civilian and military production in the same plan, and (3) Aim for greater work force stability for both R&D and for production. None of these recommendations go against using bidding or contracting as a procurement mechanism. They merely call attention to possible changes in industrial organization and defense policy which may be desirable. For example, what price are we willing to pay for flexibility and surge capacity is a defense policy question whose answer must be tempered with economic sense, but the prime question is military and diplomatic not economic.

2.3. A Motivating Example: The SSN-688 Program

The general information above was provided to set the context for the more specific study of naval procurement. We use the SSN-688 program to provide an example.[1]

The SSN-688 Class Nuclear Attack Submarine Program was initiated

---

[1]Much of the information presented here is based upon the study of Lt. Cdr. W. J. Pollock (1981).

in early 1968 and was assigned the highest national priority by the President. It was a new design--the ship's size and power were substantially larger than its predecessor of the SSN-637 class. The Navy assigned high quality personnel to the design, construction control and management of the program. After conducting a series of studies, the Navy published the basic description of the SSN-688 class. This consisted of a set of ship's characteristics: size, speed, operating depth, weapons, combat capabilities and missions. On this basis the Naval Ship Engineering Center prepared a Preliminary Design (completed in March, 1969). At that stage the Navy selected one contractor--Newport News Shipbuilding and Dry Dock Company (NN)--to be the Design Agent. This means that NN was to prepare the Contract Design, the Detail Design, and to build the Lead Ship. In the Contract Design stage, the description of the ship was further elaborated to the level of specification which allowed shipbuilders to prepare technical and cost offers for construction contracts. This stage ended in October, 1969, after which the stage of the Detail Design started. At that point the plan was to have two more contractors--Electric Boat (a division of General Dynamics, EB) and Litton-Ingalls (LI)--compete with NN for the follow ships. NN was to supply the design data and services to all potential contractors. In February, 1970, NN was formally awarded the Lead Ship, and in January, 1971, as a result of the competition over the follow contracts, NN received four ships and EB received seven. For the rest of the program (which in 1982 is still on-going), these two contractors competed on the follow ships. In January, 1971, the contractors were believed to have enough data to bid, but not yet to construct a ship. Only about 200 of the 6,000 anticipated detail drawings were available at the time.

Due to the objective of having the most rapid deployment possible of the new ships, the construction of the lead ship by NN and of the first follow ship by EB started before the Detailed Design was completed. As construction progressed, NN transferred detailed drawings and other information to EB, who translated the information to their framework (reflecting the fact that there were considerable differences in the contractors' construction practices).

At the same time that the Detailed Design was taking place, most of the electronic systems and computers were being developed by other contractors. This in turn complicated the design stage and necessitated many revisions. It is a well-publicized fact now that a strong adversary relationship between the contractors and the Navy started during this period, culminating several years later with huge litigation battles and then settlements.

The delivery of both the lead ship and the first follow ship (the EB ships are known as the SSN-690 class) occurred two years after their respective schedules (end of 1976 and mid-1977, with scheduled delivery dates at end of 1974 and mid-1975). Labor problems and material (both government-furnished and contractor-furnished) were important reasons for the slippage. As Pollock comments: "...the inability of the follow yard (EB) to increase its work force by an order of magnitude and achieve the productivity used as a basis for contract pricing was a primary factor in the schedule slippage and resultant cost increases experienced by Electric Boat" (Pollock, 1981). EB sees things differently. They blame the frequent design changes for most of the cost and schedule overruns.

The story of the SSN-688 program demonstrates that the problems

the government faces, in the course of a weapons program, do change. At the initial stage, the problem is largely a management problem, compounded by data transfer problems, design changes and coordination between producers. At this stage efforts for improvement should focus on management and planning, rather than on the design of a perfect contract. But as the weapon system matures, i.e., when the procured systems start to be very similar to systems procured in the past, focus needs to be shifted to the source selection process and to the contract design. The construction costs, the construction time, and the performance characteristics of the system are not as uncertain as those of a newly designed system. For example, the two nuclear attack submarines of the SSN-688 class, contracted for in 1979 will be similar in many respects to the 31 submarines in the same class which have been contracted for or built by EB and NN shipyards during the previous nine years.

The first S688 (Los Angeles class) built by Electric Boat was contracted for in 1970 and it was completed 1977. Since then, Electric Boat has delivered its 13th of these 360 ft. fast attack submarines. Electric Boat has a backlog of 15 more SSN-688 scheduled for delivery over the next five years. Contracts for 3 more were awarded unilaterally to Newport News for $1.5 billion in 1981.

The approximate cost of an SSN-688 is currently of the order of $500 million. This contrasts with $1.3 billion for a Trident submarine and $2.7-$3 billion for a Nimitz class carrier. These approximate numbers indicate that even a small percentage saving in procurement costs could involve substantial sums.

Figure 1 (reproduced from Pollack, Figure 3) shows the performance versus schedule for the lead and first follow submarine in the SSN-688

