A STUDY OF SHIP ACQUISITION COST ESTIMATING IN THE NAVAL SEA SYSTEMS COMMAND

A REVIEW AND ANALYSIS OF THE COST ESTIMATING PROCESS AS IT RELATES TO RECENT COST GROWTH IN SHIP AND WEAPONS PROCUREMENT IN THE NAVY

FINAL REPORT

OCTOBER 28, 1977

International Maritime Associates, Inc.

NAVAL SEA SYSTEM COMMAND
DEPARTMENT OF THE NAVY
WASHINGTON, D.C. 20362

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IMA

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October 28, 1977

Rear Admiral J. W. Montgomery, USN
Naval Sea Systems Command
Department of the Navy
Washington, D.C. 20362

Dear Admiral Montgomery:

We are pleased to submit our final report entitled "A Study of Ship Acquisition Cost Estimating in the Naval Sea Systems Command" prepared as part of Contract No. N00024-77-C-2013. This report evaluates the ability of Navy estimators, particularly in the Naval Sea Systems Command, to adequately forecast required funding for shipbuilding.

Over the past year, we have studied many aspects of estimating and cost growth problems. Obviously, in the economic and industrial areas, inflation has played a large part in causing estimating errors and difficulties in project management. More subtle problems have had an equally important impact, however; productivity has been decreasing at a substantial pace, overhead costs are rising at double the rate of labor costs and the real costs of social legislation have been extremely difficult to assess.

Since estimates are an important element of the planning, funding and procurement systems of the Navy, we evaluated how the systems and estimates interact. Certain problems exist in this area also; the planning process does not produce sufficient program stability to allow careful estimating from a solid engineering base; the funding process from Navy management to Congress is largely political in nature and estimates are modified or programs changed with little regard for fiscal realities; current procedures require that funding estimates be made far in advance of appropriation and that these predictions remain accurate over periods of many years in good economic times and bad; finally, characteristics and engineering changes are so prevalent as to preclude estimate precision over lengthy periods. All these administrative and political problems take their toll on even reliable estimates.

(continued)

A third area of problems relates to engineering and construction activities. Schedules are often missed and this plays a large part in cost growth and apparently low estimates. The motivation for increased military capability and performance overshadows the important motivation to comply with funding commitments.

The impact of all these problems has been significant in recent years. It is recognized that the Navy and NAVSEA have varying degrees of control over the situations and problems that exist. Accordingly, the recommendations offered assume that the estimating environment and processes will not be self-correcting with the passage of time and that there are limitations on NAVSEA's ability to produce more accurate estimates. However, if NAVSEA does take steps to eliminate estimating deficiencies that presently exist, rationalize a system based on sound estimating techniques and support such activities with experienced staff and adequate funding, the accuracy of estimates will improve markedly, as will the management's ability to cope with the "environmental" problems outside its control.

This is not to overlook the improvements made in the Cost Estimating and Analysis Division over the last ten years -- particularly the establishment of a Cost Analysis Branch. This group has made substantial contributions to the general understanding and appreciation of the impact of economic and industrial factors upon shipbuilding costs.

Ten recommendations are offered as steps in the course of action being proposed: seven for NAVSEA implementation, three as suggestions NAVSEA may propose to other organizations impacting the estimating process.

1. A General Strengthening Of The Cost Estimating Process Is Required.

2. The Cost Estimating Staff Should Be Closely Associated With The Ship Production Staff And Should Be Given Greater Organizational Prominence.

3. A Procedure Should Be Instituted That Requires Periodic Auditing And Post Mortum Reviews Of Estimates.

(continued)

4. A Substantial Continuing Effort Should Be Made To Keep Abreast Of The Impact Of Changes In Shipyard Productivity, Overhead And Other Economic, Social And Market Factors.

5. The Concept Of Estimate Classification Should Be Redefined And A Supporting System Of Estimate Preparation Established.

6. A Standard System Of Preparing, Maintaining, Retaining And Transmitting Configuration And Estimating Data For GFM Items Should Be Instituted.

7. Senior Cost Estimating Staff Members Should Be More Involved In The Contract Negotiation Process.

We feel that these seven recommendations would provide an effective capability for NAVSEA. Since it is recognized that actions of other organizations can limit the amount of improvement, the next three suggestions affecting higher echelons are submitted for use at your discretion.

8. Planning At All Levels Should Be Redirected To Provide A Firm Engineering And Estimating Base.

9. Acquisition Programs Should Not Be Included In The Budget Until They Complete The DSARC II Milestone Or Its Equivalent.

10. A Continued Emphasis Should Be Placed On The Accountability Of Planning And Program Management To Operate Within Established Budget Dollars.

Although we believe that each of these recommendations individually would improve the quality of cost estimating, the impact of implementing all of them, we believe, would have a synergistic effect that would bring about

(continued)

a most substantial improvement in cost estimating performance.

We would not want the opportunity to pass without expressing our appreciation to Captain John A. Buck, USN and the Steering Committee, and to George Main and Joseph Fetchko and others too numerous to mention whose guidance, cooperation and assistance was invaluable.

We sincerely hope that this study serves the purpose for which it is intended and provides the basis upon which the Naval Sea Systems Command can improve the vital function of ship cost estimating.

Sincerely,

INTERNATIONAL MARITIME ASSOCIATES, INC.

James R. McCaul
President

JRM:jtj
Enclosures

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I. INTRODUCTION

I INTRODUCTION

This is a report about cost estimating in naval procurement and the ability of Navy estimators, particularly in the Naval Sea Systems Command, to adequately forecast required program funding. It is also an attempt to carefully ascertain where improvements can be made.

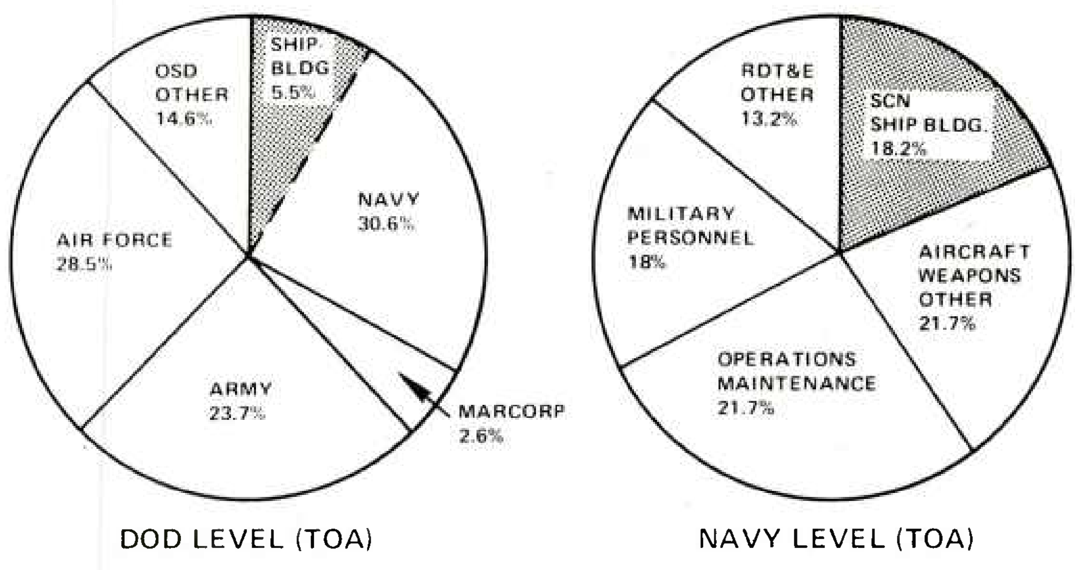
It is recognized that the cost estimating problem is extremely complex and, if at all possible, improvements should be made. Obviously, the national interest is at the heart of the matter. It is believed that specific action can be taken by NAVSEA to improve its capability and inasmuch as other government and industrial organizations interact in procurement activities so profoundly, areas are pointed to where NAVSEA may want to suggest complementary actions by organizations outside its control.

1. COST OVERRUNS IN NAVAL SHIP ACQUISITION HAVE BECOME AN IMPORTANT NATIONAL ISSUE

The Navy's shipbuilding program is an important component of the defense budget. The Figure which follows demonstrates this significance by comparing the Navy Fiscal Year 1977 Shipbuilding and Conversion (SCN) Appropriation budget to the Navy-wide budget and further by comparing SCN funding to Department of Defense budget totals.

FIGURE I.1

FISCAL YEAR 1977 BUDGET RELATIONSHIPS



SOURCE: OPNAV HISTORICAL BUDGET DATA BOOK

In terms of specific dollar amounts, Navy shipbuilding and conversion budgets over the past five years have been as follows:

TABLE I.1

NAVY SCN FUNDS AS A PERCENTAGE OF THE TOTAL NAVY BUDGET
(Dollars in Billions)

Fiscal Year	Amount	Percent of Navy Budget
1973	2.9	12.8
1974	3.5	14.4
1975	3.1	12.2
1976	3.9	13.6
1976 T	0.5	7.2
1977	6.3	18.2

In the Fiscal Year 1977 Budget, the Navy presented a five year shipbuilding program estimated to cost approximately $35 billion. In the development of this program, estimators were asked to make judgments about complex systems to be built over many years under economic conditions which have been, during recent years, difficult to predict. Since this program would represent a significant portion of the national budget, it could be expected that the Congress, acting for the public, would anticipate program estimates that accurately predict the cost of the ships required. This becomes a critical issue when viewed in the light of recent experience with respect to ship acquisition cost estimates.

(1) Cost Growth Of Significant Magnitude Has Characterized Most Ship Acquisition Programs In Recent Years

Three perspectives of cost growth serve to define the problem. Each year the Comptroller General reports on the financial status of major government acquisitions to the Congress. A perspective on cost growth in Navy programs is provided in this report as Table 1.2. This publication tends to show programs at their worst by showing an early estimate and comparing it to a current estimate -- no matter what took place in between. It is widely distributed, however, and often is used as a benchmark. All Navy programs active during the period of the report -- ships, weapons, aircraft, etc. -- show cost growth of over 40 percent, according to this document.

TABLE 1.2

COST GROWTH OF SELECTED SHIP CLASSES
(Dollars in Millions)

	Baseline (Development) Estimate	Current Estimate	Percent Growth
FFG 7	3244.5	9014.8	178
DD 963	2581.2	3810.8	48
LHA*	5747.5	9690.8	69
CVN 68	4010.2	4653.2	16
CGN 38	820.4	1251.7	53
All Programs	89,316.4	127,355.3	43

* Adjusted for quantity changes.

SOURCE: Comptroller General, Report on Financial Status of Acquisition as of July 1976; published January 1977.

It is understood that cost growth in the context of GAO Acquisition Status Reports reflects increases from estimates prepared during early development phases where uncertainties are more likely to be present. Budget estimates, when looked at in the aggregate however, should show less cost growth since the year by year submissions tend to become self-correcting. Large variances do occur in these budget estimates when compared to currently estimated or actual costs as Table 1.3 shows.

TABLE 1.3

SHIPBUILDING PROGRAM PROPOSED BY NAVSEA
(1970-1977)

	---------Then Year Dollars In Billions-----			
	Budget Estimate	New Estimate or Actual	Difference	Percent
SSN 688	6.033	6.382	.349	6
TRIDENT	3.320	3.816	.496	15
CVN	1.418	1.943	.525	37
CGN	0.944	1.140	.196	21
DD 963	2.739	3.696	.957	35
FFG	2.136	2.370	.234	11
LHA	0.590	0.872	.282	47
AD	0.579	0.708	.129	22
AS	0.434	0.577	.143	33
AOR	0.057	0.086	.029	51
AO	0.443	0.375	(.068)	(15)
PHM	0.096	0.243	.147	153
Total	18.789	22.208	3.419	18

Note: SSBN conversions not included.

SOURCE: Budget Documents

The table above shows total budget requests for major ship types between the years 1970 and 1977. Funds requested to maintain these programs in a fully funded status has amounted to $3.4 billion -- a cost growth of 18 percent. Obviously, inflation plays a large part in increases computed as they were in Table 1.3. When inflationary effects are removed by using BLS Shipbuilding Indices and all figures are indexed to 1970 constant dollars, however, a 12 to 14 percent increase remains.

A difficulty with these figures is that the FY 1976 and FY 1977 programs presently show negative cost growth since program development is not very far along. If past history is a guide, these programs could exhibit cost growth in similar proportions to FY 1970 through FY 1975 thus maintaining a high level of cost growth.

The point that comes through here is that even after removing the effects of unanticipated inflation, cost overruns due to management and other problems occurred in significant amounts.

Further study of the Navy budget documents from which these figures were taken indicates that several out of the eight basic categories of expense show large overruns. Figure 1.2 identifies these categories and, in order of importance, they are unanticipated escalation, basic construction, ordnance growth. Other categories are either negligible in amount or are contingency categories.

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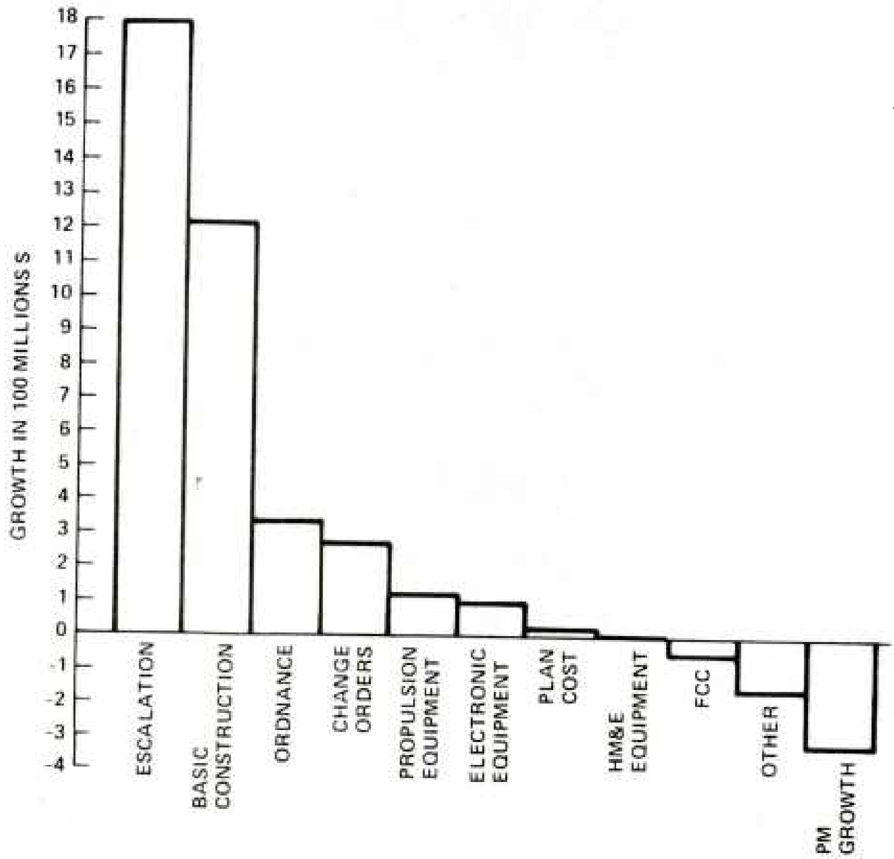
FIGURE I.2

CUMULATIVE COST GROWTH FY 1970-1977 PROGRAMS INCLUSIVE



SOURCE:
NAVSEA BUDGET DATA

(2) <u>The Effect Of Recent Cost Overruns And Lack Of Predictability Has Been To Focus Critical Attention On The Navy Program</u>

The focal point of criticism is in the Congress during annual hearings on the Budget. In several recent years, the Navy has had to request additional funding, over and above that originally appropriated, for the increased costs of prior year programs. For FY 1976, it was $2.268 billion; for FY 1977, three-quarters of a billion dollars. Congress sees new appropriation requests for programs which have been previously authorized either as mismanagement or cost growth due to optimistic initial cost estimates. The upward increase in estimated end cost is usually dramatic and often cannot be completely explained by inflationary factors.

These kinds of cost aberrations, the inability to consistently cost predict, the state of affairs in the shipbuilding industry, etc., have led Congress to declare a "crisis of naval shipbuilding".

Many government organizations have experienced overrun problems in recent years, but Congress has expressed repeated concern about the Navy. During July 1976, hearings on the Navy shipbuilding program were held by the Defense Subcommittee of the House Appropriations Committee and the subject of cost overruns and faulty estimating was being discussed as part of reviewing the FY 1977 budget requests. Speaking for the Navy, Vice Admiral R. C. Gooding, USN, stated that all Navy estimates are honest attempts to predict end cost but that Navy estimators did not always succeed in preparing accurate forecasts.

> "Where we missed the ball badly was in our estimate of future escalation...the ship-building costs, judging by the BLS indexes between 1970 and 1975 went up, I believe, some 52 percent. Wheat went up three times. Petroleum went up 2-1/2 times. We did not foresee increases of that magnitude and again, I don't apologize for that because my crystal ball is as cloudy as anybody elses.
>
> I would like to add that I plan to hire an outside contractor, one independent and unbiased by the Navy procedure or situation. We will have him make an independent appraisal of our cost estimating procedures and results. We will certainly review the report of that study with great care and take actions as necessary."

In October 1976, International Maritime Associates, Inc. was contracted to perform the study mentioned in Admiral Gooding's testimony.

2. THE OBJECTIVE OF THIS STUDY IS TO IDENTIFY THE CAUSES OF COST GROWTH AND TO SUGGEST IMPROVEMENTS IN THE COST ESTIMATING PROCESS

This study starts with the assumption that a solution of the cost problem lies in improvement of estimating capability, proper use of the improved estimates in management systems and provision for a clearer understanding of the limitations of estimates which are only predictions subject to uncertainty. It is unlike other studies which have generally addressed broader organizational and management policy matters.

More specifically, the objectives of this study are to:

- Identify the root causes of cost overruns and the increase of costs -- from earliest stages of ship development to current status.

- Study the organizational and procedural capability of the Navy for estimating and predicting accurately the end cost of ships, weapons and other GFM.

- Recommend specific improvements in staffing, systems and methods in NAVSEA that will contribute to better estimating.

The focus of the study is limited. Although it covers such broad subjects as the nature of shipbuilding, the DOD acquisition process, studies over the last ten years, etc., the fundamental focus relates to the influence of these subjects on cost estimating. The overriding goal of the effort is to provide practical evaluations and recommendations for improving the cost estimating process.

The contractual tasks requested for this study -- and which are covered in various sections throughout the report -- are outlined over the next paragraphs, along with a brief discussion of problems which would presumably be addressed in carrying out the tasks.

Unique problems and circumstances characterize the shipbuilding industry -- both in the U. S. and overseas. The shipbuilding industry undertakes extremely lengthy, complex, labor intensive projects and when unforeseen economic problems occur they are exaggerated by these characteristics.

A second industry problem is the rather drastic reduction in productivity over the last four to six years.

Task 1
"A review of the characteristics and status of free world shipbuilding to develop comparisons between: a. U.S. shipbuilding versus heavy construction, manufacturing and/or aircraft b. U.S. Naval shipbuilding versus U.S. Commercial shipbuilding c. Foreign versus U.S. shipbuilding d. Subsidies and government involvement The above comparisons are to be used to develop the nature of the shipbuilding business and to outline the implications relevant to Navy cost estimating."

Thirdly, the marketplace for Navy shipbuilding is peculiar in its structure. Increasing lack of competition has directly affected prices of naval ships.

Fourthly, world-wide labor and material inflation surprised most countries and industries, not only the shipbuilding industry.

It was these kinds of problems which motivated a study of free-world shipbuilding.

Many governmental and non-governmental groups have been commissioned to study the cost growth problem. Literally, dozens of recommendations have been made to the Navy concerning cost growth as part of at least 20 significant studies.

Task 2
"Review and analysis of all studies and reports since 1966 dealing with Naval ship construction estimating and budgeting. The major studies in this area are listed as GFI under this contract."

The number and variety of suggestions as to how to solve the problems has become somewhat bewildering.

The planning, programming and budgeting system is an elaborate process which depends on reliable estimates. Program planning and resource allocation depend on accurate estimates to produce the proper mix of cost effective systems. Inaccurate estimates can cause the program selection process to either include too many programs or too few to optimally utilize available resources.

Task 3
"Review and analysis of the SCN POM and budget sequences and evaluation of the time elements involved therein."

The system imposes scheduling constraints that interfere with careful estimating. The long lead information requirements preclude estimate tuning in times of fast-paced economic change.

The primary focus of the study was the Navy's ability to reliably estimate the cost of ship construction. The estimation of costs for a complex ship is not an easy task. It requires a rational methodology, skill, experience, engineering, return cost data banks -- and time. Task activities have sought to determine how well the NAVSEA organization has performed.

Task 4
"Evaluation of Navy ship construction cost estimating capability from 1966 to 1976. This will include an analysis of the following: a. Staffing and organizational structure b. Data banks c. Returned cost and bid data d. Escalation and inflation predictions e. Quality vs. available technical description f. Estimating response time g. Review procedures h. Technical complexity and value of a unit of the product This evaluation will also include an assessment of the mission of the ship cost estimating group in NAVSEA and a comparison to other such groups in OPNAV, OSD, NAVELEX, NAVAIR, NAVFAC, and the shipbuilding industry."

Also of interest was the general comparability of other cost estimating groups within and outside of the Navy -- both public and private.

A detailed review of estimating performance over the years was lacking and needed.

In addition to basic estimation of ship construction, many other activities are carried on by Navy estimators. While each may be of value

Task 5
"Review and analysis of related cost estimating and analysis functions and their impact on the basic cost estimating function. These related functions are: . Program planning . Economic analysis . Economic forecasting . Technical cost analysis reviews . Should cost . Design to cost . Conceptual/Parametric costing . Life cycle cost . Overhead monitor . Contract cost analysis . Cost modeling . Specialized program costs"

in itself, the increasing need to credibly perform these functions tends to dilute time and diverts staff from basic ship cost estimating.

This task required looking at each function and analyzing staff performance relative to it with a view toward recommending a proper balance between these duties and other equally important activities.

The quality of estimating for GFE has been suspect over the years. The management of GFE programs is relatively independent of each other and therefore no single mechanism exists in the Navy to develop consistent, reliable estimates on a continuing basis.

Task 6
"Evaluation of cost input estimates for major weapons systems and major items of GFE. This review and analysis will parallel the evaluation of shipbuilding in paragraph 3 above and cover the same points."

A second problem area is the customer/contractor relationships where often sole source contracts are suspected of being higher priced than warranted.

There has been no lack of criticism of the Navy regarding cost growth.

Task 7a
"Identification and interview of critics, and an evaluation of the criticism made."

The annual hearings on the defense budget are the most visible forum for the examination of cost growth on Navy programs. Others in the shipbuilding industry, the press and government have been critical of the Navy on occasion. In this task, efforts were made to categorize the varied criticisms and evaluate their merits.

In order to test the study's findings, three ships and eight items of GFM were examined in-depth. Definitive conclusions required that various

Task 7b
"Selection and documentation of case histories which will include a nuclear ship, a non-nuclear combatant ship and a naval auxiliary, such as the AO 177 class."

ship programs be studied carefully to ascertain whether estimating was being performed satisfactorily, but other factors had an impact on estimates; or whether, in fact, estimating was not what it should be in support of Navy ship and GFM programs.

Social legislation over the past ten years has had a direct impact on

American industry. Whatever impact on productivity and overhead costs this legislation has had, it has generally been hidden or at least not addressed openly. Its impact in the shipbuilding industry is dramatic and definitely is a contributor to cost growth.

Task 7c
"Review and analyze social legislation such as OSHA, EPA etc., to evaluate its impact on cost control."

3. <u>THE PRODUCT OF THIS STUDY IS PRESENTED IN SEVERAL DOCUMENTS: AN EXECUTIVE SUMMARY, A FINAL REPORT AND AN APPENDIX</u>

As might be expected, the product of a year's study is quite voluminous. It is also recognized that several audiences exist for the results of this work. Several volumes have therefore been written which provide increasing detail regarding study findings. Volumes provided are:

- An Executive Summary (about 50 pages) which covers the problems surfaced, their effects and recommendations for their solution.

- The Final Report itself -- this volume of 435 pages -- which is the primary document discussing the cost problems broadly and following staff thinking through to conclusions and recommendations.

- The third volume (over 1,000 pages) is a reference document comprised of Appendices to the Final Report. Each Appendix covers a specific contract task area and contains a great deal of detailed background data upon which the Final Report is based.

It is felt that adequate documentation has been provided to support the Report's conclusions and suggestions for improvement.

II BACKGROUND OF THE COST PROBLEM

II THE BACKGROUND OF THE PROBLEM

Navy estimating must be evaluated in the context of the environment in which it is performed. It is an activity carried out in relation to general economic conditions, specific circumstances in the shipbuilding industry, government resource allocation systems and professional disciplines of various types. Performance judged without regard to these interrelationships would be a mistake.

This section of the report provides an overview of the shipbuilding industry, placing into perspective the cost problems experienced in naval ship construction. It describes the nature of the industry and its problems, emphasizing:

- The concentration of the industry reflected by the increasingly limited number of shipbuilders;
- The concentration of worldwide naval shipbuilding in only two countries;
- The sudden, eratic movement in labor and material cost that has impacted shipbuilders world-wide;
- The decrease in shipyard productivity;
- The often hidden, but nonetheless severe impact of social legislation.

All of these have had important, and often unpredictable cost effects.

1. THE SHIPBUILDING INDUSTRY EXISTS IN ITS PRESENT FORM AS A RESULT OF MASSIVE TECHNOLOGICAL, INSTITUTIONAL AND SOCIAL CHANGES

Massive changes in industries around the world have taken place over the last fifteen years. The complexity and rapidity of these changes have generally been understood only after their effects have created secondary and tertiary problems. The specific effect of social legislation and changes in the work ethic, for example, was understood only when productivity was no longer a stable and predictable industrial component and overhead costs began to increase drastically. The effect on American industry of the following kinds of changes has only recently been pieced together.

- Technological developments of the 60's and 70's could be referred to as a second industrial revolution. Progress in nuclear propulsion and exotic fuels, automation of industrial and administrative activities, solid state electronics, supersonic and space flight, inertial navigation, to name a few -- all have had a revolutionary effect on industry.

- International economic changes took place that were caused by:

  - a new nationalism in many countries around the world;

  - radical changes in currency exchange rates;

  - the disruptive effects on all countries of seemingly uncontrollable inflation.

- The slow but steady effects of social legislation relating to occupational health and safety, racial and sexual equality, environmental quality and the like -- the real cost of which is only now becoming apparent.

- The change in industrial structure and capital distribution caused by the trend toward conglomerate ownership and management of basic industries.

These factors, and others, have contributed in varying degrees to the current industrial environment.

(1) <u>There Has Been, During This Period, A Widespread Inability To Grasp The Complexities Of The Industrial Environment</u>

The private, as well as the public sectors have experienced dislocations and instability brought on by confusion about the effects of these problems. The complexities of the environment have created an attitude of uncertainty. In the 1950's, uncertainty was a secondary consideration; in the 1970's, it is an overriding concern. Predictibility of future events or requirements has become a highly inexact science due to the rapidly evolving nature of the industrial and social environment.

This attitude of uncertainty has been placed in heightened perspective by the fact that national resources are growing more slowly during a period when increasing demands are being made by many groups for larger portions of these resources. Scarcity of resources sets up its own set of constraints which act to exaggerate the effects of uncertainty. The efficient and fair allocation of available resources in such an environment is highly dependent on accurate estimation of future events and requirements.

(2) <u>The Massive Changes Over The Last Fifteen Years Are Mirrored In The Shipbuilding Industry</u>

The U.S. shipbuilding and repair industry employed 175,000 workers as of March, 1977. It accounts for about two percent of the gross national product. The industry's mix of work is comprised of military construction and repair, government subsidized commercial construction and repair, work generated through rigid cabotage laws, and some purely commercial construction and repair. Paralleling the private sector of the industry is the government sector of eight naval shipyards employing 67,500 workers performing conversion, alteration and repair activities on naval ships.

Shipbuilding, as an industry, exhibits many of the characteristics generally associated with heavy construction or other land-based activities such as refinery and power plant construction. Large, complex and expensive projects for only one, or at best a limited number of similar products, are the norm in this type of industry. Both shipbuilding and commercial heavy construction are highly labor intensive industries where manual and supervisory skills are vital. Instability of markets has been recognized as a major impediment to technological advances and productivity in such circumstances. Further, due to its heavy construction orientation, shipbuilding permits only limited application of mechanization. Even the highly publicized modern shipyards in Japan, Sweden, United States and other countries are unable to extensively use manufacturing processes for anything other than steel fabrication for later assembly in larger modular segments. These modules are invariably regulated and adjusted by hand in the final shipway or construction area.

It is against this industrial orientation that significant changes over the last few decades have occurred. Figure II.1 on the following page outlines industry characteristics during the 1950's and then, by comparison, lists differences arising in the 1960's and 1970's.