PERFORMANCE vs SCHEDULE

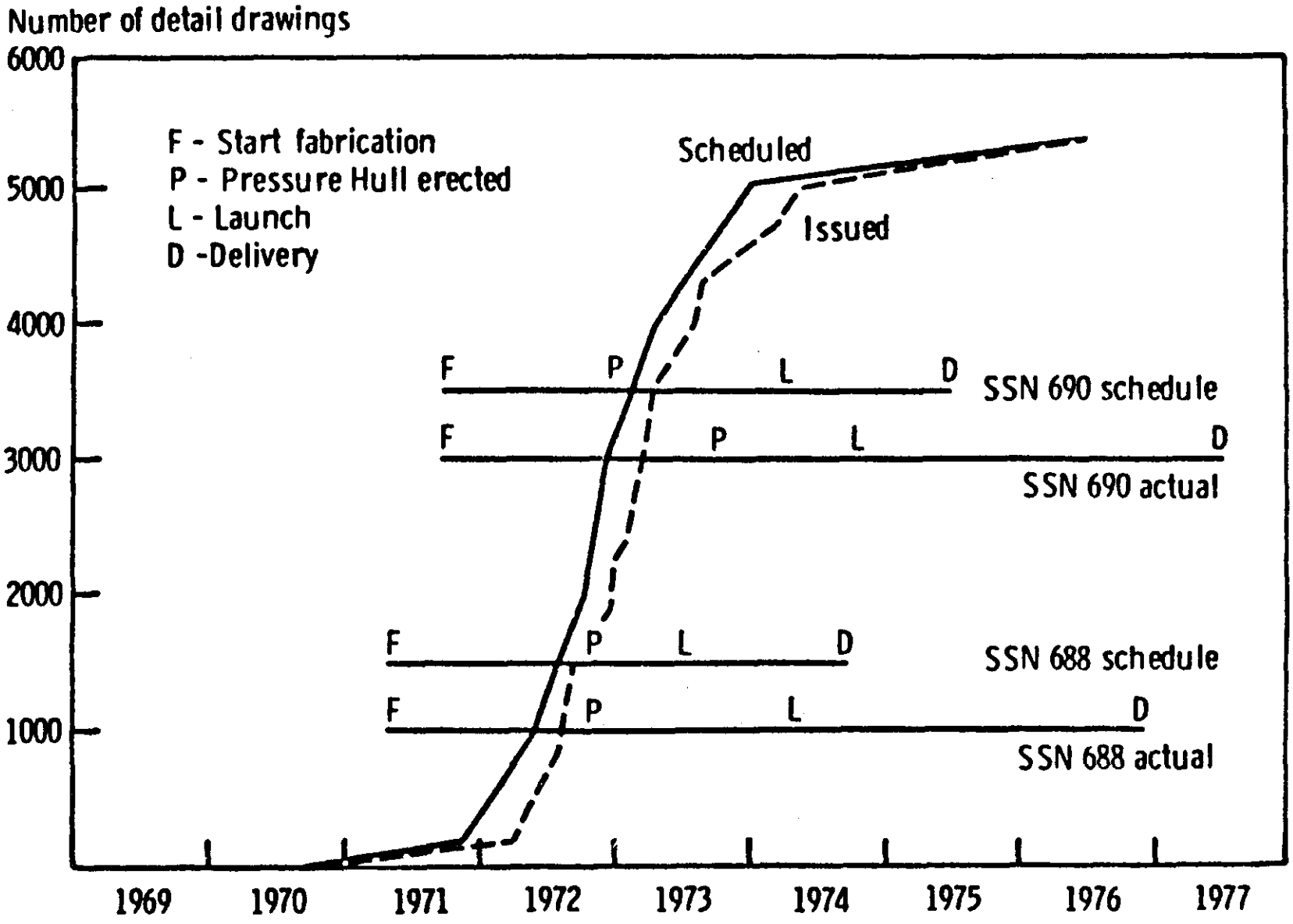


Figure 1

program (the SSN690 is the Electric Boat version of the originally named SSN-688).

The number of contract modifications issued on the SSN-690 for the period investigated in the Hidalgo (1978, p. 227) report were 498 and the value of ship changes came to $3.9 million or 6.3% of the original contract price. The report by McNichols and McKenney (1981) indicate an unadjusted cost growth of 33.5% in the SSN-688 program. But it is not what the figures are, but what they mean. The reader is referred to the publication for the several definitions needed to interpret the indices of cost growth.

3. INDUSTRIAL ORGANIZATION

3.1. Shipbuilding Firms and Shipyards

Several studies of the U.S. shipbuilding industry over time are available (Kaitz, 1980; Ward and Gavin, 1975); no attempt is made to present a detailed study here. A few salient points are given merely to provide context.

Table 5 indicates the firms and shipyards engaged in naval ship construction.

There are nine firms and eleven yards, with only Newport News having the size for the building of the nuclear powered attack aircraft carriers and Newport News and Electric Boat in a position to build the larger nuclear submarines.

The U.S. non-military shipbuilding industry has not been competitive globally as this is reflected by the preponderance of new ship construction in the U.S. being for the Navy. Admiral Rickover has suggested that for an investment of about $100 million the naval shipyard at Mare

TABLE 5

Firm	Yards
Bethlehem	Bethlehem, Baltimore, MD
Congoleum	Bath, Bath, ME
General Dynamics	Electric Boat, Groton, CT
	Quincy, Quincy, MA
Kaiser	National Steel, San Diego, CA
Litton	Ingalls, Pascagoula, MS
Lockheed	Lockheed, Seattle, WA
Odgen	Avondale, New Orleans, LA
Tenneco	Newport News, Newport News, VA
Todd	Todd, San Pedro, CA
	Todd, Seattle, WA

Island, California could be in a position to produce fast attack submarines (Boston Globe, May 10, 1981, pp. 55, 64). Relative to the costs of a Trident or a nuclear carrier the investment entry costs in the shipbuilding industry are not high. The problems appear to be more the maintenance of well managed experienced construction crews than capital outlays.

The two major companies building nuclear ships are Tenneco and General Dynamics. The size of Tenneco's shipbuilding activity is indicated in Table 6. Government sales in 1980 accounted for around 76% of revenues (Tenneco 1980 Annual Report). This included new construction and overhauling and repairing. Shipbuilding sales represent 6-7% of Tenneco's total and profits 2-3%. In 1980 Newport News had 10 Naval nuclear carriers, cruisers and submarines under construction.

Shipbuilding net assets were 3% of Tenneco's total net assets.

TABLE 6

	1980	1979	
Net sales & revenue	$ 891	$ 730	(million)
Income (before taxes and interest)	55	33	(million)
Average net assets	305	395	(million)
Capital expenditure	57	47	(million)
Business backlog	3,164	1,648	(million)
Employees	24,750	23,014	

In contrast with Tenneco, General Dynamics is the largest defense contractor in the nation with around 75% of $4.7 billion of sales in 1980 being to the government. In 1980 around 84% of General Dynamics' shipbuilding was for the government and 16% in commercial shipbuilding. Table 7 gives a sketch of General Dyanmics shipbuilding activities. We note the drop off in commercial shipbuilding. In contrast with Tenneco sales in 1980 of the General Dynamics shipbuilding activities were around 23% of total sales and assets were approximately the same (General Dynamics 1980 Annual Report). Employees were around 25,000.

In June 1978 General Dynamics and the Navy reached a settlement (General Dynamics 1980 Annual Report, p. 41) of $359 million not to be reimbursed on claims of $843 million in cost overruns on two contracts for 18 SSN-688s.

TABLE 7

	1980	1979	
Sales (government)	$902	$678	(million)
Sales (commercial)	176	256	(million)
Income (government)	23.4	18.8	(million)
Income (commercial)	.7	47.7	(million)
Assets employed	582	459	(million)
Capital expenditure	31.9	69.6	(million)

In summary, the industry to a good first approximation has the structure of an oligopoly-monopsony--a handful of firms selling to one customer. They are selling high priced indivisible items in relatively small numbers with lengthy production times and with cost estimates made even more difficult than otherwise by changes in technology and difficulties of communication between those interested in operational excellence and those interested in cost.

The major problems in industrial organization appear to be (a) how to maintain trained personnel, and (b) motivate investment where the loss of a single contract or change in a budget is measured in hundreds of millions or more. The other major problems appears to involve the degree of control and prediction that can exist on work to be scheduled. This involves coordination and contracting problems with subcontractors. The importance of this can be seen at a glance in comparing the total cost of a Trident or Nimitz class carrier with the platform cost. The most frequently mentioned problem is disruption costs caused by modifications (see for example Hammon, 1980). But to some extent the modification process represents a difficult communication problem between two cultures,

one primarily concerned with performance, the other with cost.[1]

3.2. Procurement Methods

Given that much of military procurement is between a single buyer and few firms with complex items to be produced, what sort of procurement mechanism is used or can be used to promote economic efficiency? For Department of Defense contracts as a whole the split between noncompetitive awards and competitive awards in total dollar terms has been of the order of 60% noncompetitive and 40% competitive with less than 10% formally advertised in the 1970s.