(3) Naval Ship Construction Is More Concentrated Than Merchant Ship Construction

The construction of naval ships is a sub-industry which has also undergone substantial change. In the broadest terms, the building of naval ships can be divided into construction of support/auxiliary ships and combatant ships. Auxiliaries resemble complex

FIGURE II.1

CHANGES IN SHIPBUILDING OVER LAST FEW DECADES

The 1950's	The 1960's and 1970's
• Inflation rates remained reasonably constant and manageable for all segments of the industry. • The technology of the 1940's produced a limited number of revolutionary products, hence programs were less complicated until the middle 1950's. • Competition in the ship construction industry tended to stabilize costs and provide an adequate industrial base. • Military ships were more attractive due to limited subsidized and unsubsidized commercial work. • There was an adequate supply of skilled shipyard labor. • Where shipyards experienced losses, they were not of the magnitude experienced in the 60's and 70's. • Shipyards, most of which were individually owned, had not reached the "claims" era as a means of recouping losses or overruns.	• Inflation rates started to become erratic and to increase unpredictably, thus penalizing shipyards in the late 1960's and early 1970's. • Technologies blossomed and brought about a new set of difficulties, namely, complexity of product and engineering, massive platform changes due to vastly increased weapons performance, etc. • In the 1960's shrinking demand caused a consolidation of the industry, and in the 1970's, increases in government financially assisted commercial shipbuilding programs placed additional demands on the shipbuilding industrial base. • Growing scarcity of skilled labor and competition of higher paying construction industry has limited available workforce, thus compelling use of less experienced men with resulting reduction in productivity. • Losses and overruns have become significant. • Increase in program complications and increase in claims has resulted in more stringent and sometimes costly contract administration. • Legislation relating to the environment, health and safety and increased social benefits, increased fuel and power costs, higher taxes and other factors have materially increased industrial overhead. • The conglomerate controlled shipyards began using claims as the means of recouping losses and overruns.

merchant ships with the addition of special features inherent in combatant ships. However, complex ships in the combatant category require many skills well in excess of those usually encountered in a strictly commercial yard or yards constructing naval auxiliary ships. Depending upon the ship type, the added technologies over those required for commercial or auxiliary ships could include:

- More refined naval architecture
- Ship silencing and shockproofing
- Specialized electronic and weapons engineering
- Nuclear engineering
- A higher degree of planning
- Installation of more complex machinery
- Installation and integration of highly complex electronics and weapons
- Extensive checkout, testing and quality control
- Integration and installation of avionic equipment as well as aircraft landing and recovery equipment
- Special qualifications in assembly and jointing of pressure hull materials
- Extensive metallurgical engineering
- Fabrication, installation and welding of materials for nuclear systems

As a result, shipyards tend to specialize in certain types of combatant ships. Shipyards involved in the naval shipbuilding program are indicated in Table II.1 and it is interesting to note that, apart from the FFG and SSN which are contracted to more than one yard, each specific ship type in the FY 1970-1977 programs awarded to date is built largely in a single shipyard.

TABLE II.1

U. S. SHIPYARDS BUILDING U. S. NAVAL SHIPS
(As of June 1977)

Ship Type	Newport News	Electric Boat	Ingalls (Litton)	Bath	Todd San Pedro	Todd Seattle	National Steel	Lockheed	Avondale
SSN	8	17							
DD			23						
FFG				6	8	6			
TRIDENT		4							
LHA			4						
CGN	3								
AD							2		
AS								2	
CVN	2								
AO									3

In testimony before the U. S. Senate Committee on Armed Services on April 29, 1976 the Honorable William P. Clements, Jr. testified regarding the decreasing number of shipyards engaged in naval ship construction:

> "In 1960, 14 private shipyards were engaged in the construction of 83 major combatant, amphibious warfare, and large auxiliary naval

vessels. Also, naval vessels were built in five naval shipyards. Fifteen years later, in 1975, over 90 percent of the Navy's shipbuilding program (62 out of 66 ships) was concentrated in three yards (Newport News, Electric Boat, and Litton) and no new construction ship project has been assigned to a naval shipyard since 1967."

Due to a reduction in commercial work the situation has begun to change. More shipyards are becoming involved in the construction of naval ships. Currently, nine shipyards have contracted for the construction of 88 major combatant, amphibious warfare and large auxiliary ships. Of the 88 ships that have been contracted with these nine yards, 61 (or 69 percent) are with three shipyards -- Newport News, Electric Boat and Ingalls. The trend toward a wider distribution may have been strengthened, however, considering the current estimate of a 74 ship FFG program and the involvement of three shipyards in construction of this type at the present time. Only two yards, Electric Boat and Newport News, are now involved in construction of nuclear ships. Of the nine yards constructing naval ships, four are also constructing commercial ships.

Only one other nation has any substantial interest in naval shipbuilding -- the Soviet Union.

(4) Over The Period 1964-1974 The Soviet Union And The United States Constructed 249 And 163 Naval Ships Respectively

During this period, dramatic increases in Soviet defense-oriented spending was seen. The Soviet shipbuilding program expanded to the extent that their navy currently consists of a larger number of ships than any other in the world. A major achievement of the Soviet building program occurred during 1970 when their nuclear submarine fleet exceeded that of the U. S. in number of ships.

The table below provides a comparison of U. S. and U.S.S.R. principal combatants built between 1964-1974.

TABLE II.2

COMPARISON OF NAVAL SHIPBUILDING
U.S. AND U.S.S.R. DURING 1964-1974

	Soviet	U.S.
Aircraft Carriers	0	2
Other Aviation Ships	2*	5**
Cruisers	16	16
Destroyers	27	6
Frigates (ocean escorts)	57	61
Nuclear Strategic Missile Submarines (SSEN)	45	28
Nuclear General Purpose Submarines (SSN)	56	45
Conventional Submarines	46	0
TOTAL	249	163

* 2 Guided Missile - Helicopter Carriers (CHG)
** 5 Amphibious Assault Ships (LPH)

In addition to the principal combatants shown above, Soviet small combatants, auxiliaries, and other amphibious craft showed an increase of over 1,000 for the 1964-1974 period -- while the United States increased non-principal combatants by 112.

Testimony on several occasions before the Defense Subcommittee of the Committee on Appropriations during 1977 revealed that the Soviet's have the largest, most modern submarine yards in the world, having expanded by two to four yards since 1966 alone. Additionally, almost all of the eleven principal Soviet building yards have undergone major modernization during the past five years.

Admiral H. G. Rickover, USN, stated in his testimony before the House Appropriations Committee on March 24, 1977 that the Soviets have a "nuclear submarine production capability of 20 ships a year on a single shift basis". Further evidence of Soviet accomplishments in shipbuilding is seen in the fact that the Soviet fleet of nuclear ballistic missile submarines is now 50 percent larger than that of the U. S. The Soviet shipbuilding industry is delivering SSBNs at a rate of six per year. The U. S. on the other hand has not delivered any SSBNs in the past ten years. Current U. S. submarine programs are based on a projected combined delivery rate of three to four SSN/SSBNs per year.

Other countries are constructing naval ships but not on the same scale as the U. S. and U.S.S.R. Presently the People's Republic of China, the United Kingdom and France rank third, fourth, and fifth, repectively, among the 30 nations currently building naval ships.

2. THE EFFECT OF CHANGES -- PARTICULARLY CHANGES IN COST ESCALATION AND CHANGES IN SUPPLY AND DEMAND -- HAVE BEEN FELT IN SHIPBUILDING THROUGHOUT THE WORLD

Significant changes in cost factors and workload have been taking place in the shipbuilding industry. As discussed below, these developments are not limited to U. S. shipyards.

(1) Escalation Of Material And Wages Has Been A Major Factor Driving Up U. S. Shipbuilding Costs As Well As Costs In Foreign Countries

Over the period of 1967 through 1976, U. S. shipbuilding average hourly earnings (excluding fringes and bonuses) increased from $3.44 to $6.01 per week -- or 74 percent. About half of this increase occurred in the 1974-1976 period. Hourly earnings in shipbuilding, as shown in Table II.3, are presently higher than in general manufacturing, but less than earnings in the generally similar contract construction field -- the chief competitor for shipbuilding skills. This wage "gap" causes a drain of skilled workers from the shipbuilding sector into contract construction -- creating problems in building and retaining a skilled workforce.

TABLE II.3

AVERAGE HOURLY EARNINGS IN SELECTED INDUSTRIES
1967 - 1976

Year	Shipbuilding and Repair	Manufacturing	Contract Construction
1967	3.44	2.83	4.11
1968	3.58	3.01	4.41
1969	3.81	3.19	4.79
1970	3.96	3.36	5.24
1971	4.12	3.57	5.69
1972	4.36	3.81	6.03
1973	4.61	4.08	6.37
1974	4.98	4.41	6.75
1975	5.51	4.81	7.25
1976	6.01	5.19	7.68
Percent Increase 1967-1976	74	83	89

SOURCE: Bureau of Labor Statistics, Employment and Earnings

Shipbuilding wages in other countries have also increased significantly over the past ten years. As shown in Table II.4, Swedish labor costs have risen very rapidly and are now the highest in the world. Average hourly earnings in Japan, West Germany, Netherlands and Norway have risen substantially, especially in the 1970's.

TABLE II.4

AVERAGE HOURLY EARNINGS IN MAJOR SHIPBUILDING COUNTRIES
1967-1976
(in U. S. dollars*)

Year	United States	Sweden	United Kingdom	Japan	Netherlands	West Germany
1967	3.44	2.45	1.16	0.75	1.12	1.31
1968	3.58	2.58	1.27	0.80	1.21	1.35
1969	3.81	2.82	1.40	0.90	1.32	1.62
1970	3.96	3.11	1.57	1.07	1.49	1.80
1971	4.12	3.40	1.85	1.25	1.81	2.12
1972	4.36	4.19	2.01	1.49	2.17	2.51
1973	4.61	4.95	2.33	2.00	2.81	3.36
1974	4.98	5.44	2.72	2.64	3.44	3.87
1975	5.51	6.41	3.43	3.24	4.20	4.33
1976	6.01	7.05	3.16	4.05	4.33	4.42
Percent Increase 1967-76	74	187	172	406	286	237

* Does not include fringes

SOURCE: Bureau of Labor Statistics -- Foreign Comparison Branch

U. S. shipbuilding material costs have increased approximately 95 percent in the same 1967-1976 period as shown in the next table. This is considerably higher than a corresponding increase of 82.3 percent in the Wholesale Industrial Price Index during the same period, but considerably less than the 115.9 percent increase of the Iron and Steel Index.

TABLE II.5

MATERIAL COST INDICES
(Average for Year)

Year	Wholesale Price		Iron & Steel (1)		BLS Shipbuilding Material (2)	
	Index	Percent Yearly Increase	Index	Percent Yearly Increase	Index	Percent Yearly Increase
1967	100.0	-	100.0	-	100.0	-
1968	102.5	2.5	101.9	1.9	102.2	2.2
1969	106.0	3.4	107.0	5.0	106.5	4.2
1970	110.0	3.8	115.1	7.8	113.4	6.5
1971	114.0	3.6	121.8	5.8	118.9	4.9
1972	117.9	3.4	128.4	5.4	123.3	3.7
1973	125.9	6.8	136.2	6.1	128.9	4.5
1974	153.8	22.2	178.6	31.0	159.6	23.8
1975	171.5	11.5	201.1	12.6	182.9	14.6
1976	182.3	6.3	215.9	7.3	195.0	6.6
Increase 1967-76	82.3%		115.9%		95%	
Average Annual Growth	6.9%		8.0%		7.7%	

(1) Group 10-1 of Wholesale Price Index
(2) BLS Weighted Shipbuilding Index used for contract escalation

SOURCE: Bureau of Labor Statistics

As noted, the average annual growth rate for the Wholesale Price Index was 6.9 percent, the Iron and Steel Index 8.0 percent, and the BLS Index 7.7 percent. This also shows 1974 and 1975 as being critical material inflation years as they were for labor inflation.

The Maritime Administration in its reports to Congress on the "Relative Cost of Shipbuilding in the Various Coastal Districts in the United States" for 1973, 1974, 1975, 1976 and 1977 has established basic costs (without profit and escalation) of an 89,000 DWT tanker for yearly comparisons. In this five year period, it was estimated that shipbuilder's costs had increased 86 percent. Incidently, the cost of ship's steel also increased 86 percent. Total ship material costs increased approximately 95 percent, with an annual growth rate of 18.5 percent, which is considerably greater than any of the aforementioned indices during the same period. A comparison of the various material growth indices over the past five years indicates the following:

TABLE II.6

MATERIAL GROWTH INDICATORS
1972 - 1976

	Increase 1972-1976	Average Annual Growth Rate	1976 Growth Rate
MarAd Material Increase (FY 1973-1977)	95.0%	18.5%	6.5%
Wholesale Price Index	54.6	10.9	6.3
Iron and Steel Index (10-1)	68.1	13.6	7.3
BLS Material Index	57.0	11.4	6.6

Thus, most shipbuilding materials are increasing at a greater rate than indicated by both the Wholesale Price and BLS Material Indices.

During the critical inflationary period, the term double-digit was a misnomer by implying inflation somewhat in excess of ten percent. In reality, many selected materials increased inordinately in one year. The impact of this inflationary period on the shipbuilding industry has been understated and underestimated. Its impact is still being felt in current prices of ships.

Similarly, material costs overseas have been affected by inflationary pressures. Table II.7 indicates that major shipbuilding countries have experienced wholesale industrial price increases in the range of 54 to 87 percent over the past ten years.

TABLE II.7

WHOLESALE INDUSTRIAL PRICE INDEX
(1966-1976)

Country	France	Germany	Japan	Netherlands	Norway	Sweden	U.S.
Base Year = 100	1962	1970	1970	1970	1961	1968	1967
1966	110.2	90.3	92.7	95	112	103	98.5
1967	109.2	89.4	93.8	96	113	101	100.0
1968	107.4	92.8	94.1	98	115	100	102.5
1969	118.9	95.0	95.9	96	120	104	106.0
1970	127.8	100.0	100.0	100	129	112	110.0
1971	130.5	104.3	98.9	104	129	114	114.0
1972	136.5	107.0	99.7	110	133	119	117.9
1973	156.6	114.1	114.8	117	147	133	125.9
1974	202.2	129.4	147.3	129	179	165	153.8
1975	190.8	135.5	149.6	135	187	178	171.4
1976	204.8	140.8	156.8	146	201	193	182.3
Percent Increase 1966-75	86	56	69	54	79	87	85
Percent Increase 1971-76	57	35	58	40	56	69	60

SOURCE: Bureau of Labor Statistics

(2) Labor Fringe Benefits Are Increasing At Double The Rate Of Direct Labor Earnings In The U. S.

As an adjunct to the rapid increases in shipbuilding direct labor costs, a recent overhead study of a major U. S. shipyard indicates that the 1969-1975 compound rate of growth of earnings was 6.3 percent per year, whereas fringes and benefits grew at a compound rate of 13.4 percent annually. In 1969, fringes and benefits represented about 24 percent of direct labor earnings and by 1975 they reached 35 percent of earnings.

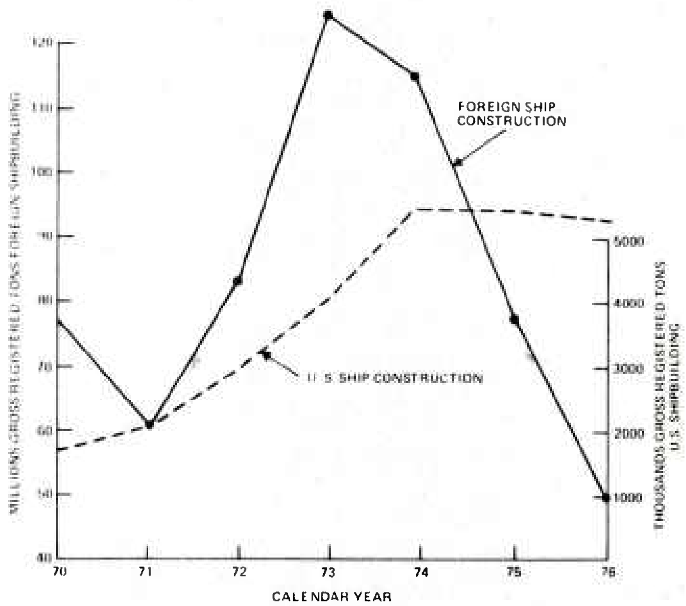
As in all industrialized countries, the fringes and social benefits will continue to increase and represent large percentages of direct labor earnings. Most of the causes for these increases are beyond the control of the shipyards.

(3) The Serious Effects Of International Inflation Are Complicated By Serious Disruptions Caused By Changes In Supply And Demand

Since the energy crisis of 1974, worldwide demand for shipbuilding has declined drastically as Figure II.2 indicates. The backlog of shipbuilding in foreign shipyards fell from an all time high of 124,833,000 gross registered tons in the fourth quarter of 1972 to 50,660,000 tons in the corresponding quarter of 1976 -- a decline of almost 60 percent.

FIGURE II.2

BACKLOG OF UNDELIVERED SHIPS ON ORDER AT THE END OF EACH CALENDAR YEAR



The result is a great deal of introspection at high government levels as to the best future course for their country's shipbuilding industry. Sweden, for example, is planning a phased reduction in the commercial shipbuilding market. Other countries have established shipbuilding commissions to study alternatives for the future. Individual shipyards are diversifying into other product areas -- and/or shifting their building activities to countries with lower labor costs.

The impact of cost escalation and the effect of market demand on end prices is demonstrated by the trend in Japanese shipbuilding prices for a 60,000 DWT "Panamax" tanker. As shown in Table II.8, the cost of this ship rose from $125/DWT in 1968 to $375/DWT in 1975 -- an increase of 200 percent over eight years. This situation is caused by underlying increases that took place in the cost of construction and changes in currency exchange rates. In 1976, however, cost dropped to $300/DWT which reflects the state of the shipbuilding market. Demand fell off sharply and Japanese yards began to scramble for business -- driving end prices down.

TABLE II.8

TRENDS IN JAPANESE SHIPBUILDING PRICES
(Dollars per DWT)

Year	$/DWT	Year	$/DWT
1968	125	1973	225
1969	150	1974	325
1970	185	1975	375
1971	175	1976	300
1972	175		

(4) Workload In U. S. Shipyards Has Fluctuated Considerably Over The Past Decade

While not always evident on a broad national basis, individual shipyards or regional shipbuiliding centers experienced yearly workload adjustments due to an inability to acquire an orderly flow of contracts. This is best reflected by Table II.9 showing average shipyard employment over the 1966-1976 period in each of the five U. S. shipbuilding regions. In 1976, there was an increase in employment of 8.6 percent over the 1975 average. This is the greatest annual increase during the past several years and due, largely, to the accelerated naval program. Naval shipyard employment during 1976, by comparison, averaged 67,500 workers, down from 85,400 workers in 1966.

TABLE II.9

AVERAGE PRIVATE SHIPYARD EMPLOYMENT 1966-1976
(in thousands)

Year	Total	North Atlantic	South Atlantic	Gulf	Pacific	Great Lakes & Inland
1966	143.6	52.6	24.8	35.6	20.7	9.9
1967	140.0	48.4	26.1	34.8	20.7	10.0
1968	141.0	46.2	27.0	36.5	22.4	8.9
1969	142.0	45.8	26.0	37.6	25.2	7.4
1970	132.7	43.6	23.2	38.8	20.3	7.6
1971	130.6	40.4	23.3	43.2	16.4	7.3
1972	138.1	39.3	28.9	46.6	15.7	7.6
1973	143.9	39.5	29.8	48.7	16.9	8.9
1974	154.9	44.7	27.7	48.9	22.8	9.7
1975	153.6	49.2	25.4	45.0	24.9	9.2
1976	166.8	56.9	26.5	45.2	26.6	11.6

SOURCE: Shipbuilder's Council of America, Statistical Quarterly, First Quarter 1977

Work fluctuations and uneven work force requirements are especially evident when comparing yearly employment in each region. Lay-offs are disastrous since only limited numbers of workers are induced to return to an industry where skills are necessary and when higher wages in the construction industry are usually achievable.

A high turnover rate is also an important component of the general labor problem in shipbuilding. During the past ten years, it averaged 15.4 percent monthly and during 1976,12.5 percent monthly. This may be compared to the much lower 1976 monthly turnover rate of 7.7 percent in manufacturing generally.

In the U. S., the shipbuilding order book has grown to a record level as also shown in Table II.10. The value of unfinished work has grown from $2.3 billion in 1967 to $9.7 billion in 1977.

TABLE II. 10

MERCHANT AND NAVAL VESSELS
BUILDING OR ON ORDER IN PRIVATE U. S. SHIPYARDS

Ships of 1,000 Gross Tons and Larger
(As of January 1, 1977)
(Dollars in Millions)

Year	Merchant Vessels Value of Unfinished Work	Naval Vessels Value of Unfinished Work	Total Value of Unfinished Work
1967	$ 543	$1,751	$2,294
1968	788	1,649	2,437
1969	800	1,700	2,500
1970	765	1,719	2,484
1971	765	1,925	2,690
1972	1,058	2,225	3,283
1973	2,950	3,160	6,110
1974	3,770	3,603	7,373
1975	4,350	5,424	9,774
1976	3,400	6,500	9,900
1977	2,930	6,802	9,732

SOURCE: Shipbuilders Council of America

The Merchant Marine Act of 1970 stimulated construction of large commercial ships which peaked at over four billion dollars of unfinished work in 1975. Since 1976, however, shipyards have been working off their commercial backlogs. Some yards have acquired naval work as a supplement and will continue to do so since naval ship acquisition has been rapidly increasing. In 1977, naval work represented more than twice the value of existing unfinished commercial work. Enactment of a cargo preference law will result in contracts for some additional U. S. flag merchant tonnage and shipyards are presently discussing this possibility with potential ship purchasers. Only limited pressure on U. S. shipbuilding facilities and labor should result in the near term however.

It is estimated that the U. S. shipbuilding and repair industry has recently been completing work valued annually at about $5.2 to $5.8 billion. About $3.3 to $3.6 billion represents naval and commercial ships with the difference comprised of repair, barge construction, oil rig construction, etc. On this basis, the shipbuilding industry is estimated to have an average of about two and one-half to three years shipbuilding backlog, much of which represents naval ships. Orderly planning and utilization of skilled labor and facilities dictates that shipyards should have new contracts about one and one-half to two years prior to completion of their backlogs. This will vary somewhat depending on shipyard facilities, type of ships and labor force. The Maritime Administration indicates that several major yards need to build up their backlog immediately and Figure II.3 so indicates.

3. A NOTABLE REDUCTION IN SHIPYARD PRODUCTIVITY HAS ACCOMPANIED THESE CHANGES IN ECONOMIC AND MARKET CONDITIONS

A special survey of 14 organizations, including seven U. S. shipyards, has been made during this study in order to identify and analyze factors affecting shipyard productivity. Participants gave opinions on the importance of a number of factors. The five on which a consensus existed are indicated in Table II.11 along with those on which no consensus could be found.

TABLE II.11

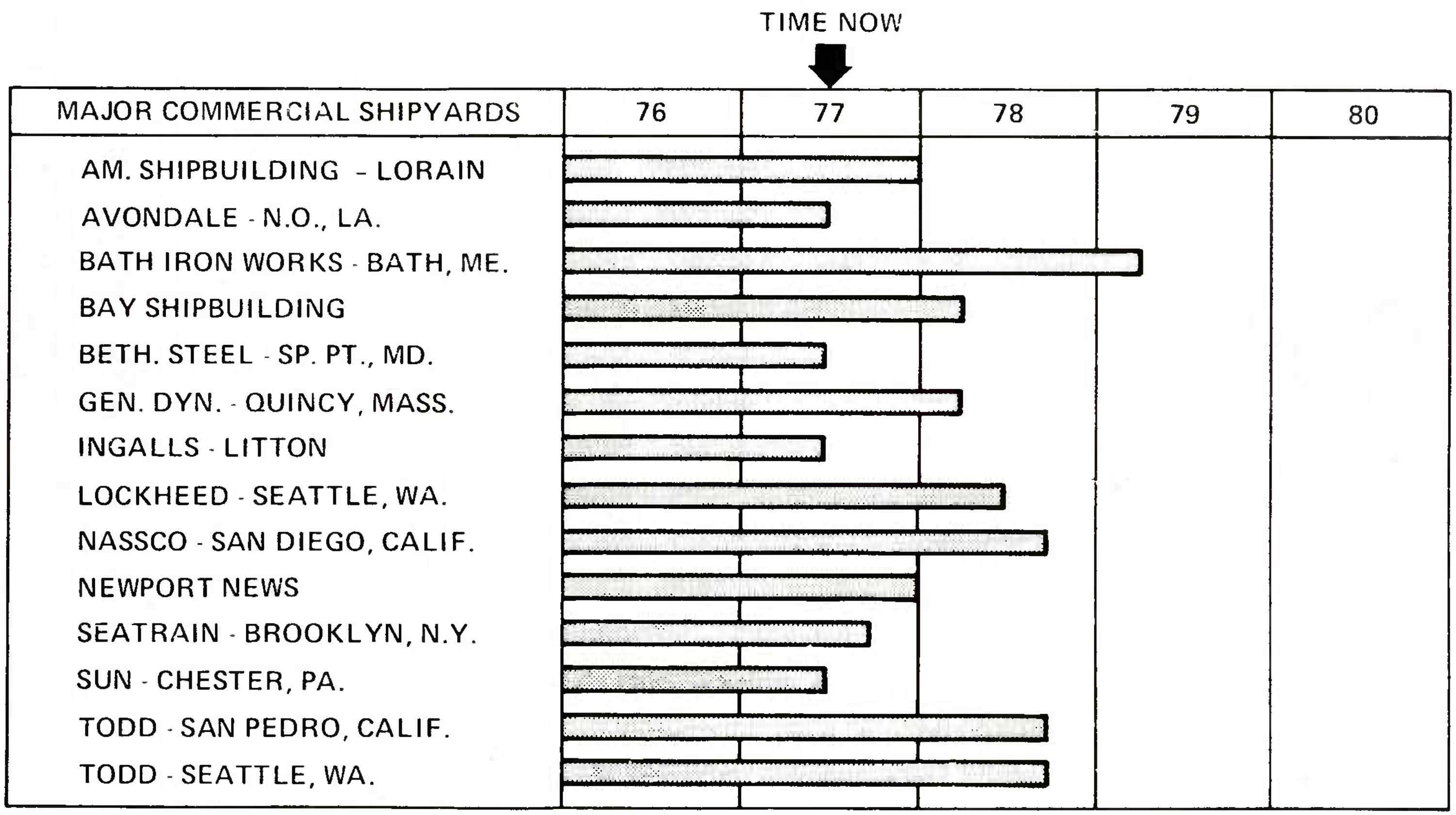
SUMMARY OF SURVEY ON SHIPYARD PRODUCTIVITY

Factors Affecting Productivity	Number of Participants	Rank and/or Range	Degree of Consensus
Stability of Operations/ Labor Availability & Turnover	14	1	High
Navy Considerations*	14	2	High
Learning	14	3	High
Social Legislation	14	4	High
Labor Agreements	14	5	High
Automation & Mechanization	14		Low
Shipyards' Engineering	14		Low
Training Programs	14		Low
Increased Complexity	14		Low
Shipbuilding Market	7		Low
Inflationary Trends	6		Low
Other Economic Trends	7		Low

* Includes contract administration, changes under contract, inspection and plan approval, quality control, GFM and GFI, delays, complexity.

FIGURE II.3

SHIPYARD STATUS: NEED FOR NEW BUSINESS
U.S. DEPARTMENT OF COMMERCE
MARITIME ADMINISTRATION



END OF BAR INDICATES WHEN YARD NEEDS NEW CONTRACTS IN ORDER TO MAINTAIN ADEQUATE BACKLOG FOR AVAILABLE FACILITIES AND MANPOWER. ASSUME 8 MONTH ADMINISTRATIVE AND PRE-FAB TIME (LEAD TIME BEFORE KEEL LAYING).

A sample of opinion relating to some of the major factors indicated that their impact on productivity is as follows:

- Loss of stability -- Productivity of new untrained employees will be 50 percent of established employees for one to two years depending on craft. In the case of employee expansion, losses of five to ten percent in productivity appear possible.

- Automation and mechanization -- Initial effects on productivity are adverse because of start-up problems. Subsequently, savings are produced, but in a relatively small part of the operation -- particularly on naval ships.

- Engineering capability -- A lack of such capability may cause losses of direct labor productivity between 5 to 15 percent.

- Training programs -- Losses of about five percent in productivity of the existing work force may occur because of the need for additional supervision and interference of on-the-job trainees.

- Increased complexity of ships -- Some losses in productivity, probably up to five percent, will almost certainly occur and could extend to 15 percent if major and complex design features other than weapons are included in a new ship. Loss of productivity for complexity of weapons cannot be evaluated for the possible variations in this factor, but the work involved in their installation cannot be performed at levels of productivity on similar work for other systems.

- Special Navy considerations -- Contract administration, inspection, plan approval, quality control, GFE and GFI, if working well will require one to three percent of the total yard force. If they are not operating well, losses in productivity of five to ten percent can occur.

These views on productivity apply generally to foreign as well as U. S. shipyards, However, some are particularly important in U. S. shipbuilding -- such as stability of operations, labor availability and turnover, learning (series production), social legislation, training programs, labor agreements and special Navy considerations.

4. SOCIAL LEGISLATION ENACTED OVER THE LAST DECADE HAS HAD GREAT IMPACT ON INDUSTRIAL CAPABILITY

Since 1965 more social legislation has been enacted which impacts on shipbuilding costs than in the previous thirty years. In the period from 1935 to 1965 the most significant socially-oriented legislation having an impact on labor cost and productivity were the Social Security Act, Workman's Compensation, FICA, Unemployment Compensation and the Taft Hartley Act.

During this earlier period, social benefits grew rather gradually and negotiated incremental cost from union contract to contract was small and usually predictable. Since 1970, however, the industry has begun to experience cost growth in these areas at a more accelerated rate due primarily to inflation and a tendency for more liberal settlements. Additional costs -- some visible, some hidden -- have been experienced, however, due to the passage of eight significant legislative acts.

- The Clean Air Act -- Environmental Protection Agency, December 1970

- Federal Water Pollution Control Act -- June 1970
- Clean Air Amendments of 1970 -- Public Law 91-604, December 31, 1970
- Noise Control Act of 1972 -- Public Law 92-574, October 27, 1972
- Coastal Zone Management Act of 1972 -- Public Law 92-583, October 27, 1972
- Marine Protection, Research and Sanctuaries Act of 1972 -- Public Law 92-532, October 23, 1972
- Occupational Safety and Health Act of 1970 -- April 28, 1971
- Longshoremen's and Harbor Workers' Compensation Act (LHWCA) Amendments -- Public Law 92-576, November 27, 1972
- EEO Legislation -- various dates

All of these acts have affected the shipbuilding industry but those that feature most prominently have been the Longshoremen's and Harbor Workers' Compensation Act Amendments, the Occupational Safety and Health Act, Environmental Protection Acts, and Equal Employment Opportunity Acts.

(1) The Longshoremen's And Harbor Workers' Compensation Act Now Applies To All Shipyards And Has Caused Certain Costs To Triple Between 1972 And 1975

According to a Newport News press release of August 3, 1976 their cost for Workmen's Compensation which is now covered by the act tripled from 1972 to 1975. For 1976, 25 percent more was expected. In predicting costs for 1980, the firm predicts costs of

$7,000,000 or a 1,600 percent increase in eight years.