Even if the initial letting of a contract is made by a competitive mechanism there are many forms that the arrangement can and indeed needs to have if a long and uncertain production process follows the bidding. In particular, in naval shipbuilding there is a clear distinction to be made between contracting for a lead ship and contracting for follow on ships. The level of uncertainty is far greater for the former. But once a lead ship has been built the experience of the initial contractor provides a large incentive to place the follow on orders with the original firm on a noncompetitive basis.

Lead Ships

The key factor in the construction of lead naval ships is risks in cost estimation where design, revision and construction can scarcely be separated. Thus it is critical for the government to take into account "track record," experience of workforce, management, and skills. Furthermore, commitment, capacity, and the ways in which joint costs and scheduling with other work are going to be handled must be considered.

---

[1] For a lengthier listing see Gansler (1980), p. 201.

The simplest contract is the fixed price contract which in theory throws all of the risk on the shipbuilder. But bankruptcy, time delays, and lengthy and costly law suits concerning design changes present risks to the buyer as well as builder. A way of risk sharing is to use cost plus fixed fee or cost plus some form of incentive fee contract.

An important difficulty with a cost plus contract is moral hazard and lack of incentive to cost control. The higher the reported costs are the better off is the contractor. There can be a built in incentive to pad costs. Thus, some forms of incentive conditions are required in order to motivate better control, estimation, and information disclosure.

Follow Ships

At what point are the "bugs" out of the line? How many Tridents or S688s must be built before the cost estimates, scheduling procedures, and technical understanding are sufficiently in hand to enable to switch from a cost type of contract to a fixed price contract. When a shipyard has been able to reduce the construction process for a complex ship to routine, how easy is it to give the follow on contract to a different shipyard? If a transfer of yards is to take place, should it be via some form of renewed competition or the negotiation of a bilateral contract with the new yard? The key abstract problems are (1) efficiency, (2) insurance, (3) incentive, (4) moral hazard and disclosure. Without specific information one cannot judge a priori the best procedure for a specific class of ships. A simple rule of thumb would be that one or two follow ships need to be built before one can switch from some sort of cost to a fixed price contract.

The two (simplistic) extremes in contracting are straight fixed price and cost plus fixed fee. In actuality many forms of hybrid exist

and the key purpose of the economic investigation of bidding, estimating, and contracting in naval procurement is to design procedures which are relatively simple to understand, promote competition, encourage clear arms-length dealing, and are reasonably hand-tailored to the specifics of ship procurement. For example, instead of a straight fixed price contract one might use a fixed price incentive contract where negotiations cover target cost, profit, and price ceiling or upper limit.

An example of current contracting practices is given by the backlog at Newport News at the end of 1980. The backlog size (Tenneco 10 K, 1980, p. 20) was $3,164 million split as follows:

($\times 10^6$)		
	$ 65	cost plus fixed fee
	$ 97	cost-type incentive contract
	$2,841	incentive contract with fixed ceiling[1]
	$ 46	fixed price reconstruction of commercial ships[1]
	$ 115	fixed price and incentive fees for ship repair and industrial products[1]

A discussion of the specifics of the four major types of contracts is given in the appendix. The contracts are (1) Cost plus fixed fee (CPFF); (2) Cost plus incentive fee (CPIF); (3) Fixed price incentive fee (FPI) and (4) Firm fixed price.

---

[1]Escalation clauses on labor and material costs.

4. THE PROCUREMENT PROCESS

One of the key difficulties faced by those who try to integrate the formation of policy, operations and theory is the overcoming of a virtual cultural gap between those wishing to work with well defined engineering type goals and mechanisms and those who recognize that goals are not given.

The newly minted Ph.D in mathematical economics or operations research believes in goals, strategy sets and measurable payoff functions. In general he regards lawyers, accountants, the G.A.O., D.O.D. and Congress as peculiarly irrational manifestations of institutional inefficiency. It is possible that he is right. But right or wrong the act of ignoring the realities of process in carrying out analysis is on par with deciding that leeches, belharzia, crocodiles and mosquitos do not exist while swimming across the Nile.

Procurement is a process. In order to understand the economic aspects of procurement; or to even consider the relative optimality of different forms of bidding processes it is necessary to consider them in the context of the procurement process as a whole. It is this process which determines goals and time lags.

4.1. Policy

In January 1977 the Department of Defense set forth its directives for policy management and procedural guidance for major systems. The four milestones for program reviews were given. These are summarized as follows:

1. Milestone 0--Program Initiation

   a. At such time as the Secretary of Defense requests or a DOD Component Head perceives a mission need to exist and determines that a new capability is to be acquired to meet the need, the DOD Component Head should submit a statement of the mission need to the Secretary of Defense and request approval to proceed to identify and explore alternative solutions to the mission need. The considerations to support the determination of the mission need shall be documented in the Mission Element Need Statement (MENS), reference (c).

   b. When a mission need is determined to be essential and reconciled with other DOD capabilities, resources and priorities, the Secretary of Defense will approve the mission need and direct one or more of the DOD Components to systematically and progressively explore and develop alternative system concepts to satisfy the approved need.

2. Milestone I--Demonstration and Validation

   a. When the DOD Component completes the competitive exploration of alternative system concepts to the point where the selected alternatives warrant system demonstration, the DOD Component Head shall request approval to proceed with the demonstration and validation effort. The recommendations shall be documented in a Decision Coordination Paper (DCP), and reviewed by the Defense System Acquisition Review Council (DSARC) and the (Service) System Acquisition Review Council ((S)SARC) prior to the Secretary of Defense decision as outlined in reference (c).

   b. The Secretary of Defense action will reaffirm the mission need and approve one or more selected alternatives for competitive demonstration and validation.

3. Milestone II--Full-Scale Engineering Development

   a. When the demonstration and validation activity has been completed and the Component Head is prepared to recommend the preferred systems for full-scale engineering development, the recommendations shall be documented in an updated DCP and reviewed by the DSARC and (S)SARC prior to the Secretary of Defense decision.

   b. The Secretary of Defense will reaffirm the mission need, and approve the selection of a system for full-scale engineering development, including procurement of long-lead production items and limited production for operational test and evaluation.

4. Milestone III--Production and Deployment

   a. When the Component Head is prepared to recommend production of the system, the recommendations shall be documented in an updated DCP and reviewed by the DSARC and (S)SARC prior to the Secretary of Defense decision. The Secretary of Defense will reaffirm the mission need, confirm the system ready for production, approve the system for production and authorize the Component to deploy the system to the using activity.

   b. Following a Milestone III decision, the DOD Component Head shall make quarterly reports to the Secretary of Defense on key program issues. The DOD Component shall keep the Defense Acquisition Executive and the OSD staff informed on key program actions as the program progresses.

   c. The DOD Component Head shall decide when the system is ready to be deployed to the using activities and shall advise the Secretary of Defense.

The time elapsed from the start of Milestone 0 until the end of Milestone III is a critical factor in the maintenance of defense flexibility as well as an important influence on the cost control and funding problems of multi-year weapons production programs.

How badly the lead times have been changing in the past decade; and where these changes have been manifested is a matter of considerable concern. Gansler (1980, p. 66) quoting airforce data indicates a marked increase in lead time for components; a Rand study indicates that for aircraft the time from FSD (full scale development) to first flight has changed little over the last 30 years but the production phase is taking longer due to fiscal stringency (Dews et al., 1979, p. 68). Admiral Kollmorgen (1980, pp. 5-15) stresses the danger of increasing administrative time to the system at the earlier stages:

> On the average, the total time to develop a new aircraft to IOC has been increasing at a rate of three months per year, each year, for the past 15 years. At the same time, the interval from design contract award to first flight has remained approximately constant. There is no reason that we should be adding costly administrative time... but it will continue to happen unless high level attention is focused on the acquisition process.
>
> The Office of Management and Budget, with the issuance of Circular A-109, defined the start of the acquisition process...Milestone Zero. How Milestone Zero is institutionalized is critical. If it is treated, as it should be, as a notification of intent to investigate and evaluate alternative courses of action to fulfill a need, there should be no lengthening of the process. But, there are indications that were about to screw it up...and demand more.
>
> At Milestone Zero it is certainly reasonable to expect a service sponsoring a program initiation to have an initial plan of action, strategy if you like, for arriving at Milestone I.
>
> However, it is unreasonable to expect a complete acquisition strategy, impact statements for

> manpower, reliability, NATO RSI, Life Cycle Cost, etc....to the point where a preferred solution emerges...it is my understanding that such activity is properly concept formulation. And, that is what approval at Milestone Zero...is specifically designed to authorize.
>
> Unfortunately, the first few years' experience with implementation of A-109 within the DOD indicates a strong proclivity to put the concept formulation cart in front of the Milestone Zero horse. This institutional weakness must be recognized and the propensity redressed...with vigor! Or...we'll have a Milestone Zero Prime next.

Martin and Glover (1980, pp. 4-33) have provided a useful sketch of the contracting process in Figure 2 reproduced on the following page.

They also characterize the type of cost estimation which accompanies the various phases of the weapons acquisition process.

In several studies (e.g. Dews et al., 1979) program manager tenure has been noted as being relatively short as compared with the program. Data indicate a growth in tensure from about 18 months in the 5 years around 1963 to 32 months on the 5 years around 1976 (Dews, et al., 1979).

In the 11 year history of the SSN-688, for example, there has already been three project managers. It is of interest to note that Soviet military job tenures appear to differ considerably (Collins, 1980).

4.2. The Timing of Construction

What time span is involved from the perceived demand and the idea leading to a feasibility study to the completion of the lead ship and the completion of the first follow on? Some insight is provided by a chart from the Hildalgo (1978, p. 62) report reproduced here as Figure 4.