The Commission on American Shipbuilding has produced the most authoritative study done on this subject (February 1973). Their appraisal of the impact on shipyards reads as follows:

> "The shipyards responding to a survey aimed at determining the additional cost of the increased benefits provided by the Amended Act per $100.00 of payroll indicated that current additional expense would be $4.20 and prospectively $7.22. Relating these costs to the base labor rate of $4.41 per hour as developed by the Bureau of Labor Statistics for shipbuilding and ship repair work as of September 1972, the current increase in the hourly billing rate would be $.185 and prospectively $.313. Assuming an hourly billing rate of $10.00, the percentage increases would be 1.85 percent and 3.13 percent."

The most recent estimates from the Shipbuilders Council of America are approaching 3.56 percent.

In Congressional testimony on September 26, 1977 the President of Lockheed Shipbuilding and Construction Company stated that for full Workmen's Compensation insurance the rate for the year April 1976-1977 was quoted at $25.00 per $100.00 of payroll cost. This was a 227 percent increase over the previous year.

Table II.12 shows growth in Department of the Navy outlays for Workmen's Compensation between 1962 and 1976.

TABLE II. 12

DEPARTMENT OF NAVY WORKMEN'S COMPENSATION COSTS
(Dollars in Millions)

Year	Cost	Year	Cost
1962	1.8	1970	14.6
1963	3.1	1971	21.0
1964	4.4	1972	30.3
1965	5.8	1973	30.1
1966	6.6	1974	40.3
1967	7.6	1975	60.8
1968	8.2	1976	82.9
1969	11.1		

Obviously, then, the affect this legislation has on industry is to greatly add to overhead and administrative expense. Firms are concerned as to the eventual affect on corporate financial statements.

(2) The Occupational Safety And Health Act Of 1970 Is One Of Nations Most Important Pieces Of Legislation From A Regulation Point Of View

The Occupational Safety and Health Act of 1970 went into effect on April 28, 1971 and it established the Occupational Safety and Health Administration (OSHA) within the Department of Labor. OSHA is empowered to set safety and health standards for just about every non-governmental employer; the only exceptions are employers already covered by another Federal safety program, small employers and businesses operated solely by members of a family.

OSHA is empowered to regulate such items as areas with dangerous atmosphere, surface preparation and preservation, welding, cutting and heating activities, material handling, etc.

An early survey in September 1972 by the National Association of Manufacturers indicates the initial (one-time expense) impact of compliance with known OSHA requirements to be of the following order of magnitude.

TABLE II. 13

PREDICTED IMPACT OF OSHA
ALL INDUSTRIES

Company Size (Number of Employees)	Estimated Expense (Weighted Average)
1 - 100	$ 33,000
101 - 500	104,000
501 - 1,000	212,000
1,001 - 2,000	372,000
2,001 - 5,000	863,000
Over 5,000	7,146,000

The impact of OSHA on the shipbuilding industry in not unlike industry in general. Shipbuilders' compliance costs to date have been for the purchase of protective equipment coupled with the replacement of tools, ladders, scaffolding and machinery/equipment components which do not meet the OSHA Standards. In shipbuilding, three areas are most affected: tool standards, noise standards and housekeeping.

- An example of tool expense to meet standards was the modification of hand chipping hammers. The reported cost to one shipyard was $295,000 for one-time costs and a 50 percent loss in productivity over the long term.

- The OSHA noise regulations are brief, but far-reaching. Basically, there are two sections: the first sets maximum levels of industrial noise to which an employee may be exposed; the second explains what action the employer must take if these levels are exceeded.

The Navy has reviewed the impact of OSHA requirements on the eight naval shipyards and estimated that $239.3 million per year would be needed to meet their interpretation of current OSHA regulations.

TABLE II.14

ESTIMATED OSHA EXPENDITURES

By Yard	Million $	By Category	Million $
Portsmouth	11.8	Serious	61.9
Philadelphia	82.4	Non-Serious	173.2
Norfolk	54.4	Minimal	4.2
Charleston	39.4		239.3
Long Beach	6.1		
Mare Island	23.0		
Puget Sound	17.7		
Pearl Harbor	4.5		
	239.3		

Considering the impact created with 67,500 naval shipyard employees amounting to over $3,500 per employee, concern has been expressed as to the ultimate impact of OSHA requirements.

(3) Environmental Legislation Has Had A Significant Impact On The Shipbuilding Industry

No assessment of the United States shipbuilding industry would be complete or conclusive without putting into perspective the economic impacts of pollution abatement and other environmental requirements on the shipbuilding industry's activities. A shipyard facility is an integrated industrial, waterfront complex and unique in that it is usually subject to the overlapping authority and actions of agencies within Federal, state and local governments with respect to pollution abatement and environmental concerns.

Data shown in Table II.15 was prepared by the Commission on American Shipbuilding and represents what 34 installations are or will experience financially and operationally due to environmental considerations. The facilities owned and operated by the responders represent 79 percent of the major shipyards in the United States. The current and projected increases in overhead, hourly production cost billing rates, etc., are significant and have considerable impact on the industry.

TABLE II.15

PREDICTED EFFECTS OF ENVIRONMENTAL LEGISLATION

		Low	High	Average
Overhead - Est. Percentage of Change	Current Prospective	+.2 +.3	+50 +53	+4.2 +7.1
Hourly Production Cost - Est. Percentage of Change	Current Prospective	- 2 - 7	+28 +30	+3.2 +5.4
Hourly Billing Rate - Est. Assigned Cost ($)	Current Prospective	+.01 +.01	+1.38 +1.72	+.19 +.54
Facilities Improvement - Est. Additional Costs Expended ($)	Industry	0	100	20
Specific Maintenance - Est. Additional Cost Incurred (%)		0	75	12.6
Additional Man-Days Expended for Environmental Matters		0	6,525	1,378

(4) Since 1969, Minority Employment In Shipbuilding Has Increased By 62.5 Percent As Compared To 1.3 Percent For Other Groups

Equal Employment Opportunity legislation has promoted the employment and advancement of racial minorities, women and the handicapped and has affected shipyards in terms of productivity loss due to necessary training requirements and a lowering of moral among experienced non-minorities because of real or imagined loss of advancement opportunities -- or simple prejudice. To our knowledge, no serious or published effort has been made to quantify this effect in the shipbuilding industry.

An analysis of the records of the Office of Civil Rights of the U.S. Maritime Administration shows that advances have been made in promoting minority employment in the shipbuilding industry. Since 1969, employment has grown about 13 percent, representing 14,969 jobs. Of this growth, 13,703 went to minorities and 1,266 went to non-minorities. This represents a 62.5 percent increase in minority employment (from 21,918 to 35,627) and 1.3 percent growth for non-minorities (from 89,529 to 90,795).

The growth of minority employment at Newport News, for example, as a percent of total employment is shown on Figure II.4. Minorities now occupy 36.2 percent of all jobs as of January 1977 compared to 27.5 percent in 1969.

FIGURE II.4

MINORITY EMPLOYMENT CHANGE AS A % OF TOTAL WORK FORCE AT NEWPORT NEWS

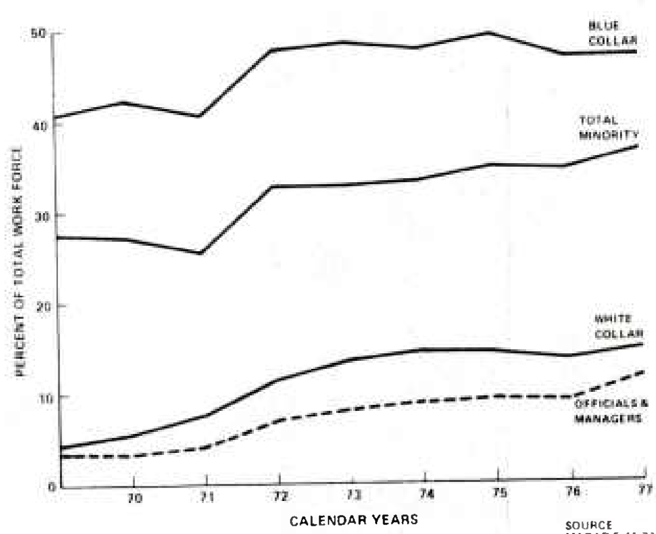
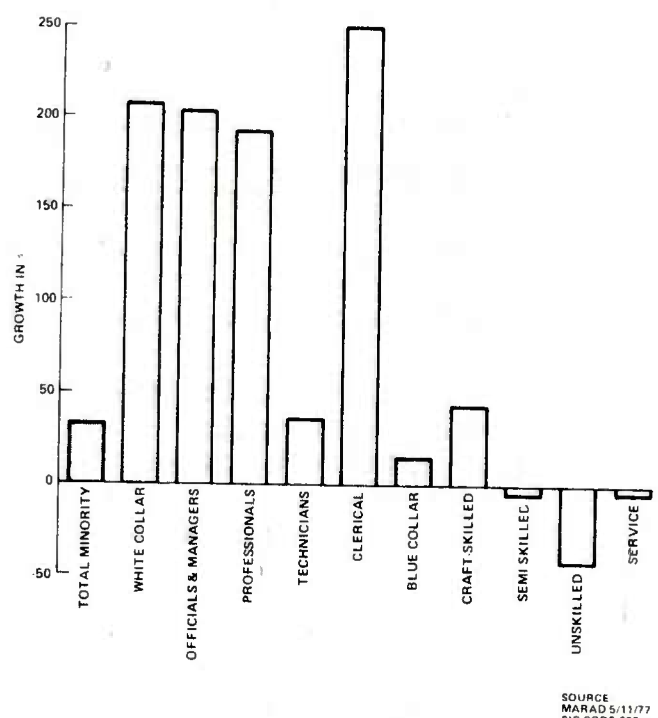


Figure II.5 illustrates the percentage increase of minority employment in various categories and emphasizes the trend to white collar employment and a shift in the blue collar trades from unskilled and semi-skilled to skilled categories. The increase in skilled crafts such as welders, shipfitters, machinists, etc., has been 43.3 percent.

FIGURE II.5

MINORITY EMPLOYMENT GROWTH IN % FROM 1969 TO 1977 NEWPORT NEWS



(5) <u>The Overall Impact Of Social Legislation During The Last Ten Years Is Believed To Be Substantial</u>

A review of published data on the impact of social legislation upon shipyards indicates that no recent overall evaluation has been made. The study on this subject made for the Commission on American Shipbuilding in 1973 remains the latest overall analysis on the subject.

The shipyards visited during the course of this study point to a substantial increase in overhead costs and decline in productivity as reflecting the long term price being paid for these social improvements.

5. COST ESTIMATING DIFFICULTIES HAVE BEEN EXPERIENCED BY SHIPBUILDERS AROUND THE WORLD DUE TO THESE UNPREDICTABLE BASIC INDUSTRIAL CHANGES

It has been mentioned that labor and material costs in ship construction have been increasing significantly over the past decade. More important to this study, however, is that the rate of cost growth has not been at all consistent. Many shipbuilders throughout the world have experienced the consequences of trying to make accurate cost projections in a period of erratic shifts in cost factors.

(1) The Relatively Consistent Growth In Labor And Material Costs In The 1960's Has Been Replaced By An Erratic Pattern Over The Past Five Years

Labor and material cost in the major shipbuilding countries tended to exhibit fairly consistent growth patterns between 1966-1972. There are exceptions, of course, but a review of Tables II.3 and II.7

indicates that a relatively predictable, consistent pattern of increase existed during this period.

Between 1972 through 1974 both material and labor costs took a big jump in all shipbuilding countries. Japanese labor costs, for example, increased $1.24 per hour during this period -- an increase of 62 percent. Material costs in Japan (as reflected by the Wholesale Industrial Price Index) increased over 47 percent during the same period. Increases of a similar nature were experienced by European builders.

(2) The Erratic Pattern In Labor And Material Costs Has Created Estimating Problems In Japan

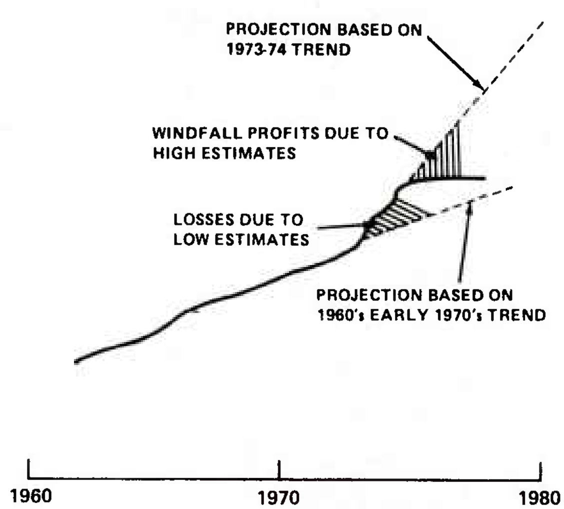
According to a senior cost estimating official at Kawasaki Heavy Industries, estimates made by Kawasaki prior to 1973 "were generally within two to three percent of the final price". But the unexpected rise in labor and material costs in the period immediately following the "oil shock" resulted in estimates "20 percent under the final delivered price". According to this official they had estimated escalation of material at eight to ten percent annually -- whereas actual experience was a sudden increase of 30 percent in a one year period following the "oil shock".

Then the situation reversed itself. In an attempt to take the more rapid factor cost increases into account, the firm "has over-estimated recent ships by 10-12 percent". They had not anticipated the sudden leveling-off in both labor and material costs. The situation experienced by Kawasaki is graphically shown in Figure II.6.

As a result of this more erratic pattern, Kawasaki now makes a thorough in-house review of economic trends every three months and this is the basis of cost projections for estimating purposes. Previously, it was considered adequate to update the economic review once a year.

FIGURE II.6

ESTIMATING EXPERIENCE (MAJOR JAPANESE SHIPBUILDER)



SOURCE:
INTERVIEW WITH FIRM OFFICIAL

An official at Mitsubishi reports a similar experience encountered by his firm. The oil shock caused a 20-30 percent jump in actual costs -- whereas estimates were based on a much lower historical projection. This official indicated that the financial consequences of low estimates were muted by the fact that substantial profit margins had been included in estimates made in the period immediately preceding the oil shock. "Losses due to underestimates would have been much greater had the profit cushion not existed."

IHI, a major Japanese shipbuilder, reports in its 1975 Annual Report to Shareholders that:

> "A characteristic of our products is the considerable time lag elapsing between receipt of an order and delivery of the finished article. Thus, while deliveries made on orders received in past years bolstered our turnover, the resulting profits were squeezed down by the 23 percent rise in wholesale prices that came after the oil crisis, which inflated our production and operating costs beyond all expectations. As a result, net earnings decreased by 18.5 percent to ¥ 6,800 million.

Despite the fact that inaccurate cost estimating is currently generating windfall profits -- as the official at Kawasaki sums it up -- "cost estimating is now a big problem to Japanese builders". Their ability to predict future costs is much less than in earlier years.

(3) Unpredicted Increases In Labor And Material Costs Have Affected Original Cost Estimates In Other Countries

There are many examples in other shipbuilding countries where the cost of labor and material took an unexpected jump in 1973-1974. Perhaps a relevant example is that of the contract for six Mark 10 frigates ordered by the Brazilian Navy from Vosper Thornycraft in the United Kingdom. On the basis of a design proposed by Vosper Thornycraft, a contract was signed in September 1970 valued at about £ 100 million for six ships. According to a recent article, "the contract provided for adjustment to cover increases in the costs of labor and materials and these, together with subsequent changes in the specification have resulted in the present value of the contract being about £ 150 million."*

Another example is the 7800 GRT ferry, St. Columbia, ordered by British Rail from Aalborg Vaerft in Denmark. Original cost was estimated at £ 14 million but turned out to cost £ 19 million.*

(4) In The United States Shipbuilders Have Been Experiencing Great Difficulty In Accurately Estimating Costs -- For Ships Far Less Complex Than Naval Combatants

The relatively uncomplicated merchant shipbuilding programs

* Shipbuilding and Marine Engineering International, Jan./Feb. 1977.

in the United States have also resulted in shipyard overruns and losses, largely due to the yards' inability to project reasonable labor, material and overhead costs during the recent inflationary period. The numerous and continuing shipyard claims being made against owners demonstrate the effort being made to recoup losses through arbitration or the courts.

Review of shipyard data for manhours to complete relatively simple (i.e., compared with navy combatants) merchant ships indicates a considerable variance between estimated and actual hours. The variances (for ships of similar design) range from an underestimate of nine percent to 27 percent.

Dun's Review reported in mid-1974 on the impact of underestimated costs as follows:

> "Avondale had a tough year in 1973, points out Leopoldo Clemente, an analyst for Merrill Lynch, Pierce, Fenner and Smith, because they underestimated their costs. But all of these contracts have since been renegotiated and are now profitable."

> "Another Merrill Lynch analyst is bearish on General Dynamics shipbuilding operation. The overall history of their Quincy (Massachusetts) yard has been terrible, he points out. Their cost estimates were way off and neither their customers nor the government are willing to renegotiate the contracts. So the company now has a claim against the government for $200 million."*

* Dun's Review, May 1974. Underlining added.

6. PROBLEMS OF PRODUCTIVITY, OVER-CAPACITY, LABOR TURN-OVER AND COST ESCALATION WILL CONTINUE TO CHARACTERIZE THE SHIPBUILDING INDUSTRY OVER THE NEAR FUTURE

U. S. News and World Report (September 5, 1977) noted some of the problems facing the shipbuilding industry in the near future.

> "Shipbuilders everywhere are sighting gale warnings lasting into the 1980's. A crisis of overcapacity will buffet both shipyards and the international shipping business. So says a committee of the Paris-based Organization for Economic Cooperation and Development. Expect rough going at least until 1983. Other experts say debt-laden tankers will sink owners into bankruptcy."
>
> "The recovery of world trade in 1976 helped some, but not a lot...'Overtonnage' will be around for years. One reason: year after year, more ships keep sliding down the ways around the globe."
>
> "The world's merchant fleet increased by 10 percent in 1976, despite many order cancellations and the scrapping of old ships. At year-end, the surplus oil-shipping capacity alone was a staggering 60 to 70 million deadweight tons. This year, the oil-hauling fleet may add another eight percent, attaining a new peak of 360 million tons. And the capacity in dry-bulk carriers of medium size is expected to jump by 25 percent in two years -- far in excess of needs."
>
> "Government subsidies help prop up many of Europe's shipbuilders. But the order books for new vessels in some countries will be bare by the end of 1977. Meanwhile, the 'third world' and Communist Eastern Europe also battle for ship work."
>
> "Add it all up: an oversupply of ships, low demand for coal and iron ore for slow-paced steel mills, reduced calls for grain shipments. Experts say it means that profits in shipping may be elusive for a long time to come."

Inflationary trends, uncertain workloads, reduced productivity, shortage of skilled labor and high labor turnover can be expected to continue, and beyond that, the U. S. shipbuilding environment over the next ten years may be characterized as follows:

- Naval ship procurement is expected to remain at generally high levels over the next few years.
- Slackening commercial construction will provide additional facilities for building naval auxiliary ships -- and possibly combatant ships -- thus stimulating competition and relieving cost pressures.
- U. S. commercial ship demand in the immediate future will be less than during the banner 1974-1975 period and will consist of limited numbers of container ships, product tankers, smaller bulk carriers, specialized ships and major conversions.
- Enactment of cargo preference legislation, which appears imminent at a relatively low percentage of total shipping, will somewhat reduce availability of commercial yards for naval construction, and affect pricing conditions. Uncertainty related to the magnitude of the tanker program generated under a variety of cargo preference options may pose a problem for Navy estimators.
- The Administration's defense policy may place greater emphasis on smaller, conventionally powered ships which could broaden the present naval shipbuilding base.
- Demand for U. S. constructed naval ships for foreign delivery will continue at a moderate rate.
- Private shipyards will continue to be uncompetitive in the international commercial market except for highly specialized and innovative ships.
- Major shipyards will continue to depend upon Government naval and government-sponsored commercial programs as their shipbuilding base.

- The present rates of shipbuilding labor and material inflation are expected to continue and remain difficult to forecast.

- Availability of skilled labor will be a continuing problem, particularly if Federal policy entails stimulation of the construction industry.

7. <u>AS A MATTER OF BALANCE, IT MUST BE MENTIONED THAT SHIPBUILDING HAS NOT EXPERIENCED PROPORTIONATELY LARGER OVERRUNS THAN OTHER CIVIL AND MILITARY PROJECTS</u>

It has not been demonstrated that the greater complexities of naval ship construction have resulted in proportionately larger overruns than those in most major civil and other military acquisition programs in the United States. The relatively uncomplicated merchant shipbuilding programs in the United States have also resulted in shipyard overruns and losses, largely due to the yards' inability to project reasonable labor, material and overhead costs during the recent inflationary period and accurately predict productivity. The numerous and continuing shipyard claims being made against the owners demonstrate the effort being made to recoup losses through arbitration or the courts.

The General Accounting Office Report to Congress of January 18, 1977 referred to in the Introduction on the subject of "Financial Status of Major Acquisitions As Of June 30, 1976" indicates that 753 civil and military acquisitions checked had an original expected cost of $276 billion and are currently estimated to cost $452 billion or an average increase of 64 percent.

This compares to 43 percent overrun for all the current Department of Navy programs. An analysis of those agencies with acquisition programs of $1 billion or greater indicates the following anticipated increases over the baseline estimates:

TABLE II. 16

SELECTED GOVERNMENT DEPARTMENT OVERRUNS

Agency	Percent Increase
Appalachian Regional Commission	580
Department of Air Force	49
Department of Army	36
Department of Navy	43
Department of Army, Corps of Engineers	11
Bureau of Reclamation	72
National Park Service	27
Federal Highway Administration	160
Federal Railroad Administration	0
Urban Mass Transportation Administration	9
Energy Research and Development Administration	46
Environmental Protection Agency	37
National Aeronautics and Space Administration	24
Tennessee Valley Authority	36
Washington Metropolitan Area Transit Authority	121

The Report states:

"Unanticipated development difficulties, inflation, faulty planning, poor management and poor estimating will increase the costs of major acquisitions. Cost growth cannot always be prevented or anticipated, particularly when a project is in development and production extends over long periods."

III THE COST ESTIMATING AND ANALYSIS PROCESS

III THE COST ESTIMATING AND ANALYSIS PROCESS

Cost estimating in the Navy takes place in the context of two formal management systems. One is a Department of Defense resource allocation system called PPBS or the Planning, Programming and Budgeting System. The second is the Phased Acquisition Process in which end of phase review points are specified at key milestones for analysis of progress by the Defense Systems Acquisition Review Council. At various times during the operation of these processes, program cost estimates are made for planning, program review or budgeting purposes.

These management systems are an attempt to minimize uncertainties which affect management decisions. When cost estimates are used in the planning process, they are critical to providing defense management the ability to create a balanced, capable force structure within fiscal limitations authorized. Preparation of an estimate with that kind of accuracy, however, requires a stable program stream that allows time for preliminary development activity.

An interdependency exists, then, between the system and the estimate. Both must work in harmony for either to function correctly.

- First, to estimate accurately for future programs, planning must develop a relatively stable program -- not only for the short term, but up to five years out.

- Second, given a stable program, sufficient design and engineering activity must take place to allow a reasonable base for cost estimating.

- Third, estimators must use consistent and professional methods to provide accurate information for proper management decisions about program worth versus available resources.

1. <u>A HIGHLY COMPLEX SYSTEM FOR PLANNING AND FUNDING (PPBS) PROVIDES THE BASIC FRAMEWORK FOR PROGRAM DECISION MAKING WITHIN THE DEPARTMENT OF DEFENSE AND THE NAVY</u>

The cornerstone of DOD management over many years has been the Five Year Defense Plan. It is a history of past accomplishments, a record of current activities, and a forecast of future objectives.

PPBS is really an updating system for the Five Year Defense Plan and is directed toward funding of defense programs. It is used by DOD to organize its complex activities into an understandable procedure with orderly schedules, cost assumptions, and event documentation. It is a virtually continuous operation involving almost every defense component. In most general terms, it is a "proposal, review, approval/disapproval, restatement, send to higher authority" process. It serves to provide the necessary forums for weeding out weaker programs and promoting those worthy of eventual implementation.

(1) "Planning" Establishes Goals And Directions For A Five Year Time Period

Navy planning takes place on two levels.

- There is constant activity directed by the Joint Chiefs of Staff toward identifying possible need for new force structures by responding to intelligence and threat assessments in the light of national objectives, treaty obligations, current equipment inventories and apparent deficiencies.
- The Chief of Naval Operations (CNO) directs Navy five year planning. It is a continual process of determining fleet requirements, characteristics of desired ship types, inventory levels and the like.

This second level of planning is the most meaningful with regard to Navy acquisition and budget planning. As part of this planning, trade-off analyses are performed for potential ship designs, as are Life Cycle Cost and Design-To-Cost analyses.

These planning activities are carried on in the context of the Navy Five Year Defense Plan which contains fundamental information used by the Navy to tie together the diverse activities required to fulfill its charter. It describes what has been accomplished in programs during the past 15 years, what is happening currently, what can be expected in the short term future and what can reasonably be expected beyond the short term future. The program descriptions cover force structure requirements, manpower levels and funding in terms of total obligational authority. It is in the context of this document that planning for near and long terms, management decision-making for currently developing systems, force deployment and everyday problem solving is carried out.

At specified periods during each year, this planning is formalized and presented to higher level Defense management in a process called "programming".

(2) "Programming" Is The Translation Of Planning Direction Into Specific Programs Geared To Fiscal Realities

Programming activities for the five year plan extend over an 11 month period and begin with staff activities at the Systems Command level as part of the CNO Program Analysis Process. In early stages, potential programs for future years are proposed by means of briefing presentations prepared by Naval Operations mission and resource (platform and support) sponsors with staff assistance from appropriate Command personnel. The potential programs are reviewed during analysis sessions held by the CNO and result in the issuance of CNO Program Analysis Memoranda (CPAMs). These memoranda explore alternatives and courses of action available for inclusion in the Navy's program. During CPAM analysis, sponsors for competing solutions appear at hearings to discuss important program-related issues. Studies using the Resource Allocation Display cost model (a subset of the Five Year Defense Plan) are carried on concurrently with the CPAM process and assist in achieving the best mix of programs within anticipated funding levels. At the end of the CPAM hearings, a summary CPAM is drafted and approved by the CNO. He supplements the approved program draft with his initial fiscal guidance, the CNO Planning and Fiscal Guidance Memorandum.

The final stage of program development begins with a series of "exercises" to test out and firm up programs. Any adjustments necessary to weed out problems are made during these sessions where the sponsors review and define their programs. At the conclusion of the Sponsor Program Review, the CNO Executive Board resolves major problems and finalizes the Summary CPAM.

The Program Objectives Memorandum (POM) is the primary Navy program document and is submitted to the Office of the Secretary of Defense by the Secretary of the Navy. The CNO provides the Secretary of the Navy with the Summary CPAM together with the overall program rationale in his final CNO Program and Fiscal Guidance Memorandum. The Secretary of the Navy, after combining the Navy program with that of the Marine Corps, prepares and submits the total Navy Program Objectives Memorandum to the Secretary of Defense.

The POMs from each Service are part of a DOD review process -- Program Decision Analysis -- the purpose of which is to balance the service submitted programs and those of other DOD components to total available defense resources and settle, where appropriate, issues that arise during the programming process. These issue meetings and hearings are contained in Program Decision Memoranda issued by the Secretary of Defense which, along with the POM, are the definitive program documents. The so-called POM cycle is one of the major update triggers for the Five Year Defense Plan -- in May for POM data and in October to reflect PDMs.

Once the POM has been approved by top Navy management, the first year in that Five Year Plan becomes the basis for the Navy budget submission and budgeting activities begin.

(3) <u>"Budgeting" Is The Proposal Of DOD/Navy And The Executive Branch To The Congress For Funding Of Specific Programs</u>

Budgeting, in the most general sense, can be categorized into the following three activities.

- Budget Formulation -- DOD components (as with all other government organizations) prepare a budget for the first program year (or, in another perspective, the current funding year plus one). Budget formulation, as a procedure, refers to activities carried on to derive budget estimates from the approved program base and the the combining of these estimates into a viable proposal to the Congress. The controlling organization within the Navy for budget formulation is the Office of the Navy Comptroller (NAVCOMPT) -- the comptrollership function in the Office of the Secretary of the Navy. Budget guidance is issued by the Comptroller to all lower echelon Navy organizations which organize and submit the latest and best estimates of what the approved program will cost during the budget year. After review and approval cycles by Command executives, individual budgets are assembled by the Office of the Comptroller into the NAVCOMPT Budget Submission.

  DOD components send their budgets to OSD for a joint OSD/OMB review. Major budget issues are presented, debated and brought to decision. The decisions are documented as Program Budget Decisions. The approved Defense budget is sent to the President for review and approval; then, printed and sent to Congress.

- Congressional Review and Appropriation -- Review of the budget by Congress is carried on chiefly by three committees in each chamber -- Armed Services Committees, Appropriations Committees and Budget Committees of the House and Senate, respectively. Further coordinating activities are carried on by the Congressional Budget Office.

  The function of the Armed Services Committees and their sub-committees is to understand the rationale behind programs presented; approve or disapprove proposals; in cases of disapproval, suggest alternative actions; and, finally, set an upper funding limit for appropriation guidance. In support of Congressional review, senior DOD officials deliver posture statements which summarize past accomplishments, mention unsolved problems and state goals for the current and upcoming years. Beyond this, other Defense officials are called by the Committees as required to discuss specific issues in terms of programs and funding. Once hearings are concluded, reports are prepared and each chamber passes an authorization bill which specifies approved programs and limits on total obligational authority. Any differences between Senate and House bills are resolved by a committee of conference and an amended Authorization Act is passed.

The Appropriation Committees of both Houses meet to hear posture statements from senior financial officials such as Secretary of Treasury, Director of OMB, etc. Once the fiscal groundwork is laid, witnesses from individual Government departments and military services are called to justify their programs. Upon completion of the hearings, the sub-committees prepare bills for full committee amendment and/or adoption.