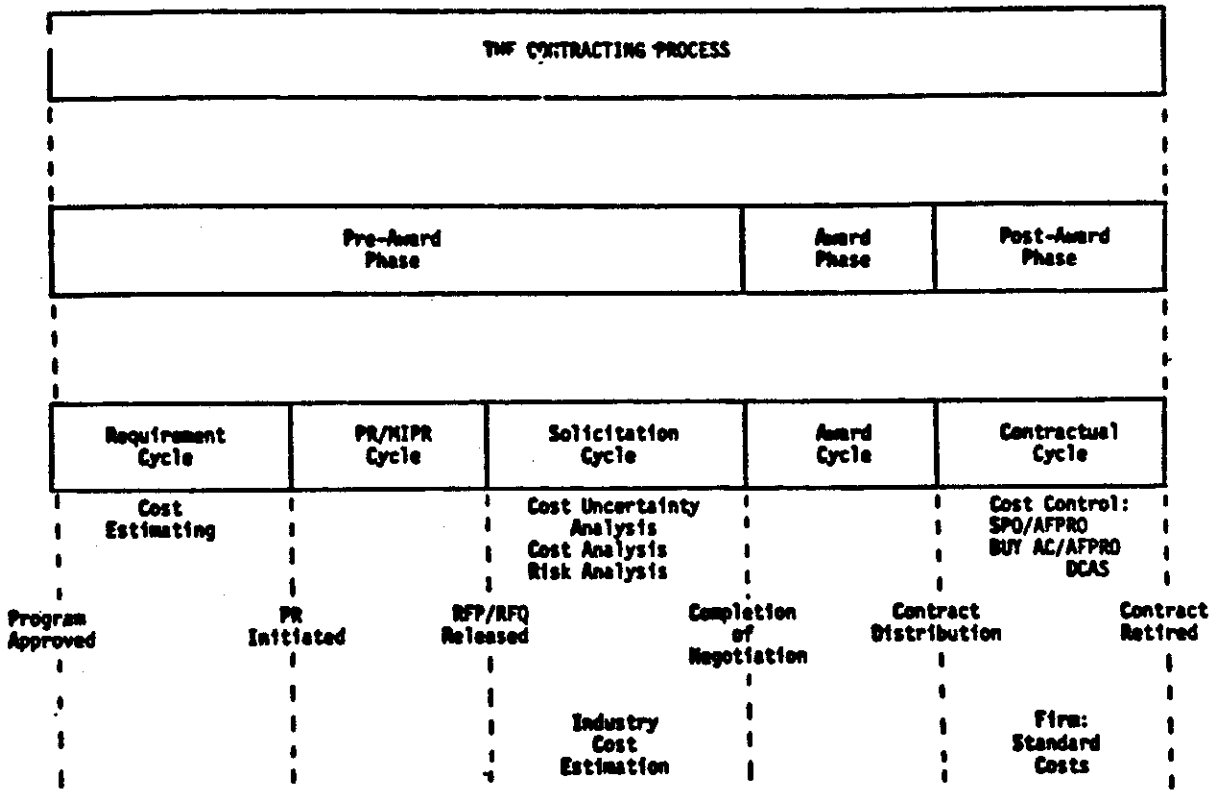


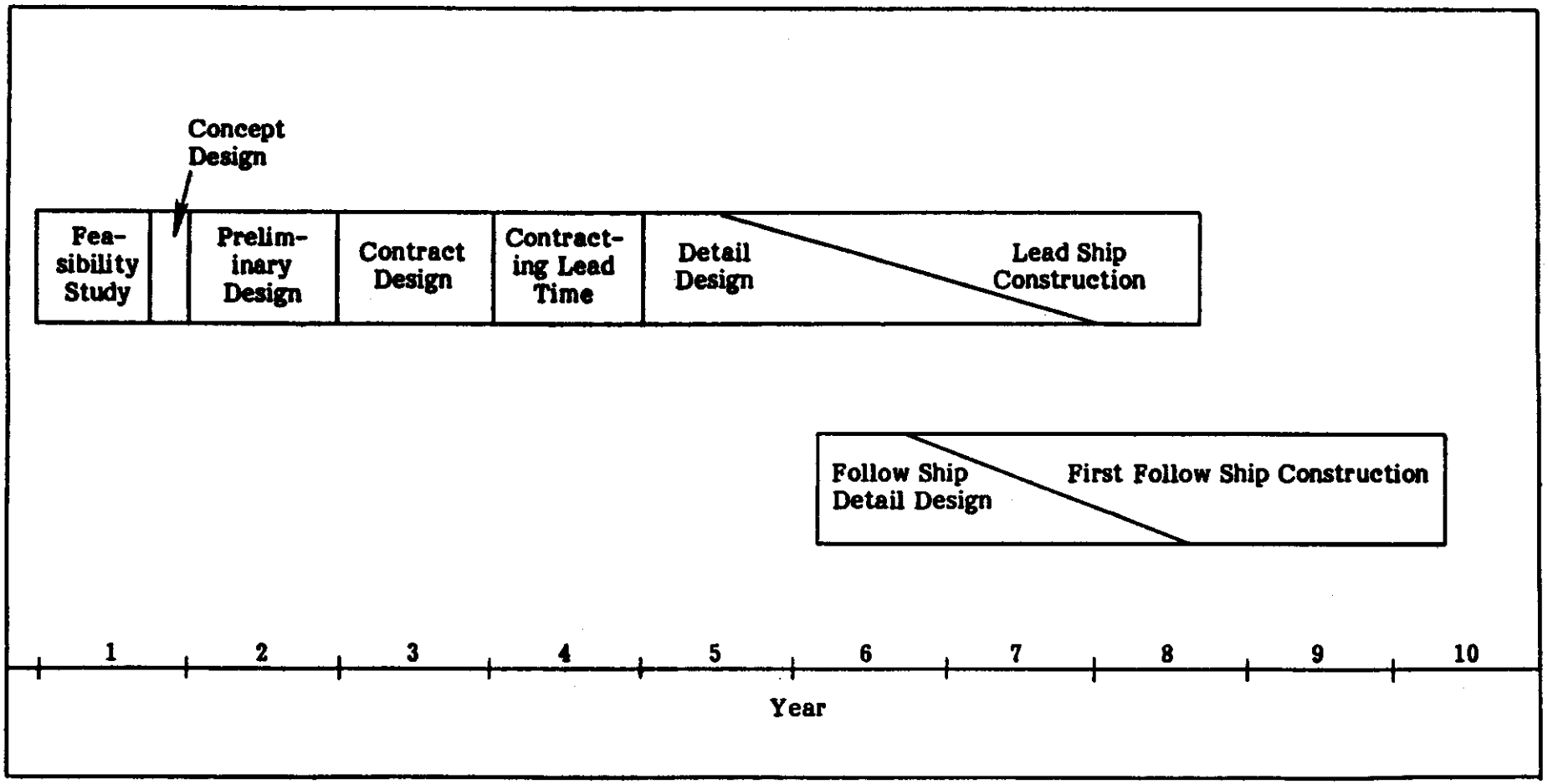
FIGURE 2. The Contracting Process

PHASE	PRE CONCEPTUAL	CONCEPTUAL	VALIDATION	FULL SCALE DEVELOPMENT	PRODUCTION	DEPLOYMENT	REUTILIZATION & DISPOSITION
COST ESTIMATING TECHNIQUE	1, 2, 4	2, 4	2, 4	2, 3, 4	3	3	3

KEY: 1 = Expert Opinion 2 = Analogy 3 = Industrial Engineering 4 = Statistical

FIGURE 3. The Weapons Acquisition Process

DESIGN CYCLE FOR A TYPICAL NAVAL SHIP



Source: NAVSEC.

FIGURE 4

5. COMPETITION AND INCENTIVES: THEORY AND PRACTICE

The two major sets of theoretical studies relevant to procurement are on bidding and on agency and incentive problems. A survey of these is given elsewhere (Livne and Shubik, 1982; also Amihud, 1976; Engelbrecht-Wiggans, Shubik and Stark, 1982). Here we concentrate on the problems faced in modeling process and the questions that are raised which are relevant to control.

5.1. Bidding Theory and Ship Procurement

There is a large literature on the theory of bidding where there is one buyer or seller facing many sellers or buyers under varying conditions of information concerning perceptions of value. Most of the models are cast in terms of one shot games in strategic form, where the uncertainty is, in essence, given exogenously. This stripped down abstraction can be described in extensive form (Shubik, 1982) for one buyer and two sellers as follows:

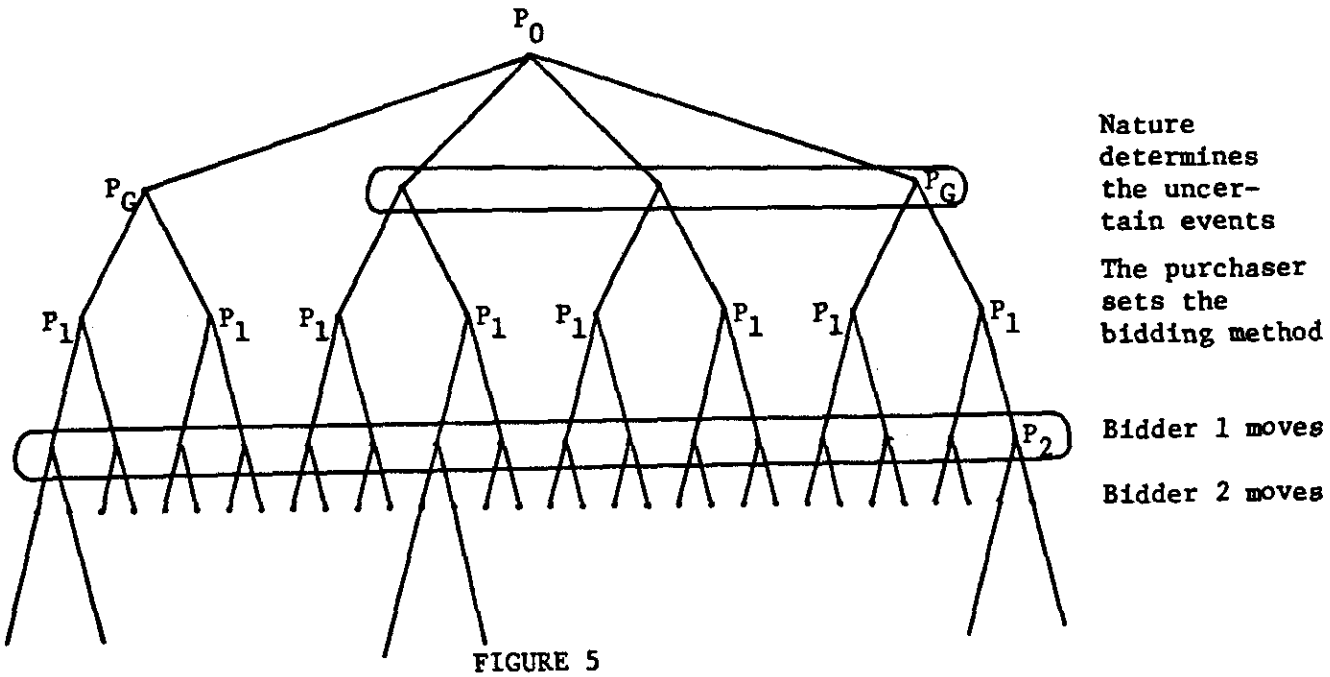


FIGURE 5

The example given here shows the buyer P_G moving first with some information; the first bidder is completely informed, whereas the second bidder knows nothing. In reality this is rarely the case. The problem faced by the practitioner and the theorist is first one of relevant and accurate description. This requires answering the following questions. Who are the players, what are their payoffs, what are their states of information, what are their strategic alternatives and what do we consider as a solution to the problem of bidding and contracting?

The first set of questions concerns the modeling of the environment and trying to describe realistically what are the rules of the game. It is important to appreciate that one group's environment is another group's set of decisions. Thus, frequently when we talk about "what is the problem?" the problem varies with the role of the interested party in the decision process. In particular, the level of enquiry here is from the viewpoint of the Naval procurement of ships given the other aspects of the United States government bureaucracy, political institutions, and corporate economy as facts of life.

The last question, "what do we consider as a solution?", is far more subtle than is usually appreciated by those who are accustomed to straightforward one person maximization problems. In much of the literature on bidding and auctions the criterion frequently accepted is the noncooperative equilibrium. When numbers are few and the action takes place over considerable lengths of time, it is by no means evident that this solution is particularly good.

5.2. Modeling with a Strategic Framework

It is suggested here that possibly the most valuable contribution that can be made to the analysis of procurement by the last twenty or thirty years of operations research and economics is an approach to the modeling of the type of process involved. In particular, we can translate the relatively abstract structure of game theory into a relatively straightforward checklist or "strategic audit" designed to pose the appropriate questions and elicit sufficiently precise answers to be able to identify the key features of the process and the possibilities for institutionally feasible improvements.

The following table provides an elementary checklist for the type of strategic audit called for in the study of the procurement process. Without going into detail, a quick checklist is presented of key factors which must be taken into account:

The major headings are: (1) Scope; (2) Time frame; (3) Players or strategic actors; (4) Rules of the game and choice sets; (5) Payoffs and goals; and (6) Behavioral assumptions.

1. Scope
    a. Socio-political process, DOD and Congress
    b. DOD and industry
    c. Tactics of contracting in a fixed environment
2. Time Frame
    a. Date of study
    b. Length of period studied
    c. Event oriented, fixed clock or both
    d. Initial conditions assumed
    e. Terminal conditions assumed

3. Players or Strategic Actors

   a. Level of aggregation

   b. Number of strategic players

4. Rules of the Game and Choice Sets

   a. Relevant political detail (own and others)

   b. Relevant bureaucratic detail (own and others)

   c. Relevant technological knowledge (own and others)

   d. Information and communication conditions

   e. Scope of feasible actions.

5. Payoffs and Goals

   a. Short and long term

   b. Defined on a finite or indefinite horizon

   c. Ordered, partially ordered or other

   d. Quantifiable (risk measures)

   e. Team or individuals goals

   f. Principal agent or fiduciary goals

6. Behavioral Assumptions

   a. Rationality

   b. Risk behavior under time pressure and/or stress

   c. Instinctive or programmed behavior

   d. Problems of perception and interpretation

Scope

The operations research or economic analyst is often faced with the difficult, implicit, critical decision of interpreting the scope of his analysis. It is not impossible that the critical factors for the improvement of a process lie in a domain outside of the scope of the

problem as originally posed (Brunner, 1965). The researcher may then choose the safe, but not overly important, approach ot sticking to the problem as narrowly defined or interpreted; or he may diagnose the difficulties as being located elsewhere, but in the act of enlarging the scope he runs the simultaneous dangers of being vague and of exceeding the bounds of institutional feasibility.

One individual's parameters are another individual's variables. In the context of the specific problem of naval ship procurement the critical limitations of scope are as follows: we must take the broad general aspects of the U.S. political process and social attitudes as given. The budget process requires interaction among DOD, the Federal bureaucracy, in general, and Congress.

Although the broad scope of the political process must be taken as given, there appears to be an important case to be made for long range funding as a way of improving acquisition efficiency but the way to achieve this is beyond the scope of this discussion.

We also take as given the symbolic importance attached to an ill-defined but broadly appealing concept of competition. Unless it is virtually dysfunctional to do so we assume that it is desirable to design processes where at least two firms compete in as unbiased a manner as possible for government business.

Do we take the naval procurement bureaucratic structure as given or as a candidate for change? As we have made no formal studies of the structure and the existing incentive system we take it for given, with the caveat that it is possible that the major source of improvements in procurement may be in changes within the naval bureaucracy. In particular (1) what are the promotion possibilities and other associated incentives

in naval procurement program management? (2) Should there be a close relationship between length of time in a post involving procurement supervision and the length of the shipbuilding program? What are the rewards and penalties for the accurate or poor estimation of major change costs?

Limiting our scope to the situation in which the socio-political and naval administrative environments are taken more or less as given we may still ask and hopefully answer useful questions concerning the possibility of improvements in procurement through feasible changes in bidding and contracting methods. In order to do so we must formalize who are the players and what are the payoffs?

Players and Strategic Actors

Aggregation

In many military and economic studies the first implicit assumptions made concern aggregation. Thus we may talk of the U.S.A.: DOD or the Navy as though they were well defined unified entities who act as a single unit with well defined procedures and intentions. The legitimacy of the level of aggregation depends upon the question at hand. Here the description of the firms (and potential entrants) is relatively easy in comparison with the description of DOD and its purpose.

The Number of Players

The players, as a good first approximation, may be regarded as the nine firms noted in Table 5 together with an aggregate possible "foreign competition" and new entrants. To these must be added the Navy with Congress and the remainder of society as part of the environment.

Payoffs and Goals

The price paid for treating complex aggregates as single players is that it becomes difficult to ascribe clear cut goals to them. The composite player is not unlike a schizophrenic—what one part of the aggregate may want another part rejects.