Appropriation bills are passed by each Chamber, a committee of conference resolves differences and the Appropriation Bill is submitted for enactment by the Congress. The President's signature completes the enactment process.

- Apportionment and Allocation -- During the formulation and appropriation process, budget items are proposed which are different than those finally approved. In the apportionment process, determination is made by OMB as to the amount of funds which can reasonably be expected in the appropriation process and how much can be obligated during specified periods throughout the budget year and over the several years of multiple year appropriations under full-funding of projects. This prevents overspending of established funding authority and provides for orderly use of appropriated funds between Government departments.

Apportionment defines funding authority to the level of a DOD component(such as DON). Allocation and sub-allocation are terms used to describe the passage of funding authority below 'component level' to CNO, CNM and below that to fleet and SYSCOM levels in preparation of operations budgets.

Figure III.1 which accompanies this description of PPBS illustrates the timing and complexity of these activities.

(4) Good Cost Estimates Are Critical To The Efficient Operation Of PPBS

The importance of accurate cost estimates cannot be overemphasized. This is particularly so as a program approaches the "Budget" phase. The credibility of the Navy in the eyes of Congress to estimate the cost of its programs and to maintain fiscal stability have become a problem when predicted costs are often found to be too low.

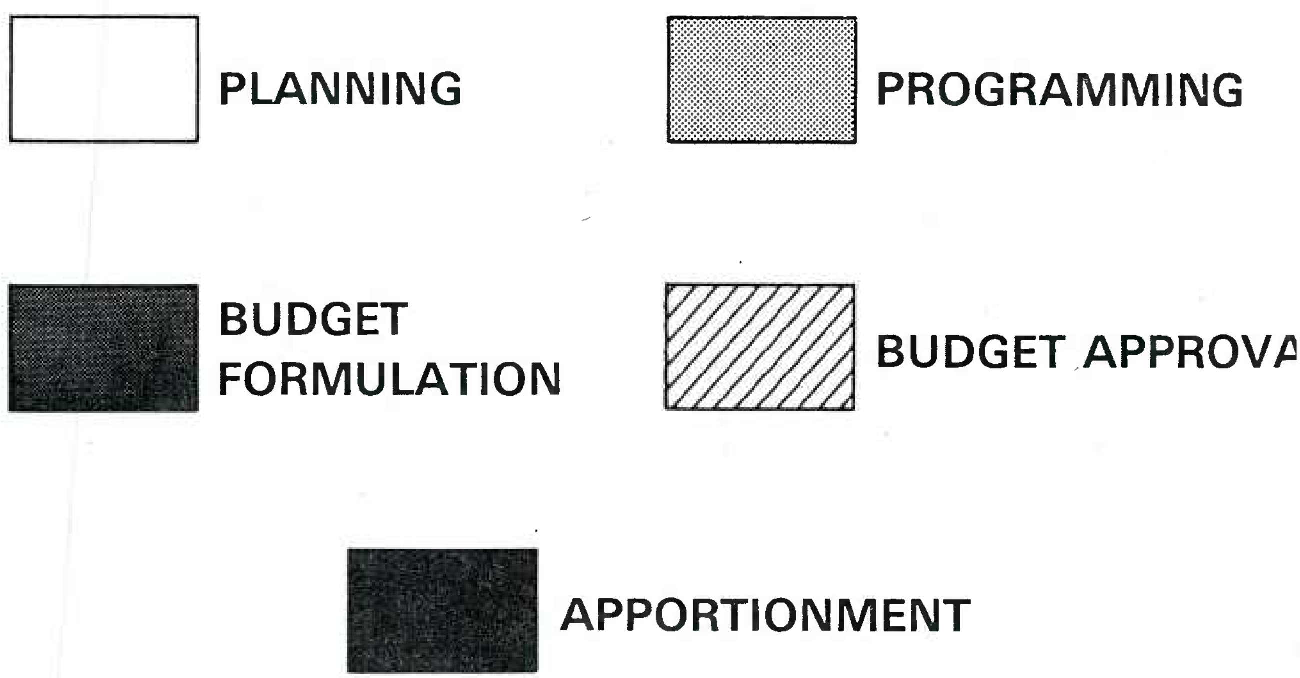
Since Congress has primary control over the resources of the nation, estimates prepared by the Navy and submitted as part of the annual program are given careful scrutiny. PPBS was designed to give Navy decision-makers every opportunity to submit estimates which the Congress could consider as reliable.

PPBS controls the DOD/Navy organizations and processes by assuring that the following takes place:

FIGURE III.1

THE DOD/NAVY PLANNING, PROGRAMMING AND BUDGETING SYSTEM

SINGLE CYCLE FORMAT



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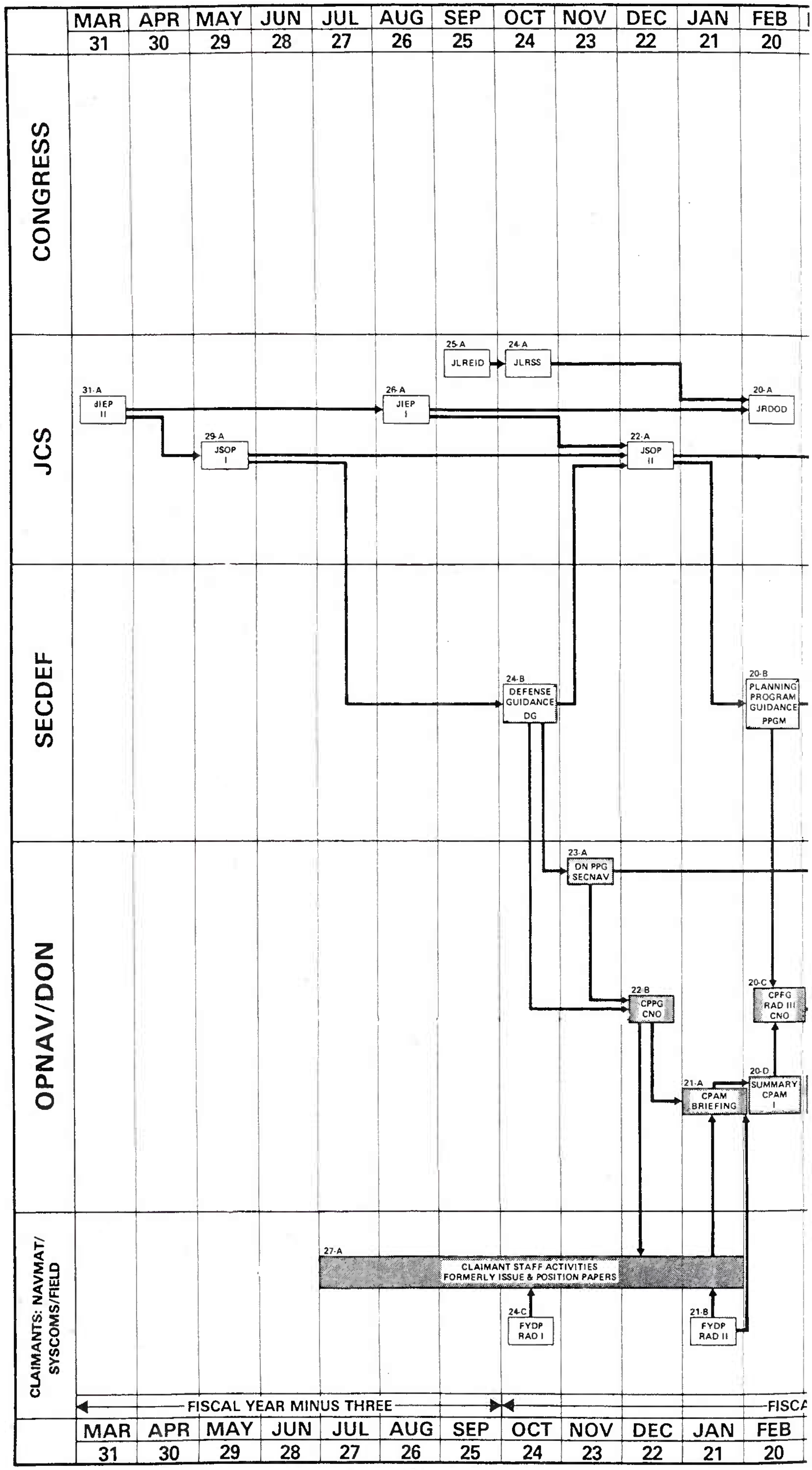

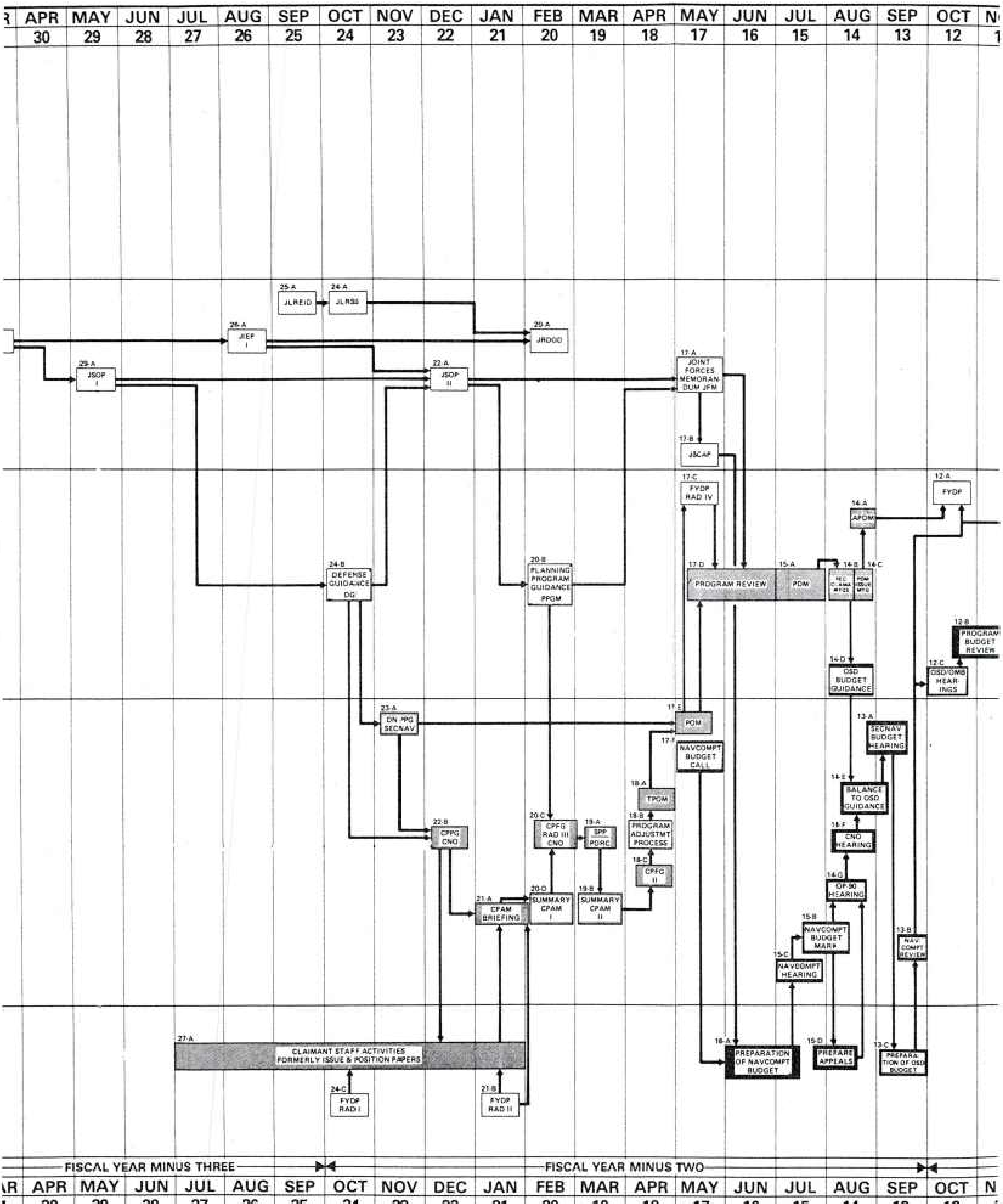

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25-A JLREID
24-A JLRSS
26-A JIEP I
20-A JRDOD
29-A JSOP I
22-A JSOP II
17-A JOINT FORCES MEMORANDUM JFM
17-B JSCAP
17-C FYDP RAD IV
12-A FYDP
14-A APOM
24-B DEFENSE GUIDANCE DG
20-B PLANNING PROGRAM GUIDANCE PPGM
17-D PROGRAM REVIEW
15-A POM
14-B
14-C
12-B PROGRAM BUDGET REVIEW
14-D OSD BUDGET GUIDANCE
12-C OSD/OMB HEARINGS
23-A DN PPG SECNAV
17-E POM
17-F NAVCOMPT BUDGET CALL
13-A SECNAV BUDGET HEARING
18-A TPGM
14-E BALANCE TO OSD GUIDANCE
22-B CPPG CNO
20-C CPFG RAD III CNO
19-A SPP PDRC
18-B PROGRAM ADJUSTMT PROCESS
14-F CNO HEARING
18-C CPFG II
14-G OP-90 HEARING
21-A CPAM BRIEFING
20-D SUMMARY CPAM I
19-B SUMMARY CPAM II
15-B NAVCOMPT BUDGET MARK
13-B NAV COMPT REVIEW
15-C NAVCOMPT HEARING
27-A CLAIMANT STAFF ACTIVITIES FORMERLY ISSUE & POSITION PAPERS
16-A PREPARATION OF NAVCOMPT BUDGET
15-D PREPARE APPEALS
13-C PREPARATION OF OSD BUDGET
24-C FYDP RAD I
21-B FYDP RAD II
FISCAL YEAR MINUS THREE
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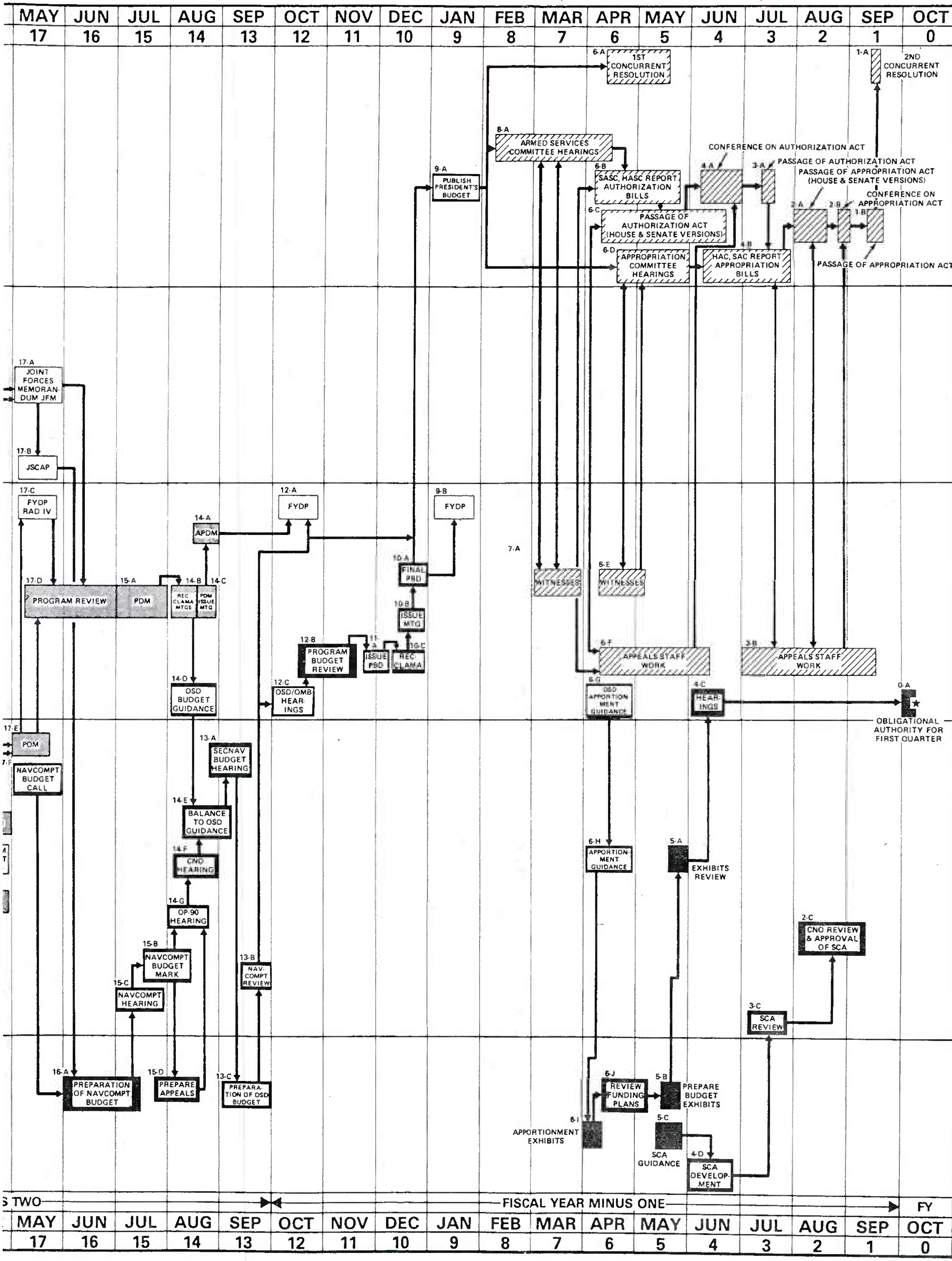

MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT
17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
6-A 1ST CONCURRENT RESOLUTION
1-A 2ND CONCURRENT RESOLUTION
8-A ARMED SERVICES COMMITTEE HEARINGS
CONFERENCE ON AUTHORIZATION ACT
PASSAGE OF AUTHORIZATION ACT
PASSAGE OF APPROPRIATION ACT (HOUSE & SENATE VERSIONS)
CONFERENCE ON APPROPRIATION ACT
9-A PUBLISH PRESIDENT'S BUDGET
6-B SASC, HASC REPORT AUTHORIZATION BILLS
4-A
3-A
2-A
2-B
1-B
6-C PASSAGE OF AUTHORIZATION ACT (HOUSE & SENATE VERSIONS)
6-D APPROPRIATION COMMITTEE HEARINGS
4-B HAC, SAC REPORT APPROPRIATION BILLS
PASSAGE OF APPROPRIATION ACT
17-A JOINT FORCES MEMORANDUM JFM
17-B JSCAP
17-C FYDP RAD IV
12-A FYDP
9-B FYDP
14-A APDM
7-A WITNESSES
6-E WITNESSES
10-A FINAL PBD
17-D PROGRAM REVIEW
15-A PDM
14-B REC CLAMA MTGS
14-C POM ISSUE MTG
10-B ISSUE MTG
12-B PROGRAM BUDGET REVIEW
11-A ISSUE PBD
10-C REC CLAMA
6-F APPEALS STAFF WORK
3-B APPEALS STAFF WORK
14-D OSD BUDGET GUIDANCE
12-C OSD/OMB HEARINGS
6-G OSD APPORTIONMENT GUIDANCE
4-C HEARINGS
0-A OBLIGATIONAL AUTHORITY FOR FIRST QUARTER
17-E POM
17-F NAVCOMPT BUDGET CALL
13-A SECNAV BUDGET HEARING
14-E BALANCE TO OSD GUIDANCE
14-F CNO HEARING
6-H APPORTIONMENT GUIDANCE
5-A EXHIBITS REVIEW
14-G OP-90 HEARING
2-C CNO REVIEW & APPROVAL OF SCA
15-B NAVCOMPT BUDGET MARK
13-B NAVCOMPT REVIEW
15-C NAVCOMPT HEARING
3-C SCA REVIEW
16-A PREPARATION OF NAVCOMPT BUDGET
15-D PREPARE APPEALS
13-C PREPARATION OF OSD BUDGET
6-J REVIEW FUNDING PLANS
5-B PREPARE BUDGET EXHIBITS
6-I APPORTIONMENT EXHIBITS
5-C SCA GUIDANCE
4-D SCA DEVELOPMENT
S TWO
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MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT
17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

- Planning to assure prudent risk-taking in developed force structures;
- Planning to optimize use of available resources;
- Program planning to present most feasible and timely development of systems;
- Programming of ships and weapons to optimize delivery and cost;
- Budget formulation which provides reasonably accurate funding estimates to carry out implementation of programs;
- Budget approval and appropriation procedures which guarantee full discussion of goals, implementation strategy and cost;
- Apportionment procedures to promote efficient cash flow for systems development within legal, budgeted constraints.

As with most systems, flawless operation is an ideal which seldom is reached. So with PPBS.

2. AS CURRENTLY EXECUTED, THE PLANNING, PROGRAMMING AND BUDGETING SYSTEM MAKES RELIABLE ESTIMATING DIFFICULT

The Planning, Programming and Budgeting System is an iterative process which, among other things, serves as the framework for developing and recording many of the decisions leading to approved shipbuilding programs. In practice, there are certain compromises which pit product quality and mix against the time and effort required for proper support -- including proper estimates.

From the viewpoint of ship program development, there are advantages in testing a large number of combinations of ship types and procurement profiles, keeping the five year program loose as long as possible. Also, there are advantages in considering ships for which concepts are not fully developed. Through this means, the possibility that the final program will be the best in terms of financial, strategic, tactical and technical balance is enhanced. Conversely, too many tests can overburden the organizations responsible for preparing supporting information for the many proposed programs and alternatives.

In the execution of the POM and budgeting processes, NAVSEA estimating capability is a vital input whether it be in support of ship concepts, alternative ship specifications and programs or the basic programming and budgeting documents. In this section, the impact of the programming effort on this estimating capability is tracked to see if the programming process, as presently executed, contributes to the often significant differences between initial and current estimates of cost.

(1) The Ship Classes In The First Programming Year, The POM And The Budget Year Vary Significantly

On a scheduled basis, NAVSEA is required to develop and update estimates for inclusion in the basic POM and budget documents. Two of these updates have particular significance, one because it becomes the budget year and programming or authorization year data in the President's budget and, the second, because it provides the cost estimates for the POM which initiates each budget cycle. As one test of the stability of the programs for which estimates are requested and, thus, as one measure of estimating workload, ship classes included in the FY 1974-1977 programs were compared. Specifically, the ship classes in the procurement annexes with the following pattern of dates were examined.

- For the FY 1974 program:
  - January 1972 -- first programming year (Authorization year)
  - April through May 1972 -- first year of POM
  - January 1973 -- budget year (President's budget)
  - July through December 1973 -- program approved by Congress
- For FYs 1975, 1976 and 1977 -- the same pattern of dates

In Table III.1, the program approved by Congress is used as the base and the number of ship classes estimated and approved versus estimated but not approved is noted.

TABLE III.1

SHIP CLASSES ESTIMATED BUT NOT APPROVED

	Total Ship Classes	Estimated and Approved	Estimated not Approved	% Hits
FY 1974				
Approved Program	7(1)	-	-	
Programming Year	7	3	4	43
POM	10	6	4	60
Budget Submission	7	6	1	86
FY 1975				
Approved Program	10(2)	-	-	
Programming Year	11	6	5	55
POM	10	6	4	60
Budget Submission	12	8	4	67
FY 1976				
Approved Program	6	-	-	
Programming Year	9	5	4	56
POM	10	6	4	60
Budget Submission	8	6	2	75
FY 1977				
Approved Program	7(1)	-	-	
Programming Year	9	5	4	56
POM	7	5	2	71
Budget Submission	7	6	1	86

( ) Approved by Congress but not included in the budget year column of the procurement annexes for the pertinent budget year.

The fact that only 43 percent to 56 percent of the ship classes included in the first programming year (first year beyond the budget year) were approved by the Congress when that year came up for consideration does raise some question as to the stability of near term programming and, incidently, to the usefulness of such information as planning input to shipbuilders. The programming improves to the point where 60 percent to 71 percent of the ship class programmed for the budget year in the POM are approved. This results largely from knowledge gained through Congressional hearings. Finally, the ship classes included in the President's budget have a good survival rate. It should be noted, however, that there is no assurance that the estimates for ships approved by Congress but not included in the procurement annexes are of budget quality. In fact, two of the four such ships indicated in Table III.1 have only class F "ballpark" estimates.

In summary, this analysis indicates that roughly one-half of the ships estimated for the first programming year and budget year gain Congressional approval. When viewed from the estimating effort required, this ratio appears reasonable. It is important to maintain the iterative nature of the process and, hopefully many of the ships not approved may be approved in the next year or two.

(2) <u>About One-Third Of The Ship Classes Appearing In The Procurement Annexes Supporting The President's Budget Are Approved</u>

In this analysis, every ship class appearing in any of the five years of the procurement annexes supporting the President's budgets for FYs 1974-1977 was counted. (This differs from the data in Table III.1 which includes data from only the budget and first programming year of the annexes). In all, 46 different ship classes, both new construction and conversion, are included in the annexes. Of this number, 16 ship classes or 35 percent were approved by Congress in one or more of the years in the Fiscal Year 1974-1977 programs.

The fact that the PPBS requires estimates for approximately three ship classes for every class approved by Congress must be recognized as an estimating workload factor, although it is noted that budget quality estimates are not needed in all instances. On the other hand, while less effort is required to prepare lower quality estimates, these poorer estimates do appear in the Navy Five Year Plan and may become the cause for criticism.

Again, this information must be of limited use to the shipbuilders because of the one-to-three ratio and the widely varying procurement profiles, year to year, for each of the ship classes.

(3) Procurement Profile Variations Impact On Estimating Workload

The procurement annexes dated in January for Fiscal Years 1972 through 1977 were reviewed to determine how widely the number of ships of a given class to be included in specific year programs vary from year to year. These procurement annexes support the President's budgets. The procurement profile for Fleet Oilers (AOs) is shown in the following table.

TABLE III.2

FLEET OILER (AO) PROCUREMENT PROFILE

Procurement Annex Date	1974	1975	1976	1977	1978
January 1972	-	2	3	3	-
January 1973	-	1	3	2	2
January 1974	-	1	3	3	2
January 1975	-	-	2*	2	2
January 1976	-	-	-	1*	1
January 1977	-	-	-	-	4

* Approved by Congress

This data shows the emergence and initial programming of a requirement followed by program changes resulting from changing priorities and other constraints. As indicated, this pattern is typical and is a part of the real world of ship cost estimating. The problems of estimating the baseline cost of a given ship are substantial and are dependent on such factors as estimates of inflation, shipyard and supporting industry, capacity to produce, efficiency of the producing shipyard and schedule adherence.

The real magnitude of the stability of programs, and estimating workload, becomes more apparent when the number of trial programs in a single year is considered. From April through December 1976, there were at least 15 different shipbuilding programs and alternates directed to NAVSEA for estimating and documentation in support of POM 78 and the FY 1978 budget. This is at a rate of nearly two per month. In the aggregate, these programs contained 24 ship classes. Thus, NAVSEA needed to have at the ready 24 individual ship building block estimates. Equally important, there was a total of 80 different procurement profiles, an average of more than three per ship class. As indicated, each of these required consideration of capacity, inflation rate, impact on other ships and similar factors. Moreover, this aspect of estimating requires very careful performance since the result is the end cost of the shipbuilding program, the amount to be appropriated.

(4) For The FY 1978 Budget Submission, NAVSEA Was Given Six Weeks To Complete All Ship Cost Estimates

The Program Objectives Memorandum (POM 79) guidance for SCN was dated 26 November 1976. In this memorandum the schedule for the development of ship estimates provided for the issuance of the final procurement plan in early December 1976 and completion of cost estimates by NAVSEA 01G, including documentation, by January 4, 1977.

The task assigned for this six week period involved the following:

- Preparing estimates involving 160 ships;
- 21 different designs were included;
- Estimates involved 15 designs that have never been previously awarded including four new designs;
- The total estimated cost -- $47 billion.

These requests are followed by numerous alternative programs of the same order of magnitude until a program is finally approved by Congress. The point being made is that this requirement is normal and requires an exceptional cost estimating organization to respond with any acceptable degree of reliability.

*   *   *   *   *

Program and budget estimates evolve as many ships and other items of government furnished material are acquired. Each of these systems follows a more or less standard system of procurement which is described next.

3. <u>THE ACQUISITION PROCESS, AS DIFFERENTIATED FROM THE FUNDING PROCESS, INVOLVES ALL STEPS FROM IDENTIFICATION OF REQUIREMENTS THROUGH DELIVERY OF THE SHIP</u>

There has been an evolution in the methods used to procure combatant ships over the years. Prior to 1966, one of the methods was that ships were "designed to requirements" by the Bureau of Ships. Design and engineering was carried on by the Navy with contracts being awarded generally after competitive bidding.

Around 1966, the idea that cost aberrations could be controlled by having the contractor build to his own design and engineering based on a performance specification caught on . This was known as Total Package Procurement and was utilized in two major ship programs between 1966 and 1972 -- the DD 963 class and the LHA 1 class.

In 1972, the Department of Defense and the Navy changed to the current phased process of acquisition. The process is an amalgam of systems and procedures for producing complex defense systems. The phases and a brief identification of specific procedures within each phase follow.

(1) The First Phase Of Acquisition Is The Origination Of The Ship Requirement

This is begun in the planning process carried on by the Joint Chiefs of Staff and followed up by the Chief of Naval Operations, his deputies and sponsors with specific proposals regarding ship types which will meet the envisioned threat.

(2) The Ship Requirement Is Then Validated By Issuing The Operational Requirement Document

The Office of the CNO (Force or Mission Sponsor) issues an Operational Requirement which sets forth the operational need and concept together with capabilities required including cost objectives. The CNO subsequently convenes the Ship Acquisition and Improvement Panel which, after a review of the requirement, appoints a Program Coordinating Committee to assist in preparing the Top Level Requirement (TLR) and Top Level Specification (TLS). A Ship Acquisition Project Manager (SHAPM) is appointed by the CNO or his delegate.

(3) Early Design And Acquisition Planning Take Place In The Concept Phase

Based on information in the Operational Requirement, the SHAPM prepares a Development Proposal for submission to CNO which proposes a specific approach to system development. This proposal eventually will be modified and updated to become a draft Decision Coordinating Paper (DCP). Having finished the Development Proposal, the SHAPM begins several activities intended to add substance to the system concept. These relate to preparation of outlines and preliminary reports for the Ship Acquisition Plan, Test and Evaluation Plan, Combat Systems Management Plan, Advance Procurement Plan, etc. The SHAPM also takes steps to activate the Ship Project Directive System which enables quasi-contractual arrangements to be made with other Systems Commands and technical organizations for ship design and for design, procurement or construction of Government Furnished Material (GFM).

Paralleling the SHAPM-directed activities is the work of the Program Coordinating Committee which develops the TLR and the TLS to reach a desired level of conceptual definition called a Conceptual Baseline.

At this point the DCP draft is updated to include information developed by the Program Coordinating Committee and the SHAPM, leading to the DNSARC and DSARC I proceedings. Assuming favorable response to system status, approval is granted to proceed with the Preliminary Design Phase.

(4) The Functional Requirements Are Determined During The Preliminary Design Phase

During this period, activities begun during the conceptual stage are continued from outline form to functional design level. An example is the completion of the Combat Systems Management Plan which allows creation of the Combat System Design Requirement and the Combat System Operational Requirement. These activities are begun after CNO freezes the military payload of the ship.

Two new activities which relate to eventual post-construction use of the ship are begun. The Tactical Operational Requirement is drafted along with the Integrated Logistics Support Plan.

The additional information and specifications worked up during this phase are reflected in an updated TLR/TLS which reaches, at this point, the level of Functional Baseline. As with the conclusion of other phases, the DCP is rewritten in draft form reflecting new levels of development and DSARC II clears the way for contract design, full-scale development.

(5) <u>All Remaining Activities Leading Up To Contract Award Are Completed During The Contract Design Phase</u>

Activities in this phase are oriented toward creation of a specification package on which contractors are capable of bidding and which will provide a base from which to negotiate a contract with a selected builder.

A new activity begun in this phase is the preparation of the Program Integration Plan which documents methods of tying weapons systems together with the required navagational, fire control and monitoring systems.

Increasing sophistication of ship specifications and confidence in program plans leads to the creation of the Contract Data Requirements List, Bid Specifications from the Allocated Baseline, Qualified Bidders lists and finally, the Request for Proposal.

The technical level of plans and specifications should allow, in this phase, cost estimates of C quality, scheduling estimates of fairly high reliability and evidence in final program reports that development is proceeding satisfactorily. Documents supporting this level of confidence are a final Ship Acquisition Plan, Combat System Design and Operational Requirements, Test and Evaluation Plan and Ship Logistics Management Plan. Also, during this phase, specific projects for Government Furnished Equipment are funded and design/construction started.

The DCP/DSARC III process signals the end of the Contract Design Phase.

(6) Detailed Design And Construction Of The Lead Ship Of A Class Follow Award Of The Contract

This phase begins with the issuance of RFP's to qualified bidders; continues with submission of proposals and selection of contractor; further, to development of working drawings by the contractor and construction of the lead ship. During construction, the SHAPM activities are oriented toward overall administration of the contract, including review and approval of changes. GFM is delivered to the contractor and integrated into the ship on a scheduled basis.

The activities during construction can be summarized in general terms as follows:

- Preparation of engineering specifications for procurement of Contractor Furnished Equipment
- Laying down of ship's lines -- detailed engineering drawings
- Purchase and receipt of materials, equipment and machinery
- Pre-keel period -- fabrication of hull sections.
- Keel laying
- Construction of hull up to and including deck houses, with simultaneous installation of major machinery, equipment and ship systems
- Launching and removal to outfitting area
- Post launch activities -- completion of contractor assigned work
- Dock trials
- Builder's sea trials
- INSURV trials -- acceptance trials

- Correction of deficiencies
- Delivery by contractor to Navy
- Commissioning and turnover of ship to fleet
- Completion of fitting-out
- Ready-for-sea period
- Shakedown cruise
- Post-shakedown period for correction of deficiencies

(7) <u>In The Final Acquisition Phase, Production Of Follow Ships Is Carried Out</u>

Not all programs go through lead ship construction prior to production of other ships in the same program. Often based on urgency of use, stability of specifications, etc., the production phase will preempt lead ship construction. However, if started somewhat ahead of the others, the lead ship in a program provides the opportunity to test and evaluate platform design and construction methods, with an eye toward correcting any deficiencies or inefficiencies in future construction.

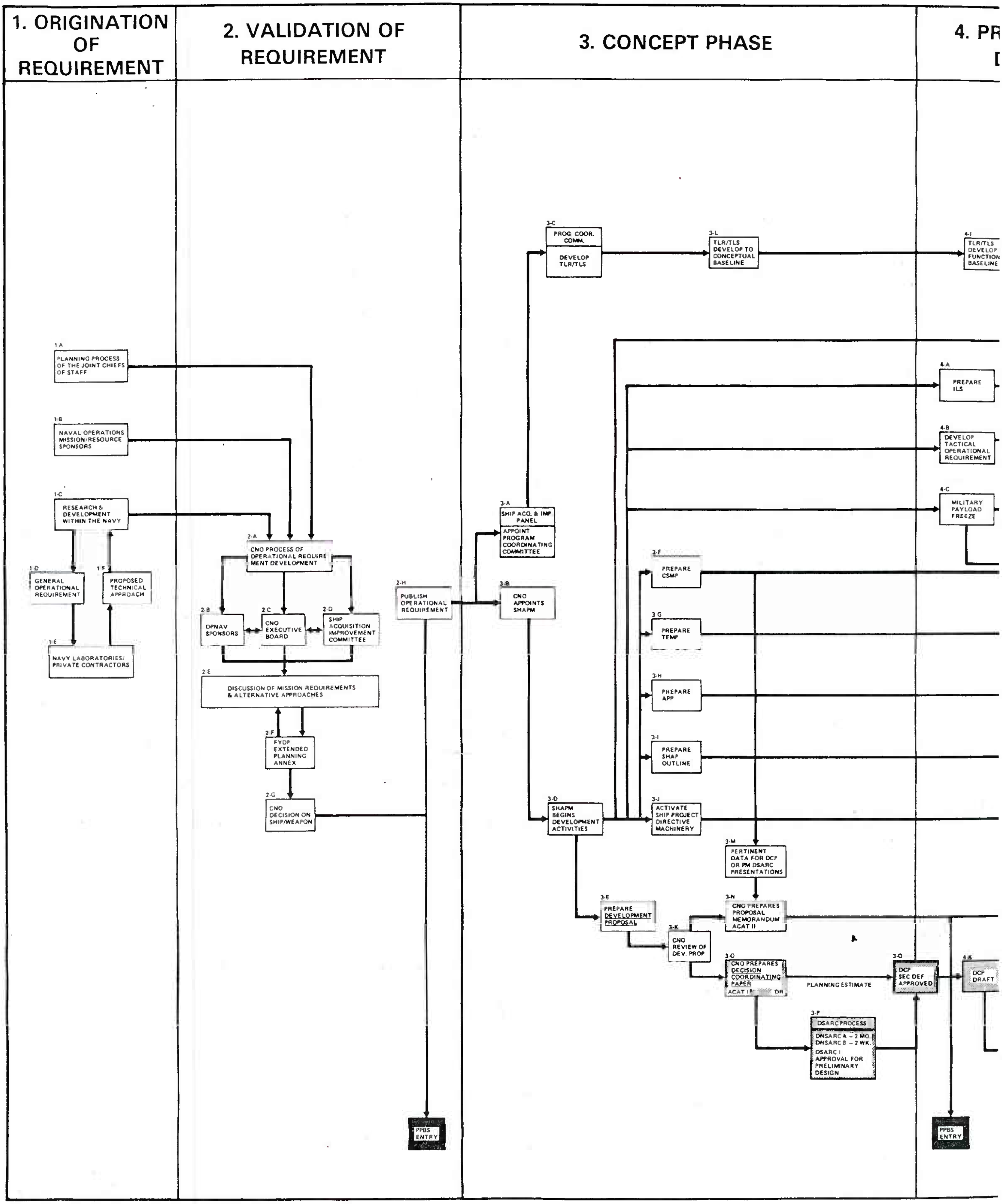
Important considerations in the production phase (which can extend for many years) relate to the number of ships built per program year, maintaining construction schedules in spite of possible disruptions -- material shortages, strikes, personnel turnover, economic instability, engineering changes brought on by new technology, etc. It is, therefore, in this period where cost growth may become most apparent. In general, construction and test activities follow the pattern set in lead ship construction.

FIGURE III.2

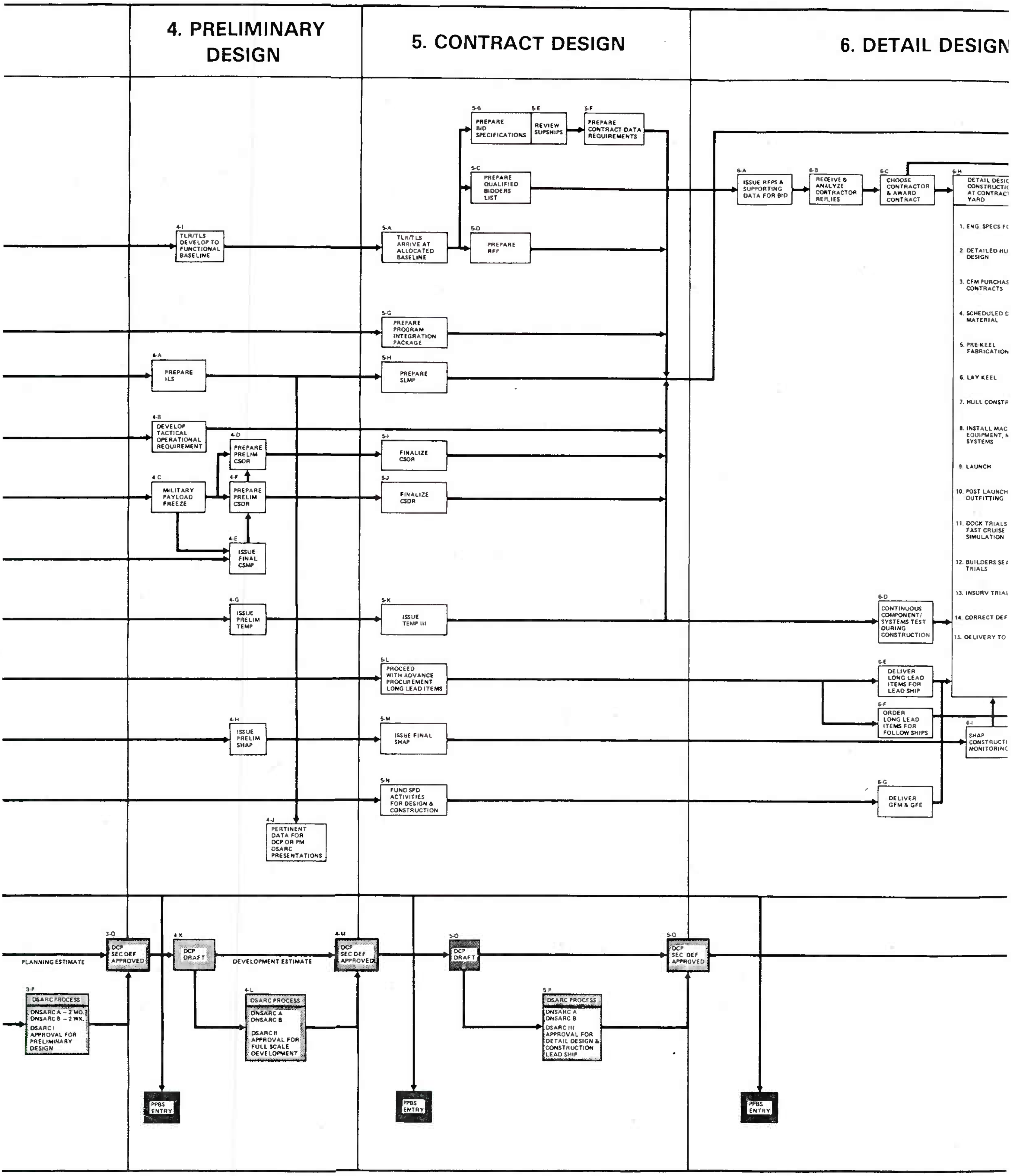
THE NAVY SHIP ACQUISITION PROCESS

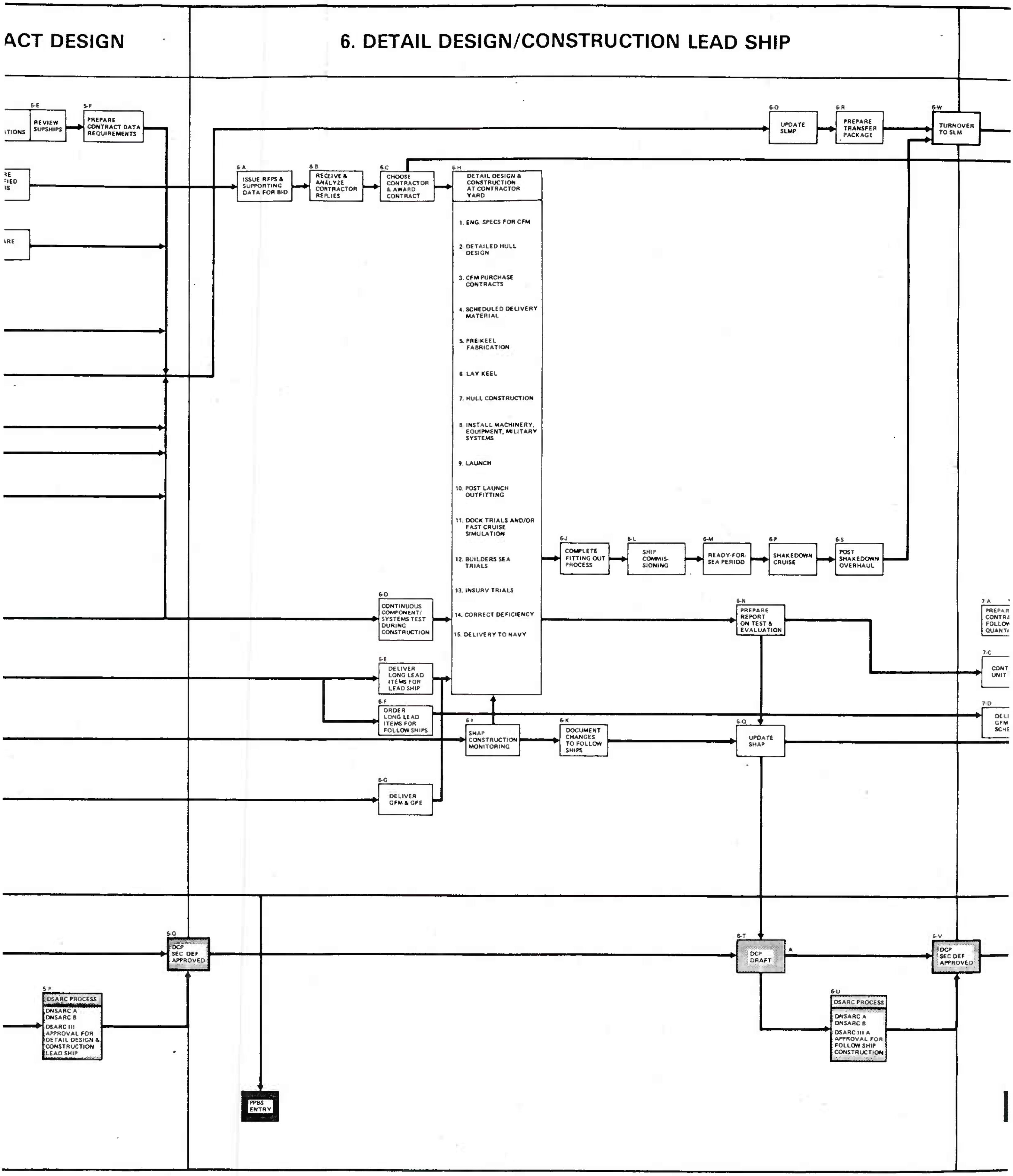
DCP/DSARC PROCESS

PLANNED PPBS ENTRIES



1. ORIGINATION OF REQUIREMENT
2. VALIDATION OF REQUIREMENT
3. CONCEPT PHASE
4. PR
1-A PLANNING PROCESS OF THE JOINT CHIEFS OF STAFF
1-B NAVAL OPERATIONS MISSION/RESOURCE SPONSORS
1-C RESEARCH & DEVELOPMENT WITHIN THE NAVY
1-D GENERAL OPERATIONAL REQUIREMENT
1-F PROPOSED TECHNICAL APPROACH
1-E NAVY LABORATORIES/ PRIVATE CONTRACTORS
2-A CNO PROCESS OF OPERATIONAL REQUIREMENT DEVELOPMENT
2-B OPNAV SPONSORS
2-C CNO EXECUTIVE BOARD
2-D SHIP ACQUISITION IMPROVEMENT COMMITTEE
2-E DISCUSSION OF MISSION REQUIREMENTS & ALTERNATIVE APPROACHES
2-F FYDP EXTENDED PLANNING ANNEX
2-G CNO DECISION ON SHIP/WEAPON
2-H PUBLISH OPERATIONAL REQUIREMENT
PPBS ENTRY
3-A SHIP ACQ. & IMP PANEL
APPOINT PROGRAM COORDINATING COMMITTEE
3-B CNO APPOINTS SHAPM
3-C PROG. COOR. COMM.
DEVELOP TLR/TLS
3-L TLR/TLS DEVELOP TO CONCEPTUAL BASELINE
4-I TLR/TLS DEVELOP FUNCTION BASELINE
4-A PREPARE ILS
4-B DEVELOP TACTICAL OPERATIONAL REQUIREMENT
4-C MILITARY PAYLOAD FREEZE
3-F PREPARE CSMP
3-G PREPARE TEMP
3-H PREPARE APP
3-I PREPARE SHAP OUTLINE
3-D SHAPM BEGINS DEVELOPMENT ACTIVITIES
3-J ACTIVATE SHIP PROJECT DIRECTIVE MACHINERY
3-M PERTINENT DATA FOR DCP OR PM DSARC PRESENTATIONS
3-E PREPARE DEVELOPMENT PROPOSAL
3-N CNO PREPARES PROPOSAL MEMORANDUM ACAT II
3-K CNO REVIEW OF DEV. PROP
3-O CNO PREPARES DECISION COORDINATING PAPER
ACAT I
DR
PLANNING ESTIMATE
3-Q DCP SEC DEF APPROVED
4-K DCP DRAFT
3-P DSARC PROCESS
DNSARC A – 2 MO.
DNSARC B – 2 WK.
DSARC I APPROVAL FOR PRELIMINARY DESIGN
PPBS ENTRY

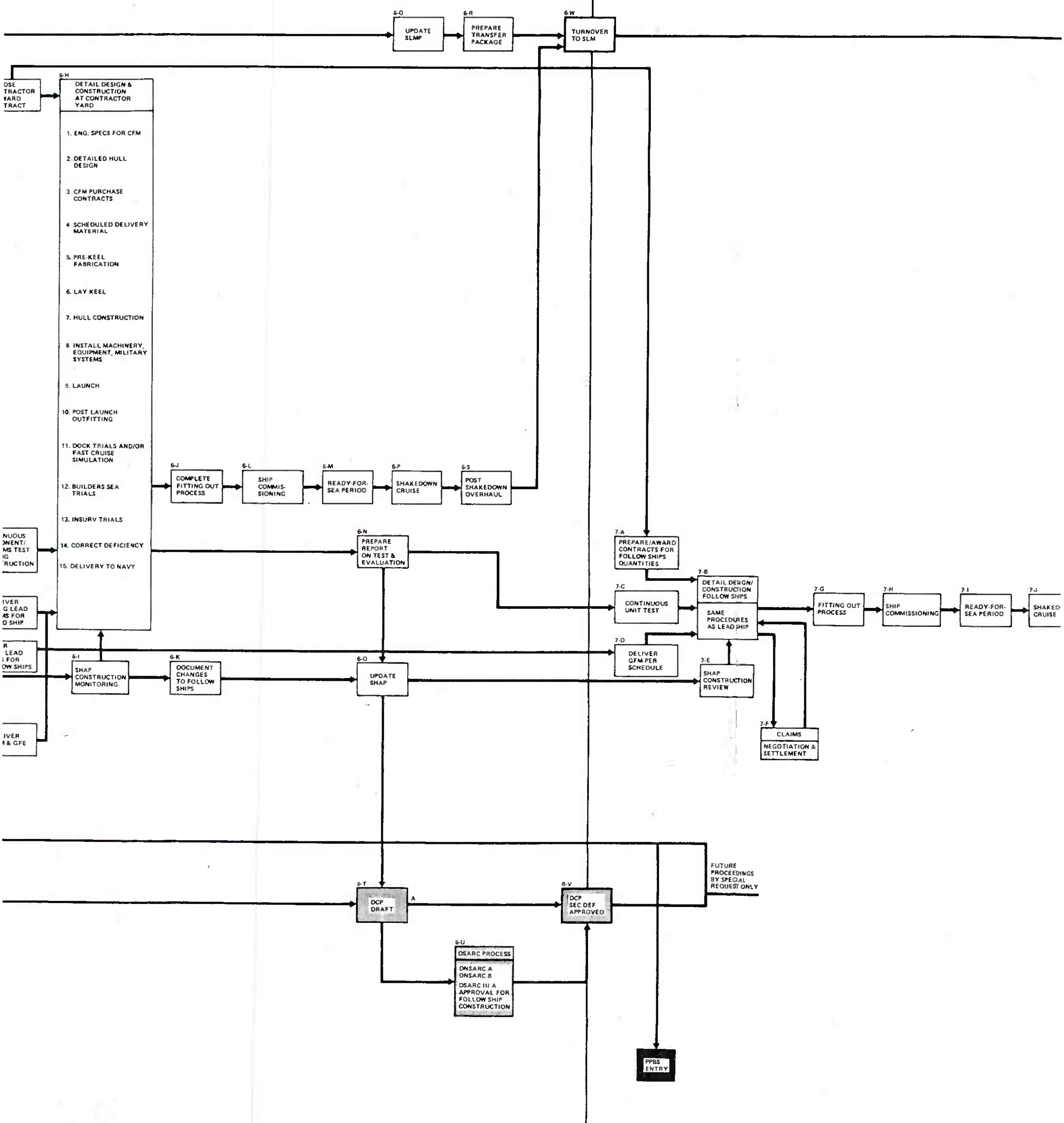

4. PRELIMINARY DESIGN
5. CONTRACT DESIGN
6. DETAIL DESIGN
5-B PREPARE BID SPECIFICATIONS
5-E REVIEW SUPSHIPS
5-F PREPARE CONTRACT DATA REQUIREMENTS
5-C PREPARE QUALIFIED BIDDERS LIST
6-A ISSUE RFPS & SUPPORTING DATA FOR BID
6-B RECEIVE & ANALYZE CONTRACTOR REPLIES
6-C CHOOSE CONTRACTOR & AWARD CONTRACT
6-H DETAIL DESIG CONSTRUCTI AT CONTRAC YARD
4-I TLR/TLS DEVELOP TO FUNCTIONAL BASELINE
5-A TLR/TLS ARRIVE AT ALLOCATED BASELINE
5-D PREPARE RFP
1. ENG SPECS F
2. DETAILED HU DESIGN
3. CFM PURCHAS CONTRACTS
4. SCHEDULED C MATERIAL
5. PRE KEEL FABRICATION
6. LAY KEEL
7. HULL CONSTR
8. INSTALL MAC EQUIPMENT, SYSTEMS
9. LAUNCH
10. POST LAUNCH OUTFITTING
11. DOCK TRIALS FAST CRUISE SIMULATION
12. BUILDERS SE TRIALS
13. INSURV TRIAL
14. CORRECT DEF
15. DELIVERY TO
5-G PREPARE PROGRAM INTEGRATION PACKAGE
4-A PREPARE ILS
5-H PREPARE SLMP
4-B DEVELOP TACTICAL OPERATIONAL REQUIREMENT
4-D PREPARE PRELIM CSOR
5-I FINALIZE CSOR
4-C MILITARY PAYLOAD FREEZE
4-F PREPARE PRELIM CSDR
5-J FINALIZE CSDR
4-E ISSUE FINAL CSMP
4-G ISSUE PRELIM TEMP
5-K ISSUE TEMP III
6-D CONTINUOUS COMPONENT/ SYSTEMS TEST DURING CONSTRUCTION
5-L PROCEED WITH ADVANCE PROCUREMENT LONG LEAD ITEMS
6-E DELIVER LONG LEAD ITEMS FOR LEAD SHIP
6-F ORDER LONG LEAD ITEMS FOR FOLLOW SHIPS
4-H ISSUE PRELIM SHAP
5-M ISSUE FINAL SHAP
6-I SHAP CONSTRUCTI MONITORING
5-N FUND SPD ACTIVITIES FOR DESIGN & CONSTRUCTION
6-G DELIVER GFM & GFE
4-J PERTINENT DATA FOR DCP OR PM DSARC PRESENTATIONS
PLANNING ESTIMATE
3-Q DCP SEC DEF APPROVED
4-K DCP DRAFT
DEVELOPMENT ESTIMATE
4-M DCP SEC DEF APPROVED
5-O DCP DRAFT
5-Q DCP SEC DEF APPROVED
3-P DSARC PROCESS ONSARC A – 2 MO. ONSARC B – 2 WK. DSARC I APPROVAL FOR PRELIMINARY DESIGN
4-L DSARC PROCESS DNSARC A DNSARC B DSARC II APPROVAL FOR FULL SCALE DEVELOPMENT
5-P DSARC PROCESS DNSARC A DNSARC B DSARC III APPROVAL FOR DETAIL DESIGN & CONSTRUCTION LEAD SHIP
PPBS ENTRY
PPBS ENTRY
PPBS ENTRY

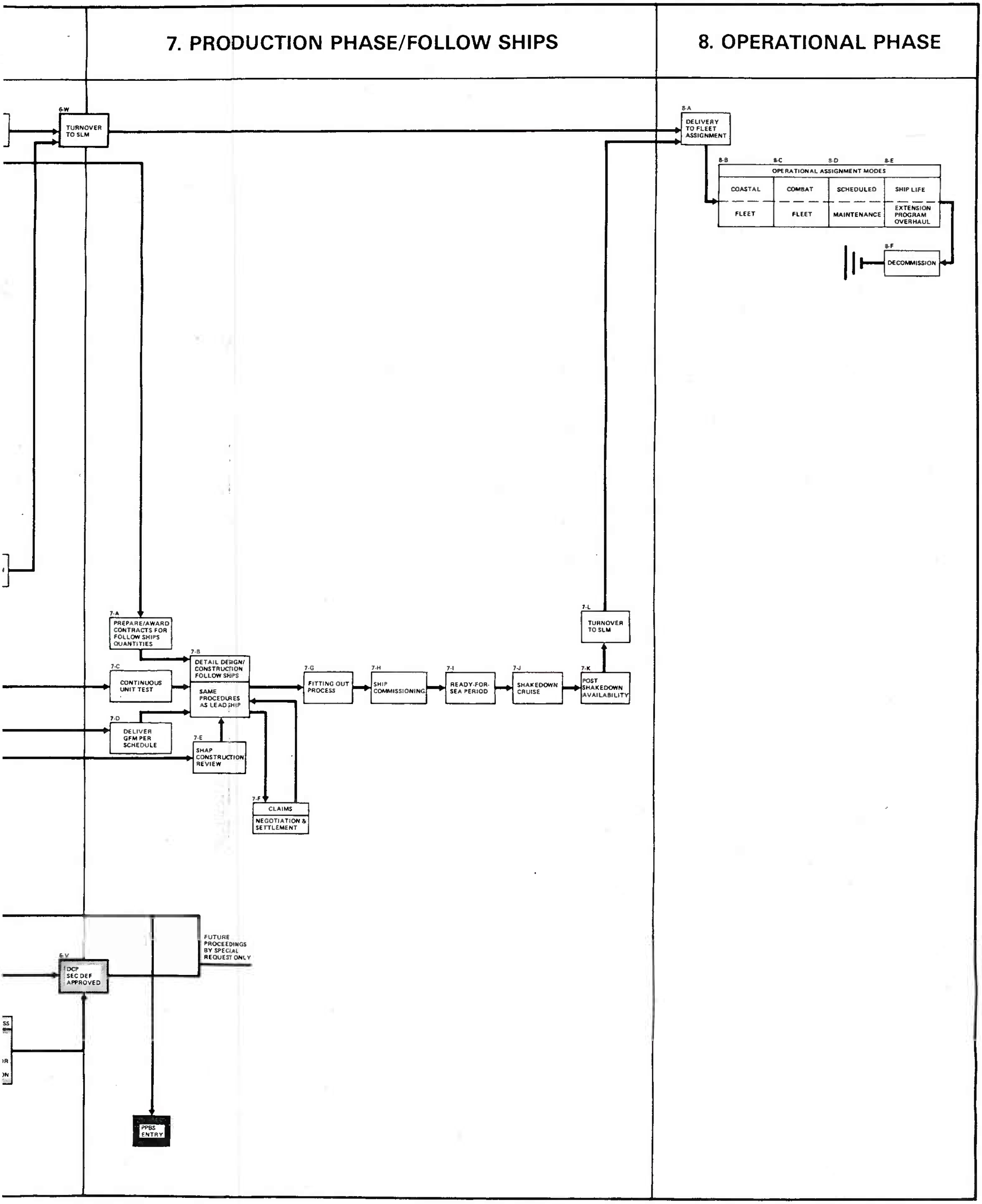


ACT DESIGN
6. DETAIL DESIGN/CONSTRUCTION LEAD SHIP
ATIONS
5-E REVIEW SUPSHIPS
5-F PREPARE CONTRACT DATA REQUIREMENTS
RE FIED RS
ARE
6-A ISSUE RFPS & SUPPORTING DATA FOR BID
6-B RECEIVE & ANALYZE CONTRACTOR REPLIES
6-C CHOOSE CONTRACTOR & AWARD CONTRACT
6-H DETAIL DESIGN & CONSTRUCTION AT CONTRACTOR YARD
1. ENG. SPECS FOR CFM
2. DETAILED HULL DESIGN
3. CFM PURCHASE CONTRACTS
4. SCHEDULED DELIVERY MATERIAL
5. PRE-KEEL FABRICATION
6. LAY KEEL
7. HULL CONSTRUCTION
8. INSTALL MACHINERY, EQUIPMENT, MILITARY SYSTEMS
9. LAUNCH
10. POST LAUNCH OUTFITTING
11. DOCK TRIALS AND/OR FAST CRUISE SIMULATION
12. BUILDERS SEA TRIALS
13. INSURV TRIALS
14. CORRECT DEFICIENCY
15. DELIVERY TO NAVY
6-O UPDATE SLMP
6-R PREPARE TRANSFER PACKAGE
6-W TURNOVER TO SLM
6-J COMPLETE FITTING OUT PROCESS
6-L SHIP COMMIS-SIONING
6-M READY-FOR-SEA PERIOD
6-P SHAKEDOWN CRUISE
6-S POST SHAKEDOWN OVERHAUL
6-D CONTINUOUS COMPONENT/ SYSTEMS TEST DURING CONSTRUCTION
6-N PREPARE REPORT ON TEST & EVALUATION
7-A PREPAR CONTRA FOLLOW QUANTI
7-C CONT UNIT
6-E DELIVER LONG LEAD ITEMS FOR LEAD SHIP
6-F ORDER LONG LEAD ITEMS FOR FOLLOW SHIPS
7-D DELI GFM SCHE
6-I SHAP CONSTRUCTION MONITORING
6-K DOCUMENT CHANGES TO FOLLOW SHIPS
6-Q UPDATE SHAP
6-G DELIVER GFM & GFE
5-Q DCP SEC DEF APPROVED
6-T DCP DRAFT
A
6-V DCP SEC DEF APPROVED
5-P DSARC PROCESS
DNSARC A
DNSARC B
DSARC III APPROVAL FOR DETAIL DESIGN & CONSTRUCTION LEAD SHIP
6-U DSARC PROCESS
DNSARC A
DNSARC B
DSARC III A APPROVAL FOR FOLLOW SHIP CONSTRUCTION
PPBS ENTRY

AIL DESIGN/CONSTRUCTION LEAD SHIP

7. PRODUCTION PHASE/FOLLOW SHIP





7. PRODUCTION PHASE/FOLLOW SHIPS
8. OPERATIONAL PHASE
6-W
TURNOVER TO SLM
8-A
DELIVERY TO FLEET ASSIGNMENT
8-B
8-C
8-D
8-E
OPERATIONAL ASSIGNMENT MODES
COASTAL FLEET
COMBAT FLEET
SCHEDULED MAINTENANCE
SHIP LIFE EXTENSION PROGRAM OVERHAUL
8-F
DECOMMISSION
7-A
PREPARE/AWARD CONTRACTS FOR FOLLOW SHIPS QUANTITIES
7-B
DETAIL DESIGN/ CONSTRUCTION FOLLOW SHIPS
SAME PROCEDURES AS LEAD SHIP
7-C
CONTINUOUS UNIT TEST
7-D
DELIVER GFM PER SCHEDULE
7-E
SHAP CONSTRUCTION REVIEW
7-F
CLAIMS
NEGOTIATION & SETTLEMENT
7-G
FITTING OUT PROCESS
7-H
SHIP COMMISSIONING
7-I
READY-FOR-SEA PERIOD
7-J
SHAKEDOWN CRUISE
7-K
POST SHAKEDOWN AVAILABILITY
7-L
TURNOVER TO SLM
6-V
DCP SEC DEF APPROVED
FUTURE PROCEEDINGS BY SPECIAL REQUEST ONLY
PPBS ENTRY

The ship acquisition process just described and illustrated in Figure III.2 provides the framework within which Navy officials manage the shipbuilding program. Systems and procedures such as these require accurate projected costs of acquisition.