As a reasonable first approximation we may assume that the firms attempt to pursue some form of profit or return on investment. But even here important problems arise tied in with the time period under consideration, the level of commitment of the firms to defense work, and their attitudes towards risk.

Return on investment (ROI) can be made high by having the government supply most of the shipbuilding capital goods. But in spite of the stress in corporate reports (see Tenneco or General Dynamics, for example) upon profits and patriotic duty the behavior of the institutions of both the corporations and the navy appear to indicate a complex of motives, caused at least in part by the bureaucratic structure of each. In particular, the tradeoff between economy and quality appears to be a complicated institutional (and possibly historical?) phenomenon which cannot be ignored in trying to formulate the goals of both the Navy and the firms.

Another key element in the description of the goals of the aggregate or compound players concerns the motivation for monitoring by naval personnel and the level of cooperative technical communication and joint economizing manifested in the construction cycle. Beyond the psychic gratification of having participated in a job well done, the more direct incentives within both bureaucracial for tight cooperative control are hard to discern.

Behavioral Assumptions

In general many economic theorists appear to have irrational penchant to view economic life as though all actors behaved with one person maximizing behavior in a nonstrategic environment. It is a safe rule of thumb to assume that firms are more or less rational; that more profit is preferred to less. But the firms expect to try to be around for a long time and the navy wants them to both be around and be efficient. The simple versions of competitive or noncooperative behavior fit none of these desires. This observation alone tends to suggest some form of contracting device as a solution which is quasi-cooperative yet has some safeguards against outright collusion between the navy and its contractors at the expense of the public.

5.3. A Comment on Formal Models

Our biases are openly and explicitly inclined towards the development of theories of acquisition, bidding, incentive contracting and principal-agent relationships. We wish to stress, however, both their value and their potential misuse in application. What it can do and can do well is to help in the provision of advice and demonstration of subtle difficulties in suggested procedures or indicate promise in new approaches.

Using the type of strategic audit suggested in 5.2 the key (implicit or explicit) modeling assumptions made in the various formal theories are noted.

TABLE 6

	Scope	Time Frame	Players	Rules of the Game	Payoffs and Goals	Behavioral Assumptions
Pure competition	Abstract economic game	Not specific "short"	Many on both sides of market	Abstract basic economic conditions	Well defined complete order	Individual profit or utility maximization
Bidding theory	Abstract economic game	In general one shot	One versus many	Abstract basic strategic form	Utility function well defined payoff functions	Noncooperative Equilibrium
Principal-agency theory	Abstract two-sided game	Two stage game contracting and performance stage	One on one	Strategic form	"	Best response strategy
Incentive contracting literature	"	Two stage game	One on one	Strategic form	"	Best response

6. CONCLUSIONS

Prior to giving our conclusions and comments we wish to make an explicit disclaimer. We have not engaged in the direct obtaining of first hand empirical information by ourselves. As is the case, in general, when using sources supplied by others, unless there is a strong presumption otherwise we assume that the data discovered is reasonably accurate and descriptive of the process being examined.

Our prime concern has been to consider the development of pricing, bidding and contracting theories and to ask in what ways are they relevant in the context of actual naval procurement. Do theorists have anything useful to say when confronted with details of a program such as the

SSN-688? The comments may be general, specific, direct or indirect. For example, all other things being equal they might be a comment on the optimality or efficiency of a specific contract. They might be comments to the effect that there are critical factors which have not been incorporated into the general theoretical models which could be considered profitably. Or there is the possibility that from the view point of bidding and contracting theory that the system is reasonably good, but that the problems appear to lie elsewhere such as in management or technical or bureaucratic problems which are not obviously directly influenced merely by changes in economic incentives.

We divide our comments into two types. General observations and questions which we feel have not been adequately answered and may be important. Then specific comments concerning the bidding methods, their properties, what the theoretical investigations have to contribute and some suggestions for work of promise.

6.1. General Comments

(1) Program management tenure and motivation appears to be of importance. Longer tenure and a better incentive system might help.

(2) The funding and the bidding structure needs to be modified to lay more stress on continuity in the maintenance of long run economic capacity and work forces. Given the integral nature of orders for major ships and the few shipyards, if skilled labor is in fact relatively immobile, a compromise between market share and competition may be called for.

(3) In spite of Gansler's eloquent warning it is not evident that endogenous costs and risks have increased abnormally in the last decade.

Inflation and an oil embargo hit the economy, and shipbuilding in the U.S. has had to face considerable foreign competition. But these are exogenous forces.

(4) Much stress has been laid upon risk sharing. There is technical risk; contracting and economic risk; and scheduling risk. These may be controlled or generated by the navy, the firm, both or neither. Who should pay for the various risks is a matter of public policy which goes beyond a narrow definition of efficiency.

It is not clear that having the navy assume responsibility for the risks generated by naval personnel provides a sufficiently tight control mechanism. We did not make a study of internal accountability, but without doing so it is not possible to decide if the assumption of the costs of risks generated by the navy is an effective way to control their generation.

(5) The short term bias in the current procurement system appears to leave it open to "buy in" bidding. The concept of buy in is real but hard to nail down explicitly. The development of guidelines to identify and discourage buy in appears to be worth while. This in turn ties in with capacity considerations.

(6) The documents used in this study were all in the public domain. No classified material was used. This includes costs and schedules for major programs. The only comparable naval shipbuilding program to that of the U.S.A. is the program of the Soviet Union. Given the nature of the information we have easily obtainable in the public domain and the lack of availability of Soviet data at this level of detail outside of the Soviet naval establishment it would appear that the only group capable of answering the question "is U.S. naval ship-

building efficient in comparison to what?" is the Soviet navy. They have the information on the appropriate comparisons.

6.2. Specific Comments

At a high level of abstraction part of the problem of naval procurement involves (1) efficiency, (2) insurance, (3) incentives, (4) moral hazard and disclosure policies. All of these are considered in one form or the other in the theories noted in Table 6. But their manifestation in many major problems in economic procurement takes place in a specific context and time frame not yet particularly reflected by the theories. In particular, many of the major procurement programs are essentially (1) dynamic, (2) involve major indivisibilities and capacity constraints (3) involve poorly perceived or at least poorly articulated goal structures. ("What price freedom?" does for newspapers, but not for GAO), and (4) are not necessarily best viewed as strictly competitive or noncooperative games.

Our specific comments are to a great extent based upon our considerations of the four bidding methods used by the navy, studied in the light of the work in the theories of auctions, bidding contracting and agency. They are presented in greater detail in a forthcoming companion paper (Livne and Shubik, 1982).

We believe that in spite of the extreme abstractions made in these theories they are of value in commenting on the bidding methods actually used. We suggest however that the bureaucratic structure of both the navy and the firms is of importance. We believe that a training and operational game addressed to context and process could be usefully constructed.

The ship procurement process is of sufficient economic importance and has a sufficiently special structure that for several reasons it could be worthwhile constructing both a training game and operational simulation of the process.