Although one organization, the Cost Estimating and Analysis Division (NAVSEA 01G), is the focal point for ship cost estimating in NAVSEA, many groups throughout the Navy contribute to the process in some way. The following sections analyze specific cost estimating activities which take place within the systems described.

4. COST ESTIMATING -- A KEY ELEMENT IN BOTH PROCESSES -- IS CARRIED ON FOR THREE GENERAL PURPOSES: PLANNING, BUDGETING AND CONTRACTING

The term "cost estimate" appears often in the instruction and procedures of the Navy. As this report continues, it will further define the elements in a cost estimate and how estimates are created and used -- but in the final analysis, estimates are used for the following general purposes.

(1) Cost Estimates Are Essential To The Planning And Programming Process

The development of the DOD/Navy Five Year Defense Plan requires that ship programs be structured over a five year period. To arrive at the eventual plan, optional programs for each year are developed by Naval Operations staff which comply with the force structure and fiscal guidance provided by the CNO as part of the planning activity. Each ship class included in a year's program must be estimated -- not only for the proposed technical requirements and numbers of ships -- but for the particular period of time over which the ships are to be constructed.

Another planning activity mentioned previously is the process of developing an operational requirement for a ship. It involves iterative cost estimating for a variety of ship characteristics to derive an optimum mix of weapons, platform and cost.

Due to scarcity of technical data available during these processes, the estimator is usually limited to two techniques -- analgous and/or parametric estimating. The analogous technique is used when the whole or major portion of the ship is similar to one built previously, or under construction, where actual cost or bid data are available. These costs are then adjusted for ship or component size difference and for building period. If the estimator is fortunate enough to receive weight data in the single digit breakdown of the Ship Work Breakdown System (SWBS), described later in this chapter, a parametric technique can be used to make planning estimates. To the platform cost, the estimator must add the cost of GFM which is supplied by appropriate program managers.

The importance of cost estimating for planning purposes is significant. There are obvious drawbacks, however, to the estimating methods which must be used during this process. Estimates of reasonable precision available during the planning phase would greatly enhance the process, but generally, newness of concept and lack of specific product definition inhibit this kind of precision.

(2) <u>Estimates Prepared For Budget Purposes Are More Precise</u>

Many of the uncertainties present in "out year" planning are resolved during the budget formulation process. Although optional programs may be suggested in budget guidance, the ship classes included are generally better defined. Estimates for budgeting, therefore, assume a new level of precision.

The preparation of budget estimates for new designs will follow the same process as those prepared during early planning -- except that the technical data and weapons complement should be better defined. Generally, most of the ships in any one budget year are repeat ships in a continuing construction program and in these cases, the estimating task is easier. Navy estimates for these repeat ships depend heavily on contractor bid data from previous awards. From bid data, rates representing manhours per ton for labor and dollars per ton for material are developed for each of seven weight groups. These rates are then applied to the most recent corresponding weight estimate prepared by the Naval Ship Engineering Center. The current weight estimate should include all changes made in the ship and reflect modifications required for new weapons, electronics and other equipments.

When estimating for budgeting purposes, estimators supplement the basic ship cost estimate with economic factors to project escalation, overhead, etc., for the projected life of the construction contract. Their objective is to prepare a budget estimate which will remain reasonably accurate from the time the estimate is prepared for the Budget to ship completion. This could be from six to ten years in the case of a major combatant ship.

(3) Cost Estimates For Contract-Related Activities Are The Highest Quality Estimates Prepared By The Navy

Estimates in support of contracting activities are prepared for the contracting officer so that he may judge the reasonableness of proposals and bids received from the shipbuilders as required by Armed Services Procurement Regulations. Such an estimate is called the Independent Government Cost Estimate and is prepared prior to receipt of quotations.

It is used to prepare the Government Contract Negotiation Objective which is developed by the Contracting Officer after receipt and analysis of contractor bid proposals. The latter is not only an estimate but also the Government's alternative position to estimates contained in a contractor bid.

This should be the most accurate of the three types of estimates due to the availability of contract plans and specifications. It is usually a parametric estimate prepared in the SWBS single digit, nine cost group breakdown which is also used by the shipyards to summarize their detailed bids. After bid opening, negotiators can compare broadly the nine line items for material, labor , overhead and profit and seek clarification where needed.

Organizations within the Navy continually use cost estimates for the three purposes outlined above. Some organizations concentrate more on planning, others on budgeting and one, the NAVSEA Cost Estimating and Analysis Division is concerned with all aspects of estimating.

5. THE PRIMARY COST ESTIMATING ORGANIZATION IN THE NAVY IS THE COST ESTIMATING AND ANALYSIS DIVISION (SEA 01G), BUT MANY OTHER ORGANIZATIONS HAVE ESTIMATING CAPABILITY

The one organization which estimates for all the purposes mentioned is SEA 01G. Its primary task is estimating the total end cost of ships. This requires a capability to not only prepare estimates for a ship by various methods, but also the collection of cost data from other sources for weapons and other Government Furnished Material.

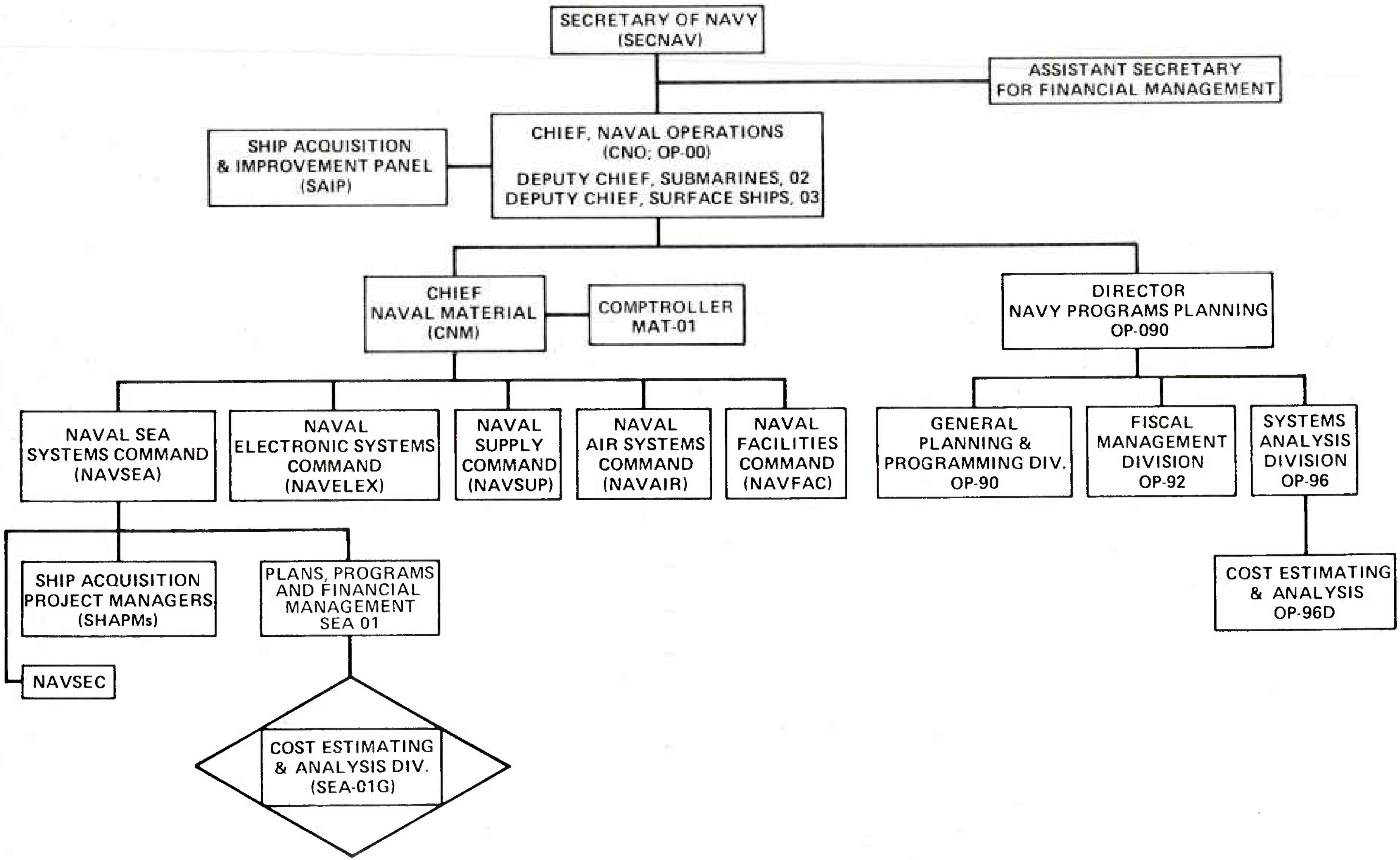
Figure III.3 illustrates the location of SEA 01G in the Navy organization and also identifies other groups which perform estimating as part of their charter. A review of these groups starts with the System Commands where the acquisition process is managed.

(1) Estimating In The Systems Commands Supports The Acquisition Process Directly

The Systems Commands are the organizations responsible for construction management of ships, weapons and other items of GFM. Estimating carried on in support of these activities is more or less continuous.

FIGURE III.3

COST ESTIMATING ORGANIZATIONS IN THE NAVY



- Naval Sea Systems Command

ShipAcquisition ProjectManagers within NAVSEA (SHAPMs) have the organizational responsibility for cost estimating related to ships under their cognizance. NAVSEA 01G acts for the SHAPMs in preparing budget cost estimates, cost estimates for Program Objectives Memoranda, contract estimates, and other special studies. It is also the focal point for estimates provided by other Systems Commands, but its duties go beyond that of being only an assembler. NAVSEA 01G estimates the cost of the ship construction, the cost of installing the various systems/equipments that are GFM, validates estimates provided by other offices and forecasts escalation and inflation percentages for use by the various Project Managers.

Other groups within NAVSEA, such as the Naval Ship Engineering Center (NAVSEC), have limited cost estimating capability for ship systems or complete ships. In all cases, however, NAVSEA 01G performs the coordinating function with regard to the ship end cost estimates.

- Naval Electronic Systems Command

NAVELEX 504B is the Central Cost Estimating and Analysis Group in this Command which validates estimates furnished to NAVSEA 01G. These cost estimates may originate in the Material Acquisition Directorate, NAVELEX 501A, for follow on procurements of production systems/equipments or from the cognizant engineer for initial production items.

- Naval Air Systems Command

NAVAIR has a Cost Analysis/Cost Estimating Group (NAVAIR 506) which acts as its focal point for estimating and provides cost estimating policy and guidance to the Command. Cost estimates for the POM and other ship equipment/system requests are provided

NAVSEA 01G by NAVAIR 537, the Ship Installation Division. The cost estimating function of NAVAIR 537 is a secondary one as their primary mission is installation of shipboard equipment to support aircraft. NAVAIR 506 is the primary provider of aircraft, aircraft equipment, and missile cost estimates.

These three Systems Commands are the prime system acquisition managers for the Navy. The remaining two Commands deal with logistic and supply functions and are not, therefore, in the main stream of estimating for major hardware acquisitions.

Other organizations within the Navy have cost estimating groups, however, and the capability of these groups is described briefly.

(2) Divisions Within The Office Of The Chief Of Naval Operations Prepare Estimates For Planning And Validation Purposes

The responsibilities of the CNO include the definition of ship requirements, the preparation of the Navy Program Objectives Memorandum, and the provision of annual budget information. The groups which perform activities related to these responsibilities are as follows:

- <u>General Planning and Programming Division (OP 90)</u>

  OP 90 validates costs and program factors for the Five Year Defense Plan, CNO Analysis process, POM preparation, and pricing for other documents such as Selected Acquisition Reports. The group also maintains the Navy Resources Model and the Navy Cost Information System.

- <u>Fiscal Management Division (OP 92)</u>

  This group reconciles planning and programming cost estimates with annual budget back-up estimates; validates budget costing and provides budget and prior year cost data; reviews budget cost estimates that are inputs to economic analyses required to support budget programs.

- <u>System Analysis Division (OP 96)</u>

  This group maintains a permanent, dedicated cost estimating group capable of making periodic on-request studies of Navy programs, both ongoing and proposed, for the purpose of validating acquisition and ownership costs of major weapon systems, providing cost validation functions in support of cost effectiveness studies, and cost estimates in support of CNO Executive Board and Program Review Committee presentations. This group employs parametric cost analysis with other techniques to keep the Office of the Chief of Naval Operations and, particularly, program sponsors informed of the results of independent analysis and validation.

(3) <u>The Naval Material Command, Headquarters (NAVMAT), Performs Various Activities Related To Cost Estimating</u>

The Chief of Naval Operations provides weapons, aircraft and ship requirements to the Chief of Naval Material (CNM) for development of more detail in terms of designs and specifications and several cost estimating functions are performed in support of these CNM responsibilities. NAVMAT personnel coordinate SYSCOM cost analysis and estimating functions within the Command to:

- Provide the capability for preparing independent cost estimates and evaluations of contractor proposals based on actual cost experience and statistical techniques.

- Perform research on new methods and techniques useful in cost analysis and estimating.

- Collect, process, validate and store data in support of the cost analysis programs.

- Coordinate between cost estimating organizations in the Commands, the weapons managers, equipment project managers or other responsible groups.

CNM activities as with all Navy cost estimating organizations outside SEA 01G, are largely for purposes of validation or planning and control.

(4) In Considering The Total Estimating Capability Of The Navy, Some 50 Different Groups Are Involved In Estimating For 6 Different Appropriations

The Navy prepares estimates for ship and weapon acquisition, modernization and repair, and research and development. The specific appropriations are:

- SCN — Shipbuilding and Conversion, Navy
- RDT&E — Research Development, Test and Evaluation
- FMS — Foreign Military Sales
- O&MN — Operations and Maintenance, Navy
- OPN — Other Procurement, Navy
- WPN — Weapons Procurement, Navy

The organizations that participate in preparing estimates for these appropriations are widespread and are indicated in Figure III.4. Organizations having primary responsibility for appropriation estimating are shown with dark borders. It can be generally be observed that SEA 01G is the predominate organization with respect to new construction and conversion estimates and performs many support functions such as economic analysis and economic forecasting.

GFM estimating is performed primarily by SEA 06, SEA 04 and other participating managers within the SYSCOMS. Field organizations, such as PERA or SupShips, have a predominate role with respect to engineering changes, fleet modernization programs, overhauls and claims.

FIGURE III.4

SHIP COST ESTIMATING AND COST ANALYSIS RESPONSIBILITIES

	APPROPRIATIONS	NAVSEA HEADQUARTERS	OTHER SYSCOMS & SUPPORT	OTHER GROUPS
ACQUISITION				
SHIP				
New Construction & Conversion - Total Cost	SCN RDT&E FMS	01G	SEC 6112D	OP96D CNA
Conceptual	SCN RDT&E FMS	01G	ELEX, AIR	OP96D OSD - CAIG
Budget	SCN RDT&E FMS	01G		
DSARC	SCN RDT&E FMS	01G	N.S.Y.	
Contract - Private Shipyards	SCN RDT&E FMS	01G		
- Naval Shipyards				
Change Orders			SUPSHIP	
Budget	SCN FMS	01G		
Contract	SCN FMS	01G PM		
Alterations/Repairs (FMP)			PERA'S N.S.Y. SUPSHIP	
Budget	OMN FMS	SLD's		
Contract	OMN FMS			
Contract Escalation				
Budget	SCN FMS	01G	SUPSHIP DCAA	
Contract	SCN FMS	01G		
GOV'T. FURNISHED MATERIAL				
Search Radars	The following	01G 652		
Gun Mounts		01G 6531 653G PMS 4043		
Gun Fire Control System	appropriations	01G 6532 653G PMS 4043		
Missile Launchers		01G 654 06G5 PMS 404 PMS 403		
Missile Fire Control Systems	are possibilities	01G 654 653G 06G5 PMS 403 PMS 404		
Underwater Fire Control Systems - Subs		01G 660D 660M		
Underwater Fire Control Systems - Surface	for all GFM:	01G 661D1 660M		
ASW Launchers & Torpedo Tubes - Surface		01G 661D2 660M		
Combat System Integration & Support	SCN, WPN,	01G 06C	SEC 6170	
Sonars		01G 06H 660 661		
Z Cog. Electronic Countermeasures	OPN, FMS,	01G	PME 107 ELEX 05 SEC 6170 SEC 6140 AIR 537 BUMED	AIR 537
Z Cog. Communication & Navigation Radar Eq.		01G		
F Cog. Material	RDT&E.	01G 044		
S Cog. Material		01G 044		
Catapults & Aircraft Support		01G		
Medical		01G		
Nuclear Propulsion		08		
Gas Turbines		01G 04T PMS 399	SEC 6146	
SUPPORT FUNCTIONS				
Life Cycle Costs	ALL	01G 04V AM's	SEC 6112D SUPSHIP	DCAA OP96D CNA
Technical Cost Analyis	ALL	01G PM AM's	NAVSEC	
Should Cost Studies	ALL	01G PM 02	DCAA PV'T. Contractor	OP96D CNA
Economic Analysis	ALL	01G PM	N.S.Y. PV'T. Contractor	OP96D CNA OSD (COMPT)
Economic Forecasting	SCN FMS	01G		OSD (COMPT)
	ALL OTHER APPRO.	-		OP96D OSD - CAIG
Cost Estimate Validation	ALL	01G		OP96D CNA OSD - CAIG
Design To Cost	ALL	01G 0745 PM	SEC6112D	
Claims	SCN FMS	0282	SUPSHIP DCAA	PV'T. Contractor Various Claim Settlement Teams
Contract Cost Analysis	ALL	02	ELEX 02 AIR 02 ETC.	MAT02
Central Cost Monitor	ALL	01G		OP96D

(5) <u>As Indicated At The Outset, SEA 01G Is The Primary Estimating Group Within The Navy And It Is Organized Into Two Branches</u>

What is now the Cost Estimating and Analysis Division was, in earlier years, referred to as the Ship Cost Estimates and Analyses Office, Code 05F2, Ship Acquisition Directorate. Beginning in 1966, the office underwent several title changes until it finally acquired its present title. In 1970, it was divided into the Cost Estimating Branch and Cost Analysis Branch with both reporting to the Director of the Division. This has been the Division's organizational structure to the present time.

Figure III.5 shows the organization of the Division and summarizes the major functions of each branch and section.

- The Cost Estimating Branch is responsible for predicting the total end cost of a ship by performing basic construction estimates and including pre-prepared estimates for GFM plus guidance for future economic conditions.

- The Cost Analysis Branch is responsible for establishing the guidance for estimators regarding future economic conditions, market situations, industry norms and the like.

Another responsibility is the performance of special studies such as Life Cycle Costing, Should Cost studies and Design-to-Cost studies.

FIGURE III.5

ORGANIZATION CHART FOR COST ESTIMATING AND ANALYSIS DIVISION NAVSEA - 01G

BRIEF DESCRIPTION OF PRINCIPAL FUNCTIONS
AS OF DECEMBER 1976

PREPARED BY IMA – 12/22/76

DIRECTOR
COST ESTIMATING & ANALYSIS DIVISION
NAVSEA-01G

- **ESTIMATING BRANCH HEAD, 01G 1**
  - **COMBAT SHIP ESTIMATING SECTION, 01G 11, HEAD & 4 ESTIMATORS**
    COST ESTIMATES DURING ALL PROCUREMENT STAGES FOR: NEW OR R&D COMBATANT SHIPS; CONVERSIONS, ALTERNATIVE PROVISIONS; NAVAL SHIPYARD PLANNING OF MANPOWER. DOCUMENTATION & CLASSIFICATION OF ESTIMATES.
  - **AUXILIARY SHIP ESTIMATING SECTION, 01G 12, HEAD & 3 ESTIMATORS**
    FUNCTIONS ARE SAME AS LISTED FOR 01G 11: BUT AUXILIARY SHIPS, SMALL CRAFT, AIRCRAFT CARRIERS, PHMS.
  - **COMBAT SYSTEMS COST ESTIMATING SECTION, 01G 13, HEAD & 3 ESTIMATORS**
    COLLECT, VALIDATE, DEVELOP ESTIMATES OF COST FOR WEAPONS, ELECTRONICS, & ASSOCIATED SOFTWARE. (PRINCIPALLY GFM). ESTIMATE COST OF ALTERNATIVES. ESTIMATE COST OF COMMERCIAL TYPE ELECTRONICS. MAINTAIN INDICES FOR COST PROJECTIONS.
- **ANALYSIS BRANCH HEAD, 01G 2**
  - **COST DATA ANALYSIS SECTION, 01G 22, HEAD & 5 ANALYSTS**
    COLLECT & PROJECT ECONOMIC DATA FOR SHIPBUILDING TO ISSUE GUIDANCE FOR ESTIMATES OF INFLATION, ESCALATION; LABOR, OVERHEAD & PROFIT RATES; PRODUCTIVITY, LEARNING CURVES, ETC.
  - **SYSTEMS ANALYSIS SECTION, 01G 21, HEAD & 0 ANALYSTS**
    INTEGRATE COST DATA FOR ECONOMIC & LIFE CYCLE ANALYSIS. DESIGN AND MANAGE COMPUTER PROGRAMS FOR COST ANALYSIS & COST ESTIMATING. MAINTAIN COST DATA BANKS WITH ADP.
  - **POLICY, PROCEDURES, & REVIEW SECTION, 01G 23, ACTING HEAD (HEAD OF 01G 21) & 1 ANALYST**
    COORDINATE REVIEW & ANALYSIS OF COSTING OPERATIONS. ASSURE COMPLIANCE WITH REQUIREMENTS. AUDIT SHIPYARD MANHOURS & SURVEY CAPABILITY. PARTICIPATE IN "SHOULD COST" & TECHNICAL ANALYSIS REVIEWS.

6. COST ESTIMATES FOR SHIPS ARE DEVELOPED BY NAVSEA 01G1, THE SHIP COST ESTIMATING BRANCH

The estimating task handled by this Branch breaks down into five functions -- estimating for combatant ships, estimating for auxiliary ships, estimating for small craft, estimating for GFM, and estimating other costs commonly associated with ship construction.

(1) Total Ship Cost Is The Product Of A Basic Ship Estimate, Estimates For GFM And Factors Representing Economic Conditions Over The Time Period Of The Contract

When preparing an estimate for a ship, the three general reasons for estimates mentioned previously become important in understanding the process. Requests for estimates are passed to NAVSEA 01G1 for purposes of responding to planning requirements in the POM or other longer range planning processes, for purposes of submissions to the annual budget, for preparation of a negotiation objective for an upcoming contract, for a design-to-cost study, or any one of a number of purposes.

Naturally, the stage of engineering development at which the ship stands becomes a factor in determining how the estimate is prepared. Whether parametric, analogous or more detailed methods are used depends on the degree of detail of requirements and specifications available.

The detail or lack of detail in design and engineering specifications from which estimates are made must be understood by the end user of an estimate. Some estimates are thought to be more reliable than others in that more data exists on which to base the estimate. To account for the wide range of quality possible in an estimate, the Navy has developed a classification system which categorizes estimates as being "X or directed" through "A or contract estimates".

- A or Detailed Cost Estimate (Post Budget-Contract Estimate) -- estimate based on contract plans and evaluation of firm quotations for major material items.

- B or Bid Evaluation Cost Estimate (Post Budget-Contract Estimate) -- estimate based on contract plans and evaluation of contractor proposals in response to an RFP.

- C or Budget Quality Estimate -- estimate based on an engineering analysis of detailed characteristics of items under consideration.

- D or Feasibility Estimate -- estimate based on technical feasibility studies and/or extrapolated from higher quality estimates of similar items.

- E or Computer Estimate -- estimate developed usually by a computer model and based on cost estimating relationships and gross parameters.

- F or Ball Park Estimate -- quick cost estimate prepared in absence of even minimum design and cost information and based on gross parameters.

- X or Directed or Modified Cost Estimate -- estimate not developed by SYSCOMS through normal cost estimating processes.

For whatever purpose the estimate is made, however, the process generally followed is shown in Figure III.6.

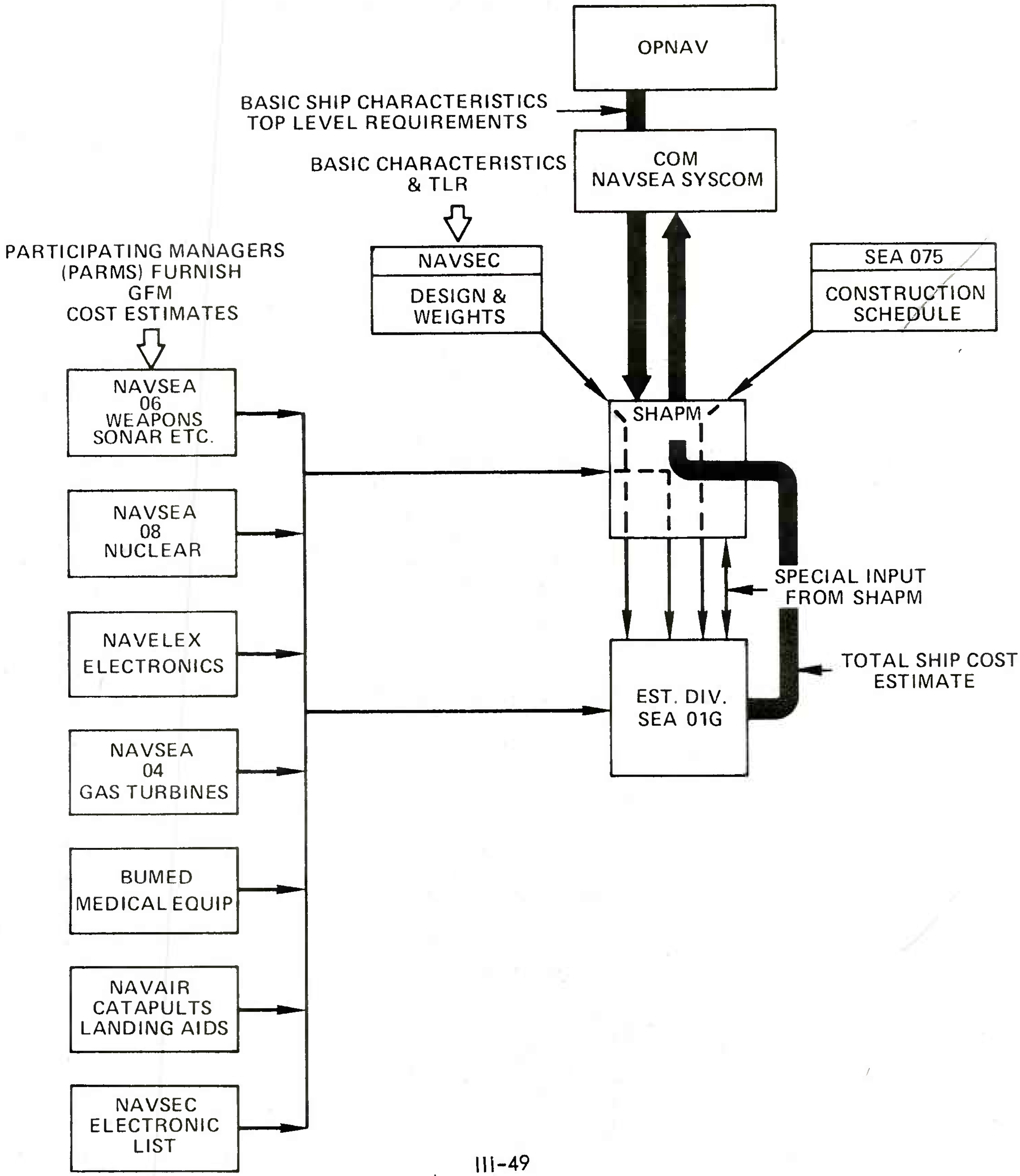
In the development of ship cost estimates, basic characteristics originate in OPNAV and are forwarded to a SHAPM within NAVSEA via NAVMAT. The SHAPM in turn tasks NAVSEC to produce a design and further tasks other Participating Managers (PARMs) for technical data and estimates for GFM characteristics required. The SHAPM also collaborates with the Ship Production Office, SEA 075, recently absorbed by the Industrial Activities Work and Resources Planning Division, SEA 071, to develop a production schedule.

All this information is conveyed to the Cost Estimating Branch where the ship end cost estimate is produced. The estimate is reviewed by the SHAPM, final changes made as necessary and the forwarded to the Commander, NAVSEA for final approval and submission to requesting organizations.

The development of the basic ship estimate follows a process of ascribing labor and material unit costs to estimated weight categories.

FIGURE III.6

TOTAL SHIP COST ESTIMATING PROCESS



As has been mentioned, it is a method based on a system which describes all activities associated with shipbuilding called a Ship Work Breakdown System (SWBS). Following this system, a ship is divided into seven major weight categories as shown in Figure III.7.

- 100 - Hull Structure
- 200 - Propulsion Plant
- 300 - Electric Plant
- 400 - Command and Surveillance
- 500 - Auxiliary Systems
- 600 - Outfit and Furnishings
- 700 - Armament

The estimator, once given weights for each of the particular groups (called at this level the single digit breakdown), computes a basic estimate. Other costs are then added as they become available which are not computable by weight, such as

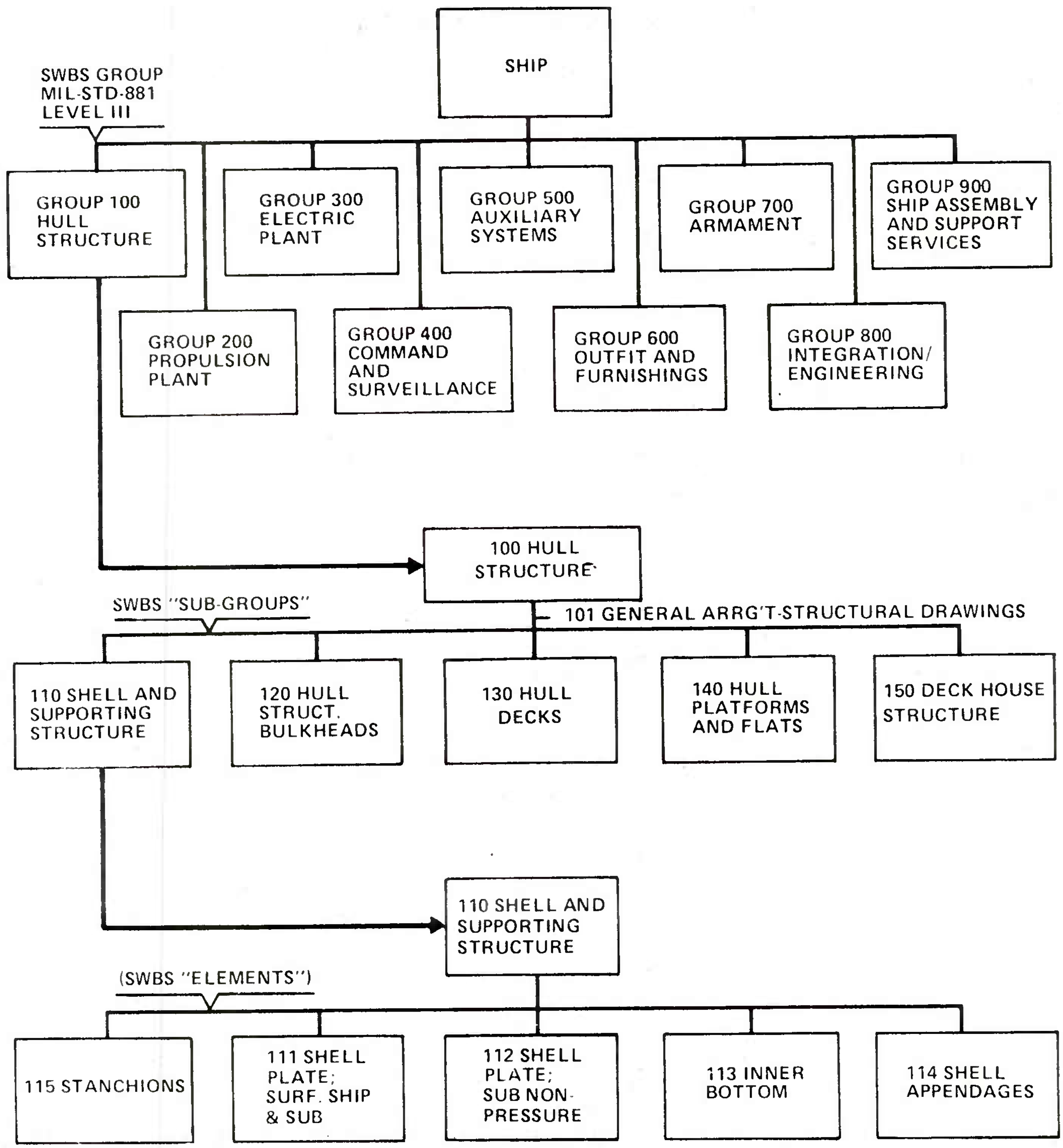
- 800 - Integration/Engineering
- 900 - Ship Assembly Support Services

More refined estimates require the application of unit costs to sub-weight groups under each of the above single digit groupings. These are commonly known as either two or three digit breakdowns, shown at the second and third levels of the SWBS.

The weights used by SEA 01G are prepared by NAVSEC and they take on increased reliability as the ship design develops. The

FIGURE III.7

EXAMPLE OF SHIP BREAKDOWN SYSTEM GROUPINGS



first weight estimating calculations are made during the feasibility study stage. These estimates are computer derived in three digit format; however, due to the nature of current computer programs, only the total (single digit sum) of the three digit values are used. These weights are really only of sufficient quality to develop a measure of merit between a number of concepts or to make a sensitivity analysis.

Computer programs utilized within NAVSEA 01G1 produce estimates using algorithms representing a variety of ship types and weight statistics. The usual input at the feasibility stage will consist of single sheet characteristics and the single digit estimated weights. This is considered satisfactory back-up for class E or F estimates.

Weight estimates prepared during conceptual design development are in greater detail because at this point one of the feasibility designs will have been selected. The degree of design definition at this stage includes machinery and electrical equipment lists, general arrangement sketches, a midship section, weapon list, etc. From this data, a three digit weight estimate is developed in NAVSEC by comparing each system to a calculated weight of a completed similar ship system. There is no attempt at this stage in the design to make sketches for the purpose of estimating such things as the weight of piping systems or electric cable and fixtures. The accuracy of these weights is such that a margin of at least ten percent is usually added.

The data bank from which weights are retrieved is composed primarily of quarterly weight reports and inclining experiment results calculated by shipbuilders on ships under construction. The data is based on actual weight figures (ten percent) with the remainder calculated (90 percent). At this point in the design, the three digit weights are considered to be more accurate than those in the feasibility stage and sufficient for a "D" class estimate.

The next phase is the preliminary/contract design stage. Very often there is not a clean cut-off point between preliminary design and contract design, but as the design passes through the Defense Systems Acquisition Review Council (DSARC) II, it becomes more stable and the weight estimates become more accurate. By the time the design is at the Functional Baseline stage, at the end of the Preliminary Design phase, a class "C" estimate could and should be made.

Under the present organizational arrangement, the SHAPM tasks NAVSEC to provide design and technical services to the project office. NAVSEC'c communication with SEA 01G is, therefore, on an informal basis.

The procedure described above of ascribing unit costs to estimated weights by categories should develop, over a period of time, a Cost

Estimating Relationship (CER). If these CERs are based on accurate and comprehensive data, parametric estimates become increasingly accurate.

The data bank which is the basis for parametric estimating in SEA 01G1 is the history of past estimating assignments as recorded in various ship or budget estimate folders, individual estimator's files, contract files, bid files and so forth. There is no organized or structured data bank that provides for timely and uniform entry of data for comprehensive retrieval or systematic development of CERs. The general procedure now being employed for a new estimate is to develop CERs from the most recent bid on similar ships. Very often these are a year or more old. Little or no current return cost data is either sought or used in the estimating process. The data used for estimating is generally not in a form where estimates can be made in greater detail than the single digit format. Even if more data were made available, it is doubtful that it could be used under current procedures and staff structure.

The estimator rarely refers directly to ship plans and specifications in the preparation of the estimate and, almost entirely, relies on weights as developed by NAVSEC. This applies equally to highly sophisticated electrical systems and hull steel. Almost no distinction is made for special materials, ship complexity or special requirements except to the degree it may be reflected on old bids of what are believed to be similar ships or systems. Further, the estimators rarely see the ship being estimated so that they can personally make these judgments of similarity with assurance.

Using the system and methods described, the basic ship cost estimate is derived. Various other sub-processes come into play, however, before the ship end cost estimate is completed.

(2) Estimates For GFM Are Provided By Other Systems Commands And By Organizations Within NAVSEA

Table III.3 lists types of major GFM included on ships, together with the source responsible for supplying cost data.

TABLE III.3

SOURCES FOR GFM ESTIMATES

Command	GFM Inputs For Ships
NAVAIR	Catpults, Arresting Gear, Landing Aids, Shop Equipment
NAVELEX	Communication Equipment, Electronic Countermeasures
NAVSEA 06	Radars (including Fire Control), Sonars, Launchers, Guns
NAVSEA 04	Naval Tactical Data System AN/UYK-7 Computers, Turbines, Gears, Generators, etc. Gas Turbines, Pollution Equipment
NAVSEA 08	Nuclear Propulsion Equipment
BUMED	Medical Equipment
SPECIAL PROJECTS	Strategic Ordnance

For the most part, cost estimating for GFM items within NAVSEA is a responsibility of the PARMs. In NAVSEA 06, the Weapons Systems and Engineering Directorate, providing cost estimates is the responsibility of the hardware Project Manager. Cost estimating, however, is a collateral duty as he must allot the major share of his time to design, procurement and delivery of systems and equipment. In NAVSEA 04, the Fleet Support Directorate, cost estimating is the result of deriving prices from existing contracts or vendor quotes since most of these systems have been previously procured via NAVSEA contracts. The variety and numbers of equipments managed by PARMs of all types are shown in the following Table.

TABLE III.4

TYPES AND APPROXIMATE NUMBERS OF WEAPONS SYSTEMS ESTIMATED

Gun mounts	15
Gun Fire Control Systems	6
Launchers for Missiles or Aircraft	11
Guided Missile Fire Control Systems	9
Underwater Fire Control Systems	6
Search and Countermeasure Radars	35
Surface Ship Sonars	22
Surface Ship Depth Sounders	2
Submarine Sonars	47
Submarine Depth Sounders	14
Central Processing Units for Computer Systems	7
Electronic Countermeasure Systems	50
Total	224

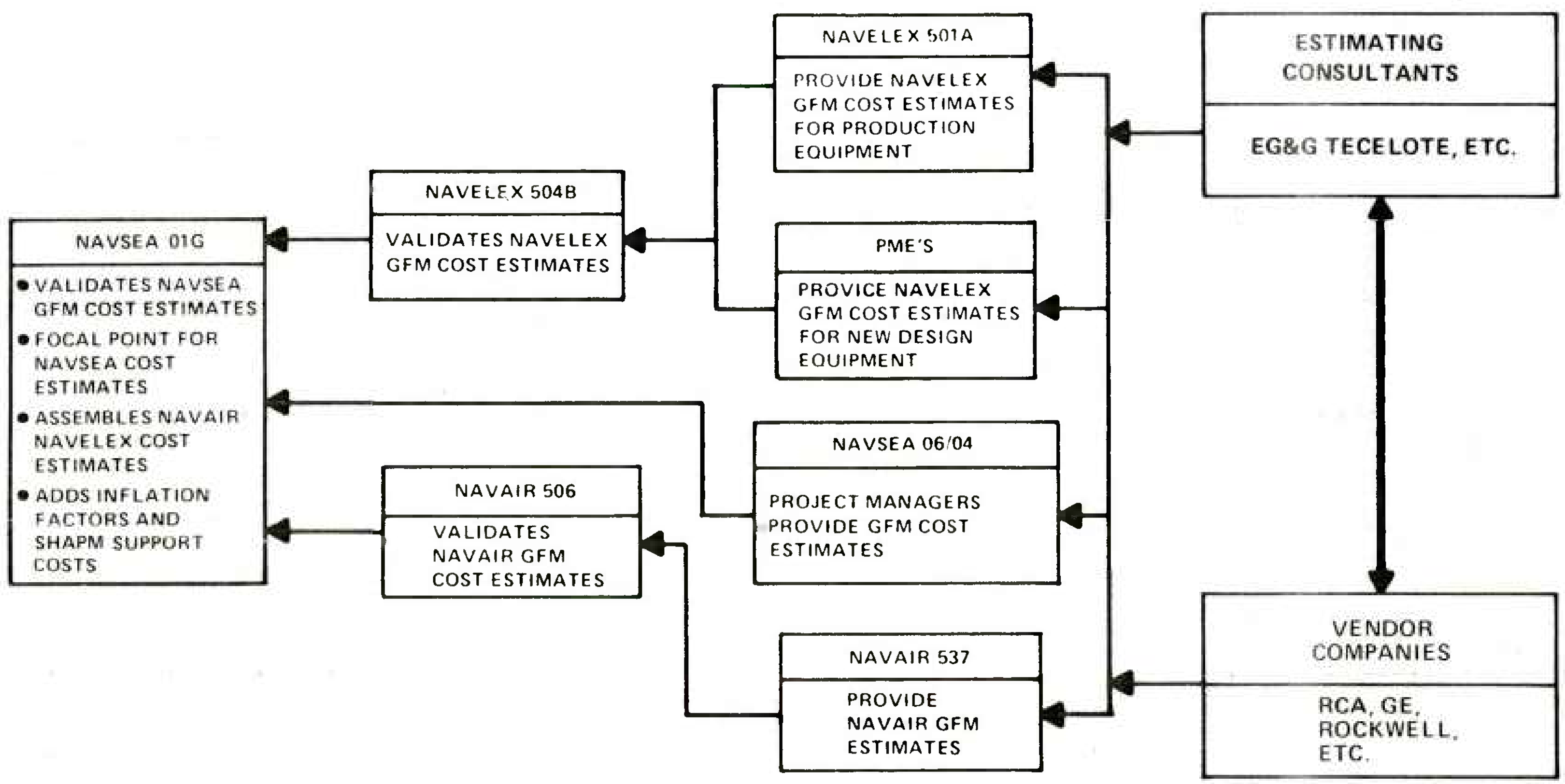
GFM estimates are requested by NAVSEA 01G from the PARMs. Personnel within PARM offices work with independent contractors or manufacturers of the equipment to arrive at an estimate for a particular ship or GFM configuration. The completed estimate is then reviewed by management and sent back to NAVSEA 01G. Figure III.8 shows the general estimating process for GFM.

It is important to note the difference in estimating philosophy between the PARMs and NAVSEA 01G. The PARM's responsibility is to provide realistic cost estimates and then control future production prices in line with the hardware contract. On the other hand, NAVSEA 01G must insure that the SHAPM will allow sufficient funding to cover the hardware cost plus amounts for contingencies related to design, installation, integration, test firings, Weapon Systems Accuracy Tests, Consolidated Operability Tests, etc. Further, NAVSEA 01G includes inflation factors as necessary and margins for projected engineering changes. The NAVSEA 01G cost estimate will, therefore, be higher than that submitted by the PARM.

The Navy, by means of ship specifications, requires the shipbuilder to integrate GFM into the ship as part of the ship construction process. This includes receiving, storing, installing and performing checkout and tests of the GFM items. This process is complex in its own right and is often a construction related cost driver. In reviewing

FIGURE III.8

GFM COST ESTIMATING



the estimating process, this complex problem of installing, checking out, and testing GFM is not treated as a separate line item. Some portion of this cost is included in each of the nine line items of the basic ship estimate.

(3) The Ship Cost Estimating Branch Also Develops Estimates For Other Items Associated With The Construction Of Ships

Figure III.9 is typical of work sheets used by estimators in SEA 01G to collect and summarize available data. Examples of the kind of information included are:

- Construction Plans -- Data is obtained from a SHAPM for a similar ship. This includes costs, numbers of drawings, etc., which are projected by the estimator to be applicable to the estimate being computed.

- Construction Plans Change Orders -- A percentage of the previous item is applied for costs expected in later years of the program.

- Stock Spares -- Lists are provided by NAVSEC or PARMs. Analogous historical data and judgment are used to price out the furnished lists.

- Basic Change Orders -- Estimates vary by type of ship and are based on historical data. On lead submarines, 12 percent of basic cost may be used (eight percent for hard core and four percent for inflation). Follow ships at the same yard, or at other yards, will receive different reduced percentages.

ESTIMATED COSTS FOR CONSTRUCTION/CONVERSION OF NAVAL VESSELS NAVSHIPS 7130/1 (REV. 10-66)

IDENT. NO	ITEM	HARD CORE	PROJECTED GROWTH	END COST
111	CONSTRUCTION PLANS			
113	CONSTRUCTION PLANS CHANGE ORDERS			
121	CONTRACT PLANS AND WORK STUDY			
531	STOCK SPARES			
541	TEST & INSTRUMENTATION - H M E			
821	ELMO SYSTEMS INTEGRATION			
	SUB-TOTAL			
211	BASIC CONTRACT OR PROJECT ORDER			
213	REHABILITATION			
311	BASIC CHANGE ORDERS			
414	ELECTRONICS PROTOTYPE HARDWARE			
418	ELECTRONICS PRODUCTION			
452	ELECTRONICS DEVELOPMENT			
521	PROPULSION MACHINERY	GOVERNMENT FURNISHED MATERIAL		
525	H M/E EQUIPMENT			
526	H/M E PROTOTYPE HARDWARE			
553	H M E DEVELOPMENT			
563	OUTFIT MATERIAL - H M E			
1111	FUTURE CHARACTERISTICS CHANGES			
1112	FUTURE DELIVERY CHARGES			
2291	ESCALATION GROWTH			
	SUB-TOTAL			
711	POST DELIVERY			
813	ACCOMMODATION BARGES			
	SUB-TOTAL			
	NAVSHIPS ESTIMATED COSTS - TOTAL			
	NAVORD ESTIMATED COSTS - TOTAL			
	NAVAIR ESTIMATED COSTS - TOTAL			
	GRAND TOTAL			

☐ NEW ☐ CONV	SHIP TYPE	☐ LEAD ☐ FOLLOW	SCB	F. Y. PROGRAM
CONV. FROM		SHIPYARD		DATE

- Testing and Instrumentation -- This cost is based on analogous historical data. The estimator's judgment is used heavily to establish an estimate based on type of ship, the shipyard, etc.

- Future Characteristics Changes -- The amount used in the estimate is furnished by OPNAV. It may be "zero" to $10 million on a complex ship.

Other considerations in an estimate may include models and mock-ups, inspection services, post delivery charges, etc., and the estimating process for these is similar to that described for the preceding items -- obtain data from another command, or from NAVSEA 01G files, and modify as required for current use.

The practice used to estimate miscellaneous end cost margins for changes, etc., is to develop more or less standard percentage factors based on experience related to the basic ship or GFM item. Some of these were developed some time ago and the derivation or rationale is no longer available. It is not the practice to up-date these factors on a regular basis from current return cost experience.

A review of a large number of actual estimate files revealed a variety of different kinds of documentation. For the most part, the estimates are hand-written, hard to follow, with only sketchy reference to the origin of technical data and CERs. There is generally a very poor record of the bridge from earlier estimates to more recent ones and little explanation of the basis for estimate changes is available. This could indicate both a lack of time to properly document estimates and/or a lack of supervisory discipline.

*   *   *   *   *

The basic estimate for a ship is worked up using engineering and construction information which is adjusted as necessary to reflect economic and market conditions expected during the building period. The adjustments are made using factors which allow for future escalation, productivity changes, overhead increases and the like which are prepared by the second group within NAVSEA 01G.

7. <u>THE COST ANALYSIS BRANCH (NAVSEA 01G2) PREPARES GUIDELINES FOR USE WITH BASIC SHIP COST ESTIMATES THAT ALLOW FOR ECONOMIC, INDUSTRIAL AND MARKET TRENDS</u>

In the years before the Cost Analysis Branch was created, estimators did their own economic analysis on an ad hoc basis, maintaining individual card files for overhead factors, labor rates, inflation estimates, etc. There was no effort to generate information in a standardized, methodical manner. In the absence of specific guidance, a wide range of economic assumptions were possible. For this reason, the Cost Analysis Branch was formed.

The primary responsibility of the Cost Analysis Branch is to furnish guidance for the Ship Cost Estimating Branch, to maintain necessary industry information and forecast industrial trends. A secondary responsibility relates to the performance of special studies on request from other Navy departments.

The guidelines maintained or under development are the following:

- Material inflation trends
- Labor rates and inflation trends at private shipyards
- Labor rates at naval shipyards
- Material escalation during life of contract
- Labor rate escalation during life of contract
- Quick estimate of escalation
- Small boat escalation
- Overhead rate trends at private and naval shipyards
- Productivity trends
- Market analysis (probable bidders)
- Profit trends
- Costs of social legislation
- Costs of metrication
- Pollution abatement
- Out-year guidelines

(1) <u>The Material Cost Index Provides Inflation Protection In The Material Portion Of Estimates</u>

One of the most important estimating steps is to adjust historical material costs to represent economic conditions of the time period during which the ship is to be built. In the interests of preparing an accurate index, the Cost Analysis Branch abandoned the BLS material index systems which were not considered representative of shipbuilding elements and formulated its own index based on material items related to the Ship Work Breakdown System. Material inputs from ten shipyards and 146 vendors are now being used as basic inputs to the NAVSEA 01G index. The index is used for material inflation projections in all estimates and this upgraded version, tailored for naval shipbuilding materials, should result in more accurate material cost estimates.

(2) A Labor Rate Index Provides Similar Allowance For Inflation In The Labor Portion Of The Estimate

Since 1970, the Branch has produced an annual guidance table for use by estimators in selecting labor bid rates. Data sources for this task are some 80 union-management agreements, Bureau of Labor Statistics studies, historical bids, U. S. Department of Commerce statistics, naval shipyard employment figures and other sources. This guidance promotes consistency in all estimates and is intended to narrow the margin of error over previous personalized methods.

(3) Overhead Guidelines Are Used In Computing The Overhead Portion Of A Ship Estimate Which Comprises About One-Third Of The Total Cost

There was no systematic or thorough method of determining overhead rates for shipyards prior to 1972. Cost estimators applied a standard 70 percent rate to all labor estimates since that figure was representative for at least several shipyards.

In 1972, the Cost Analysis Branch began its system for providing specific guidance on overhead. Its objective was to predict the rates which each yard could be expected to use in its bid estimates two years in the future.

An intensive review of actual overhead accounts at a major shipyard was conducted in 1974 by the Cost Analysis Branch jointly with auditors from the Defense Contract Audit Agency. In 1976, a computer model was completed for one major shipyard. Work is underway on additional models, as the goal is to have a model for each major shipbuilder.

Overhead costs for other yards in annual guidance are established by continued trend analysis of gross quantities using current inputs from DCAA and recent bid data. The actual overhead rate for a shipyard varies constantly and yards record it on a monthly basis. To keep abreast of developments, the Branch adjusts its data and amends its forecasts as appropriate.

Because of the dynamic nature of pertinent elements, an accurate overhead figure for the life of a contract is elusive. To further compound the problem, several recent developments detract from accuracy:

- Fringe benefits are rising faster than labor rates
- Changes in Social Security taxes, new environmental regulations, increased safety standards, etc., were hard to predict a few years ago when budget estimates were made for work now under contract.

- Cost of energy has been difficult to predict.
- Labor turnover and absenteeism has increased. Loss of skilled craftsmen requires constant training programs.

The latest national overhead average for the prinicpal yards doing Navy work is 105 percent, with a range of 70-144 percent and the trend is upward as noted above. Accurate forecasting is growing in importance, yet the difficulty in doing so is increasing.

The judgment of analysts in making overhead predictions and the judgment of estimators who use the guidance is not infallible, and they may be victimized by unexpected events in the economy, as has been frequently the case. Judgments should be evaluated by periodic comparison with actual overhead return cost data that may be available through DCAA or other audit organizations and the system adjusted as needed to further advance the accuracy of predictions.

Since overhead can be such a large part of the total ship cost, a special study has been made and is included as Exhibit D.1 to Appendix D. A significant finding of the study is that in the six year period from 1969-1975 direct labor cost grew 53 percent while overhead grew 74 percent -- this greater increase being due to a rapid increase in the cost of labor related fringes and benefits. The study also shows the impact on overhead that can be caused by a ship construction stretch-out, i.e., if a two year construction schedule is extended to four years, the overhead rate could be expected to increase as much as 80 percent or increase from 80 percent to 145 percent of direct labor.

Other overhead component costs have increased due to the pressures caused by social legislation. These problems have been discussed in Chapter II, but certainly deserve increased attention by the Cost Analysis Branch.

These and other overhead costs are not usually given as much attention as other more obvious considerations in the estimating process. It is suggested that overhead cost should be given careful analysis and that the practice of expressing it in terms of a percentage of direct labor should be supplemented by an estimate of absolute overhead costs.

(4) Prediction Of Escalation Over The Life Of The Contract Is A Key Estimating Factor

At this point a word of explanation is in order to distinguish how the words "inflation" and "escalation" are used by cost analysts in SEA 01G. Inflation is used to express general economic growth and also growth during the period prior to contract award. Thus, inflation factors are used at the discretion of the estimator to inflate old material or labor cost for the purpose of developing an estimated cost for some future date. Escalation, on the other hand, is inflation-related cost growth after contract award. The factors in this case are defined in the contract in the form of indices accepted throughout the industry.

Two basic escalation clauses are in effect on current Navy ship contracts. The clause written in 1962 applies to most ships now under construction. Payments for escalation are made quarterly in accordance with a pre-established, apportioned rate for labor and material expended (not including change orders) which extends to the contractual delivery date and not beyond. These restrictions were criticized by shipyards as not representing actual conditions and have resulted in some claims. To correct this condition, a revision to the escalation provision was instituted called the "Marshall Clause". This clause, put into effect in 1975, extended escalation payments to actual delivery date. The 1962 and 1975 clauses both rely on the BLS indices for adjustments to material and labor.

Since escalation deals with future events, and BLS indices are historical, it was necessary to forecast the future behavior of BLS indices. A method to project escalation was developed by the Cost Analysis Branch for material and labor which was first used in 1974. It is amended annually to show latest actual indices and to forecast them for a minimum of four years. Extrapolation for longer range forecasts is by extension of the four year trend curves.

The mix of materials used in these BLS indices is not an accurate representation of naval shipbuilding materials. It consists of the following: WPI-10-1 Iron and Steel - 45 percent; WPI-11-4 General Purpose Machinery - 40 percent; and WPI-11-7 Electrical Machinery - 15 percent. The formula was developed by the Maritime Administration in the 1950's for commercial vessels and is still used for computing contract escalation for naval ships primarily because it is accepted by the shipbuilders.

NAVSEA 01G is now working with the Bureau of Economic Analysis in developing a methodology to improve price prediction in shipbuilding and, more specifically, has initiated a "notional" ship concept. Under the notional ship approach, the Bureau of Economic Analysis is developing a completely new material index based on inputs from marine vendors, wholesale and other prices of materials commonly used in shipbuilding. It is anticipated that this approach will provide the shipbuilding industry and the government with a more realistic index than the one now used.

Three essential escalation outputs from these forecasts are produced by the Cost Analysis Branch: first, an escalation estimate for the total cost of each new ship in the budget; second, earned escalation and a forecast of future escalation costs for each out year for all ships under construction; third, a balance sheet showing the surplus or deficit for the entire escalation account for ships under contract to be used in the next year's budget.

(5) Market Analysis Is Performed To Aid Estimators In Predicting The Ultimate Builder Of A Ship

In 1974, the Cost Analysis Branch began to provide guidance to estimators on future market conditions. It now predicts the shipbuilding workload in 17 major shipyards two years in advance and indicates the most likely bidders by ship type in the program. The purpose of this analysis is to guide estimators in selecting appropriate overhead and profit rates for those yards having the greatest potential to undertake new work.

This factor alone can influence price substantially. In a competitive market where four or five qualified bidders respond, one could expect a low bid -- possibly 25 percent less than when only one bid is received. In the case of limited shipyard capacity, such as nuclear ships, a detailed analysis of impact of new program requirements must be made in light of existing workload and the alternative uses the owners of these facilities have available to them.

The review of NAVSEA 01G procedures indicates an awareness of these considerations, but little, if any reflection of such analysis are found in the cost estimates, themselves.

(6) <u>A Productivity Index Is Provided To Estimators Based On Bids And Returned Costs</u>

When historical costs are used in estimating labor for similar current ships, estimators must make adjustments for various factors with productivity being an important one. In the past, estimators used their own judgment, but since 1969, the estimators have been using guidance provided by the Cost Analysis Branch.