In 5.1 a modeling checklist was provided. This indicates the nature of the components to be modeled. A program such as the SSN-688 clearly requires a model of considerably more complexity than the bidding and contracting models we note in Table 6 and discuss in some detail in a more technical companion paper (Livne and Shubik,1982). However, the complexity of a model that could serve training, operational and research purposes appears to be considerably less than say the simulation of a major logistics system (see the Rand work, e.g., Geisler, 1959).

In particular, a useful game could be built calibrating it on the SSN-688 program with two or three teams using live players, the navy and NN and Electric Boat. The time span should be at least the Milestones. The other shipyards; government agencies of relevance; policy changes, labor problems, inflation, failures to deliver components and so forth should be simulated.

For operational purposes a completely simulated contingency planning model could be considered. Because of the relatively small number of the ships being constructed, the length of planning and construction and the costs, a simulation for contingency planning appears to be both economic and of reasonable scope.

Both for training and negotiating a game-simulation provides an organized structure for the assumptions made concerning the process and the risks inherent in the system. The value in the use of such an exercise comes more in making problems explicit and raising questions concerning

assumptions about risk, responsibility and accountability, than in attributing a high level of confidence to the outcome of any particular exercise.

There is no particularly useful general theory of auctions bidding or contracting in a multi-stage dynamic setting. However, there is a reasonable hope for extending results and insights gleaned from the study of static models to multi-stage situations if use is made of special structures. In particular, the special structure of ship contracting appears to be sufficiently simple and important to provide a reason to extend formal analysis to specific dynamic models.

The construction of a contracting game-simulation using naval personnel and those engaged in the development of bidding and contracting theory, among others; would serve as a communication and educational activity of value in and of itself. As our comments above indicate the theory does have some worthwhile remarks concerning practice. But the next step calls for an explicit understanding of the several important special features of ship contracting which are directly visible only when the lengthy bureaucratic process involving large integral units is taken into account explicitly.

APPENDIX

1. Cost plus fixed fee (CPFF): The government pays all costs plus a fixed fee above costs regardless of the magnitude of costs.

2. Cost plus incentive fee (CPIF): A maximum and minimum fee are established. If costs are below a certain level, A the contractor obtains the maximum fee plus his costs. If they are above a certain level B he gets his minimum fee plus costs. Between the two levels his fee is reduced according to some fixed percentage as costs rise from level A to B .

3. Fixed price incentive fee (FPI): An upper limit is set on the amount that the government will pay the contractor. A target cost with a percentage fee is set. Below that cost and above it until a "point of assumption" is reached the contractor and government share cost savings or overruns according to some fixed percentage. Beyond the point of assumption the contractor pays for all costs incurred.

4. Firm fixed price (FFP): The government pays a single noncontingent price regardless of the costs experienced by the contractor.

REFERENCES

Alexander, A. J. (1973). "Weapons Acquisition in the Soviet Union, U.S. and France," Rand Corporation Report R-4989, Santa Monica, CA.

Amihud, Y. (ed.) (1976). Bidding and Auctioning for Procurement and Allocation. New York: New York University Press.

Analysis of Defense Major System Acquisition Policy and Procedures (1977). Naval Sea Systems Command Organizational Study.

Brunner, J. (1965). Squares of the City. New York: Ballentine Books.

Collins, J. M. (1980). U.S.-Soviet Military Balance. New York: McGraw-Hill.

Cyert, R. and J. March (1963). A Behavioral Theory of the Firm. Englewood Cliffs, NJ: Prentice Hall.

Dews, E.; G. K. Smith, A. Barbour; E. Harris; and M. Hesse (1979). Acquisition Policy Effectiveness: DOD Experience in the 1970s. Rand Corporation Report R-2516-DRCE, Santa Monica, CA.

Engelbrecht-Wiggans, R.; M. Shubik and R. Stark (eds.) (1982). "Auctions, Bidding and Contracting, Uses and Theory," in process.

Gansler, J. S. (1980). The Defense Industry. Cambridge, MA: MIT Press.

Geisler, M. A. (1959). "The Simulation of a Large-Scale Military Activity," Management Science 5, 4, pp. 359-368.

Hammon, C. P. (1980). "Analysis of Program Changes and Internal Labor Adjustment Costs in Shipbuilding," Ph.D Thesis, University of Rhode Island, Kingston, RI.

Hidalgo, E. (1978). Naval Ship Procurement Process Study. Washington, D.C.: Department of Navy.

Holmstrom, B. (1979). "Moral Hazard and Observability," Bell Journal of Economics, Spring, pp. 74-91.

Kaitz, E. M. and Associates (19). Building Naval Vessels: A Handbook of Shipyard Costs. Washington, DC.

Kohlmorgen, L. S. (1980). "Affordability—Not a Dirty Word," in proceedings of Ninth Annual DOD/FAI Acquisition Research Symposium at U.S. Naval Academy, Annapolis, MD.

Livne, Z. and M. Shubik (forthcoming 1982) Procurement of Mature Systems Through Competitive Bidding for Incentive Contracts.

Martin, D. D. and W. L. Glover (1980). "An Empirical Analysis of the Relationship between Cost, Cost Estimation, and Cost Analysis," in Proceedings of Ninth Annual DOD/FAI Acquisition Research Symposium at U.S. Naval Academy, Annapolis, MD.

McNichols, G. R. and B. S. McKeaney (1981). Analysis of DOD Weapon System Cost Growth Using Selected Acquisition Reports, Management Consulting and Research, Inc., Falls Church, VA, TR-8047-1, February 27.

Nelson, R. R. and S. G. Winter (1982). An Evolutionary Theory of Economic Capabilities and Behavior. Cambridge, MA: Harvard University Press, forthcoming.

Pollack, W. J. (1981). The Submarine Detail Design Information Process--A Complex Management Problem, mimeographed, Washington, DC.

Rosefielde, S. (1982). False Science: Underestimating the Soviety Arms Buildup 1960-1980. New Brunswick, NJ: Rutgers University, Transactions Press, forthcoming.

Shovell, S. (1979). "Risk Sharing and Incentives in the Principal-Agent Relationship," The Bell Journal of Economics, Spring, pp. 55-75.

Shubik, M. (1970). "On Different Methods for Allocating Resources," Kyklos, 2, pp. 332-337.

_____. (1982). Game Theory in the Social Sciences. Cambridge, MA: MIT Press.

Stark, R. H. and M. H. Rothkopf (1979). "Competitive Bidding: A Comprehensive Bibliography," Operations Research, 27, pp. 484-490.

Ward, J. W. and L. E. Garcia (1975). "The U.S. Shipbuilding Industry: Structure, Conduct and Performance," Thesis, Naval Postgraduate School, Monterey, CA.

Williamson, B. E. (1975). Markets and Hierarchies. Glencoe, IL: Free Press.