Measurement of productivity in ship construction has eluded quantitative analysis because of the complexity and changeability of factors. Several studies have been commissioned by SEA 01G but were found to disagree to such an extent that they could not be used with confidence. The Cost Analysis Branch relies principally on recent experience to predict trends in productivity for budget estimates. The productivity trend has generally been downward in all years, except where modernized facilities were provided; even in these shipyards, however, it only leveled off and very little overall improvement has been indicated.

Productivity is best observed by the shipyards themselves. They are aware of current changes in management, technology, facilities, the work ethic, loss of skills, turnover of labor force, impact of changing safety regulations, and costs on a shop basis. These are reflected in returned costs and in turn, in their bids for future work.

The Cost Analysis Branch has analyzed shipyard bids, returned costs and obtained comparable analyses from the Maritime Administration for commercial ships to determine trends on which to base a gross productivity measure. At present, the net result of all the studies is an instruction to add an additional 15 percent to labor manhour estimates based on past bid data.

This report contains a special study on productivity, entitled "Factors Affecting Shipyard Productivity", as Exhibit D.2 to Appendix D. Fourteen organizations were surveyed, i.e., major U. S. shipyards, naval architects, industry and government agencies, and most agreed on the general nature of productivity factors, but considered accurate estimates of their effects difficult or impossible in most cases.

There was close agreement among the participants in the survey on the order of importance of several factors: namely,

.	Stability combined with labor availability and turnover	1st
.	Navy considerations	2nd
.	Learning (Series production)	3rd
.	Social legislation and training	4th
.	Labor agreements	5th

Only a limited number of quantitative evaluations are available from the survey, but it is concluded that manhours may be doubled and cost increased by half over previous performance if all factors have their greatest unfavorable effects.

A review of Cost Analysis Branch efforts to evaluate and predict productivity has indicated that it is recognized as a most important element but treated as an industry problem. No special effort is directed toward evaluating individual shipyards or to giving this factor special in-depth treatment.

(7) Learning Curve Factors Are Also Provided

For accurate estimating on multiple ship contracts consideration must be given to expected decreases in material and labor costs on repetitive operations. Such decreases have been expressed historically by learning curves which are anticipated by cost managers in Navy and OSD and must be applied by estimators.

In 1969, a management research firm completed a study of learning curves for NAVSEA. It was based on bids which reflected actual experience and serious bidding intent. As returned costs were never checked against study findings, the real merit of its conclusions is still unknown. The curves shown in the study predicted downward trends for material and labor and have been used by the Navy since with varying degrees of caution.

These conditions changed adversely shortly after the 1969 study was completed. Unexpected labor turnover and loss of skills in yards destroyed the learning curve completely at one shipyard between 1970-1974. Another yard assumed no learning in pricing a series of large tankers started in 1973. Programs for multiple ship contracts which were priced out for construction in the late sixties on normal learning curves, regardless of source, can be expected to show overruns for this factor alone.

The current estimating approach is to use the cumulative average learning curve guidance from this study on a conservative basis. The estimator's judgment, however, is the key factor in avoiding erroneous learning predictions.

(8) Estimate Of Future Contractor Profit Margins Are Based Upon An Assessment Of Predicted Market Conditions

The first issuance of profit margin guidance in its present form was prepared by the Cost Analysis Branch in 1973 and has been continued each year. Before 1971, the policy was to add ten percent profit to an estimate of cost. As a result of Armed Services Procurement Regulations of 1971, it became necessary to develop a schedule of profit rates to be used by cost estimators. The schedule is based on such things as provisions for risk, level of performance, development of facilities and return on investment.

To augment this guidance, the Cost Analysis Branch tracks profit quotations from recent bids and from negotiated contracts. Likewise, an evaluation of market conditions is also made as they may affect profit quotes in future bids.

(9) A Number Of Cost-Related Special Studies Have Been Made The Responsibility of SEA 01G2

As a result of Congressional and Department of Defense improvements over the years, a number of special tasks have fallen to SEA 01G2 staff. Instructions have been issued by various echelons of management which call for on-request studies of selected acquisition program elements such as Life Cycle Costing, Should Cost studies, etc. Since these studies require some cost and economic analysis capability, SEA 01G is generally assigned the task. Tasks are requested randomly and with little or no regard for available resources. For high priority studies, staff is required to defer basic estimating in favor of these special assignments.

A brief review of the special request items are as follows:

- Technical Cost Analysis -- is a structured in-depth analysis of a contractor's proposal by a team of Government technical experts.

- Should Cost -- is a concept of contract pricing based on an in-depth cost management and production analysis at the contractor's plant for the purpose of developing a realistic price objective which reflects reasonable, achievable economies and efficiencies.

- Life Cycle Costing -- is an analysis technique which considers research and development , investment, operating and support and other costs of ownership in the decision-making process and in selected cases for the construction of weapon systems, equipment, hardware, and related items.

- Design-To-Cost -- means selecting a unit cost goal and developing a product with that goal as a principal parameter.

- Cost Modeling -- is an estimating tool wherein a set of mathematical relationships is arranged in a systematic sequence to formulate a cost methodology in which outputs (cost estimates) are derived from inputs (descriptions of equipment or system).

- Field Audit -- is the review and evaluation of field activities relating to policies, procedures, methodology, and capability to perform cost estimating.

- Central Cost Monitor -- is the organizational unit which acts as the SYSCOM focal point for establishment of estimating policies and procedures to be followed by organizations and individuals not within the established central cost estimating group.

- Contract Cost Data Reporting -- replaces the series of performance reports, that have been known in the past as CIRs, C/SCS, etc., that are to be periodically submitted by contractors to insure that contract performance and costs are being obtained. Certain disputes arise between contractors and the government with regard to these submittals and NAVSEA 01G is responsible for resolving these disputes.

Table III.5 shows the Cost Estimating Functions of NAVSEA 01G in relation to the special study type of activities required. It shows professional time spent on each function and indicates whether or not these functions are important to the overall estimating responsibility of NAVSEA 01G. It can be seen that very little time is spent on the special projects and some thought should be given to their importance in the entire scheme of things. In fact, the following may be in order.

TABLE III.5

COST RELATED ESTIMATING AND ANALYSIS FUNCTIONS

Function	Directive	Need To Develop Good Estimate Or Data	Annual Man-Years Effort
Regular Activities			
Conceptual/Parametric	NAVSEA INST 5400.1	Important	2.0
Budget	NAVSEA INST 5400.1	Important	6.0
Contract	NAVSEA INST 5400.1	Important	1.2
Contract Cost Analysis	NAVSEA INST 5400.1	Important	0.2
Technical Analysis Review	NAVSEA INST 5400.1	Important	0.8
Economic Forecasting	NAVCOMPT INST 7111/NAVSEA INST 5400.1	Important	2.0
Cost Modeling	NAVSEA INST 5400.1	Important	0.6
Overhead Analysis	SECNAV INST 5000.2	Important	0.4
Specialized Program/Software Costs	MIL-STD-881	Important	0.9
Cost Estimate Validation	NAVMAT INST 7000.19A	Important	1.0
Central Cost Monitor	NAVMAT INST 7000.19A	Important	0.05
Documentation	NAVMAT INST 7000.19A	Important	1.25
			16.4
Special Activities			
Should Cost	ASPR 1-337/CNM PPM #55	Nil	0.5
Economic Analysis	DOD INST 7041.3/SECNAV INST 7000.14A	Nil	0.2
Life Cycle Costing	NAVSEA INST 5432.1B/OMB Circ. #A-109	Nil	0.2
Design-To-Cost	DOD INST 5000.28/CNM PPM #48	Important	0.4
Field Audit	NAVMAT INST 7000.19A/NAVSEA INST 5400.1	Nil	0.05
Contract Cost Data Reporting	DOD INST 7000.2/NAVMAT INST D5240	Important	.05
			1.4

- Review of directives to determine if these functions are still required.
- If required, provide resources so NAVSEA 01G can carry them out.
- Transfer function to some other office if it is thought to be a better option.
- Contract out its performance.

8. THE EVALUATION OF THE NAVSEA COST ESTIMATING ORGANIZATION PROVIDES EVIDENCE THAT STAFFING IMPROVEMENTS ARE REQUIRED

As part of the evaluation of NAVSEA 01G, interview and rating forms were developed for use in visits with 23 presently employed professional personnel. Over the period studied, 1966-1976, 20 other professionals were employed in the Division at various times and interviews were conducted with five of these employees and ratings developed for 11 others by reviewing personnel records. As a result, 91 percent of the total roster for ten years was researched.

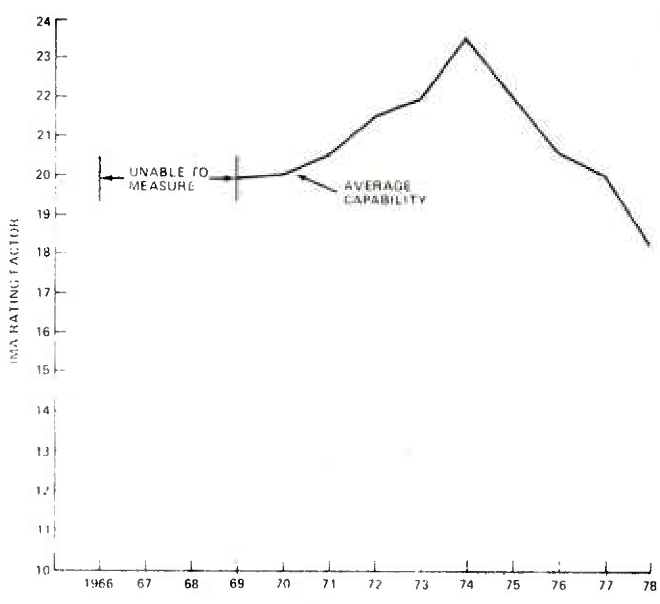
Desk interviews up to two hours duration were held with each of the current staff. These were followed by numerous discussions held over a three month period with key personnel in order to identify their responsibilities, activities, and problems. Exhibit D.3 in Appendix D outlines interview methods and describes the rating system in detail.

The results of the desk audits were assembled and are presented here in graph or summary form for as much of the 1966–1976 period as it was possible to obtain. The illustrations give a general description of capability trends and performance factors relative to NAVSEA 01G staff.

(1) Experience And Grade Level In NAVSEA 01G Are On A Downward Trend

Figure III.10 shows that the trend of average capability has been declining since 1974. (The IMA Rating Factor ranges from a low of eight for a new trainee to 40 for an experienced and well-qualified estimator.) This decrease is attributable to the departure of several experienced personnel -- all in Grades GS 13 to GS 15 -- and the influx of recent college graduates and others with less experience to replace them at lower grades.

FIGURE III.10
TREND OF AVERAGE CAPABILITY OF PROFESSIONAL STAFF
SEA-01G



PREPARED BY IMA
SEPT 1977

Table III.6 supports the above Figure in that it shows a large and adverse change in experience in recent years. This trend cannot be expected to improve so long as it is Navy policy to reduce the average grade level and to restrict hiring to personnel on the "stopper list".

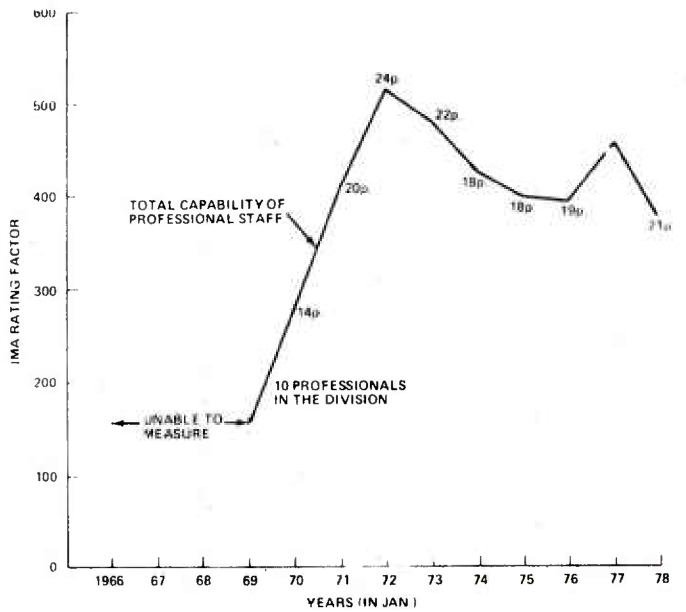
TABLE III.6

YEARS OF EXPERIENCE OF PROFESSIONAL PERSONNEL, SEA 01G
(as of December 1976)

Number of Years	Persons in 1976	Persons in 1975	Persons in 1974	Persons in 1973
1	6	4	3	0
2	5	3	0	0
3	3	0	0	3
4	0	0	2	3
5	0	2	3	5
6	1	3	5	4
7	2	2	4	1
8	2	4	0	1
9 or over	4	1	1	1
Totals	23	19	18	18
3 yrs. or less	61%	37%	17%	17%
Over 5 years	39%	53%	56%	39%

A companion graph, Figure III.11, shows a relative measure of total capability in the Division. It shows the sum of the IMA Rating Factors for the total staff in NAVSEA 01G since 1969. The number of personnel and per person capability increased until 1972. The addition of the Combat Systems Estimating Section in 1974 was offset by a net loss of six persons and a loss in capability into 1976. By 1977,

FIGURE III.11
TREND OF TOTAL CAPABILITY OF PROFESSIONAL STAFF
SEA-01G

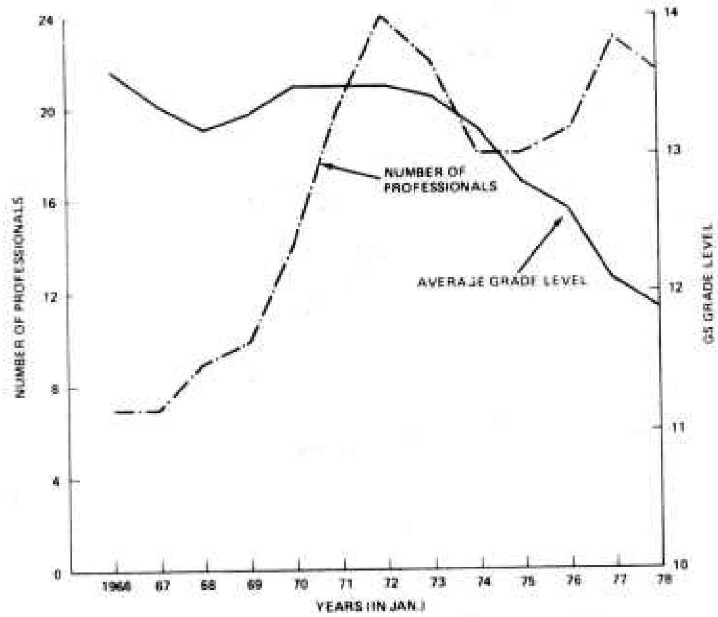


PREPARED BY IMA
SEPT 1977

there was an increase in capability but it still falls short of the 1972 level. The projected total capability will not increase substantially unless addition of experienced personnel is made possible.

Figure III.12 shows the reduction in average grade resulting from personnel changes in the past several years. It can be seen from this graph that, based on grade level and experience, the Division shows declining capability.

III.12
FIGURE
TREND OF AVERAGE GRADE LEVEL OF PROFESSIONALS
SEA-01G



PREPARED BY IMA
SEPT., 1977

(2) <u>The Educational Background Of The Current Staff Is Exceptionally High</u>

The educational background of the current staff is high -- in fact, considerably above the level of estimators in the private shipyards and certain other organizations surveyed. Bachelor Degrees are held by 91 percent of the staff and advanced degrees are held by 23 percent. Most personnel in the estimating group have a mix of engineering degrees, whereas in the analysis group, degrees in mathematics, business, and economics predominate. This composition is ideal for the nature of each group's work and the skills are generally well placed. Personnel with additional degrees in computer sciences, or training for computer work, and a law degree further round out the staff background.

The only basic talents considered lacking among staff are cost accounting, auditing expertise and purchasing experience. These skills would be beneficial and increase overall performance if, as a regular procedure, more returned costs were utilized. In private industry, estimating departments work closely with accounting and purchasing departments for current costs of materials, labor and overhead, and it is here that NAVSEA 01G could benefit from their experience.

Another observation regarding the staff's educational background is that a number of employees expressed concern that they can seldom work to their intellectual capacity. If this is the case and the office does not offer a desirable career path, high turnover can be experienced thus preventing the overall capability of the Division to grow. In contrast to this, the typical newcomer to the estimating department in a shipyard is a high school graduate with [illegible] college education and considerable experience in the shipyard's production or engineering divisions. What is more important, he considers estimating as a promotion to be sought after rather than a career starting point or stepping stone.

(3) A Lack Of Shipyard Experience Is Evident

The following data show the experience background of the current staff in NAVSEA 01G in terms of average number of years in.

- Cost analysis or estimating in Navy ... 5.7
- Cost analysis or estimating elsewhere.. 1.6
- Shipyard experience 1.3
- Other construction experience 1.6
- Engineering experience 4.2
- Shipboard experience 0.9
- Average Years Total Experience 15.3

The average of total experience indicates an adequate measure for estimating and analysis activities. However, the average is somewhat misleading as a guide to overall capability since this experience rests principally in the 39 percent of staff with five or more years experience. The preceding information on personnel experience, Table III.6, shows how rapidly this group has and is declining in size. The average 5.7 years of estimating in the Navy is similarly misleading since it also is lodged principally in the same group.

The most important indicator on the chart relative to capability is the lack of shipyard work experience -- 1.3 years per person. This is considerably below the average of estimators in private shipyards, for example, and can be a significant obstacle to accurate material and labor cost estimating. As noted elsewhere, estimators themselves expressed concern about their lack of shipyard exposure. The organization will be seriously handicapped with regard to the experience factor if it is required to make estimates in more detail than currently practiced.

Because of over-education in some of the staff and the lack of practical experience overall, the Division could improve in the future by recruiting a few employees with less formal education and more practical training and experience in shipbuilding. It is estimated that there are about 1,500 people with estimating or planning experience to draw from in Navy field activities.

(4) The Key Factor In Cost Analysis And Estimating Is Experienced Judgment

Cost estimators and analysts require judgment to evaluate and interpret large amounts of data, adjust them as needed, and make evaluations and judgments relative to its current and future use; existing data rarely fits each estimating problem precisely. This is particularly so since the new SWBS system was established and ships have increased in complexity.

Training and experience in the shipbuilding process are vital to the development of proper judgment in estimators and analysts. As indicated, NAVSEA 01G is very thin on such experience. Its level of achievement can be attributed to the expertise of a few estimators and also to greatly improving guidance from the Cost Analysis Branch over the recent past. If more key personnel are lost, present capability would be seriously eroded.

9. <u>FAILURE TO HAVE ACCESS TO TIMELY AND COMPLETE COST DATA IS A MAJOR DETERRENT TO RELIABLE COST ESTIMATING</u>

It is a known fact that an estimator, no matter how talented, is no better than his data bank. The ship cost estimating function in NAVSEA has a data bank that is composed primarily of the following:

- Nine group bid submission on all ships
- One hundred group bid back-up on some ships
- Complete bid back-up on very few ships
- Return cost on complete ships generally in three categories -- labor cost, material cost and overhead cost.

In addition, miscellaneous return costs are available but, in general, no organized or systematic attempts have been made to provide more complete estimating information.

(1) <u>NAVSEA 01G Needs Better Cost Data Than Is Now Available To Prepare Credible Estimates</u>

In order to develop estimates that are commensurate with the degree of technical data that is available on repeat ships and sometimes on new designs, the estimate should be expanded from nine line items to as many groups for which there is good technical definition and time to calculate. With a well-organized data bank and current CERs, estimates of 50 to 100 line items should be feasible under current estimating conditions.

The data bank required for estimates with this degree of detail should include, in addition to what is now being used, at least the following kinds of data.

- Return costs on complete ships showing manhours and material cost for each of the shipbuilder's record of accounts associated with corresponding material quantities.
- Same as above on ships under construction where sufficient progress has been made to give return cost some value.
- Breakdown of shipyard overhead expense for completed work and work in progress.
- All bid back-up data available under the law.

(2) <u>A Significant Portion Of The Required Cost Data Is Somewhere In The Navy, But Does Not Get To The Cost Estimators</u>

Much of the above data will be hard to come by but DOD INST 7000.2 should be used to the maximum. The contracting officers must be required to obtain all the bid data available under the law and give the estimators full access and custody if necessary.

The SupShips Offices, Naval Shipyards and DCAA office at the shipyard have access to much of the data required by estimators. This review of the estimating process has shown that contacts between NAVSEA 01G and these offices are limited.

10. <u>THE FORECASTING OF BUILDING PERIODS IS NOT ACCURATE AND CAUSES SUBSTANTIAL APPARENT COST GROWTH</u>

Cost growth due to inflationary effects are felt in many ways. Factors such as delay and schedule change, although cost problems in their own right, also have an inflation component since labor and material continue to rise as the delay is extended. Allowances for uncertainties such as these are included in estimates but can be quickly expended in a climate of two digit inflation. Margins over the last few years have been grossly inadequate.

(1) <u>Ships Are Not Being Delivered On Their Planned Delivery Dates And This Is A Major Cost Driver</u>

Table III.7 shows that ships are delayed, on average, over two years from the delivery date planned at the time they were authorized by Congress. The responsibility for evaluating the shipbuilding industry capacity and shipbuilding periods rests with NAVSEA 071 in the Industrial and Facilities Management Directorate.

TABLE III.7

ORIGINAL VERSUS CURRENT DELIVERY DATES

	Percent Completion of Construction		
	10% up	25% up	50% up
No. of Ships	28	21	17
Total Years Delay	61	50	43
Years Delay/Ship (Average)	2.2	2.4	2.5

SOURCE: Hearings of the Senate Armed Services Committee, February 1976

Ship cost estimates contained in budget requests are presumed to be based on the originally planned delivery date and, if allowances are made for delays, they certainly are not of the magnitude of the two and one-half year average indicated above.

Refined estimates of the impact of these delays on costs can only be made on a detailed, ship by ship basis. It is possible, however, to develop a rough estimate using manning curves and inflation rates. Figure III.13 shows an estimated manning plan for the budget funds appropriated by the Congress and the current manning plan which is made up of actual manning and a projection to completion. The points at which 50 percent of the direct labor have been expended are 3 1/4 years apart. This actually means that the bulk of the expenditures for shipyard labor and overhead are being deferred 3 1/4 years. As originally budgeted, about 62 percent of the costs of the CVN 69 were in the basic construction contract and, thus, subject to the 3 1/4 year delay.

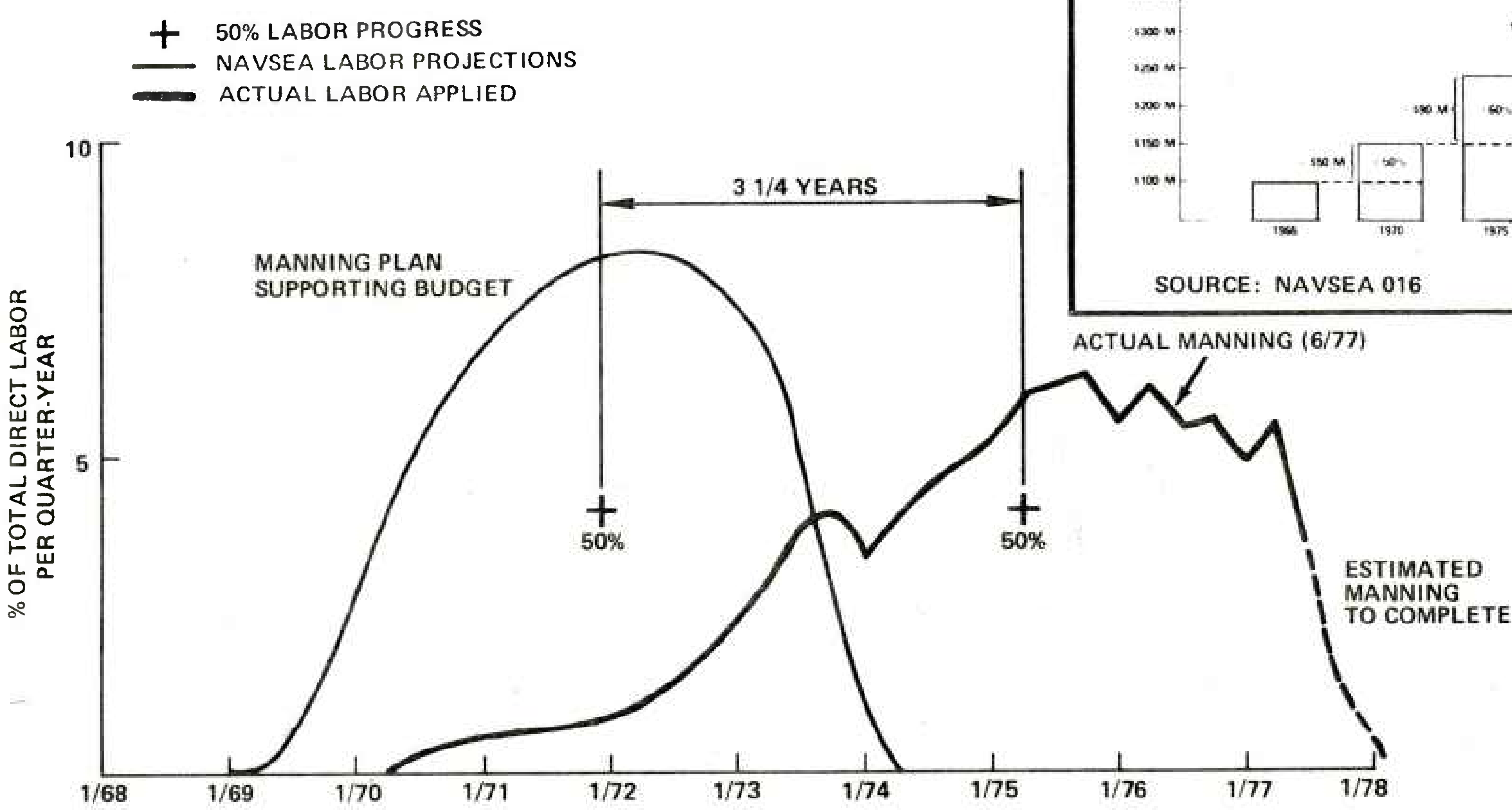
Similar analyses were made for the LHA 2 and the AS 39. The corresponding delays and percentages are: LHA 2, 2 1/4 years or 88 percent; AS 39, 3 years or 78 percent.

The cost of these delays can be approximated by using the above data and the Ship Price Inflation Index (Figure III.14) developed by NAVSEA. This index indicates that inflation in the price of ships is about 11 1/2 percent per year during the years in which the delivery delays on these three ships were occurring. The results

FIGURE III.13

CVN 69

SHIFT IN LABOR APPLICATION

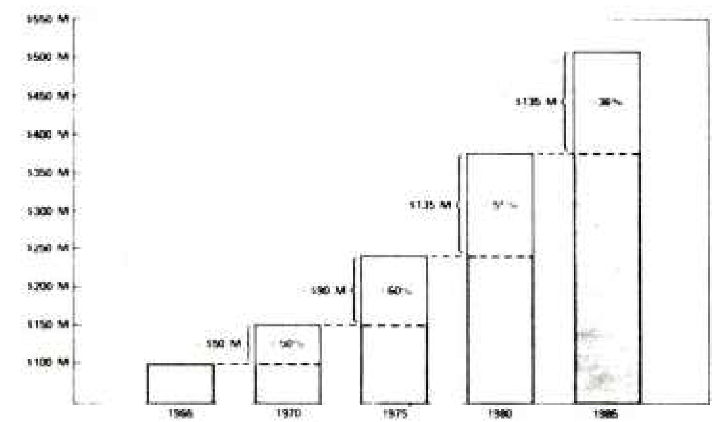


SOURCE: NAVSEA 075

FIGURE III.14

SHIP PRICE INFLATION

(EXACT SAME SHIP: NO CHANGE TO SPECIFICATIONS, WEAPONS SYSTEMS OR PERFORMANCE)



SOURCE: NAVSEA 016

of this costing follow:

TABLE III.8

COST OF DELAYED DELIVERIES
(Millions of Dollars)

	CVN 69	LHA 2	AS 39
Current Estimate	734	224	152
Original Estimate	510	144	93
Total Increase to Navy	224	80	59
Increase Due to Delay (1)	116	33	25

(1) Cost of delay to both Navy and Contractor

These amounts are conservative in that no inflation for GFM or other non-shipyard costs is included. Also, no consideration was given to the fact that disruption caused by such delays invariably increases the man-days of direct labor expended. Clearly, delays in delivery beyond the date used in estimating the end cost to be approved by Congress are a major cost driver. A reasonable estimate requires not only an adequate technical definition for pricing, but an accurate prediction of the construction time period.

11. THERE ARE NO STANDARDS OR PROCEDURES WHICH PROVIDE CONSISTENTLY ACCURATE GFM ESTIMATES

The review of organizations producing estimated costs for future GFM ship installation showed that serious deficiencies existed in the methodology for estimating this equipment. Each organization differed with respect to estimate documentation, utilization of cost verification procedures, use of return cost data, etc. No judgment can be made on this situation since no standard has been established to which these organizations can comply. The prime responsibilities of the groups researched are technical in nature and their performance is judged primarily on the capability and availability of the GFM item. Not much emphasis is placed on the budgeting or planning processes.

Becuase of this situation, cost information is submitted for budget preparation in a variety of formats with little back-up data. Figure III.15 indicates the wide variety of cost estimating practice which exists within GFM organizations.

A number of problems can be identified from this matrix.

- The NAVSEA 06 and 04 codes are not staffed with adequate cost estimating capability. There are only two professional cost estimators in NAVSEA 06 and none in NAVSEA 04.
- Cost data banks are not available in NAVSEA. Fragmented cost data can be found in the various organizations as part of the system/equipment technical files. Complete files containing cost estimates based on technical baselines, changes to

FIGURE III.15

CHARACTERISTICS OF GFM CODES STUDIED

	SEA 65311	SEA 04	SEA 65322	PMS 399	PMS 404	SEA 661C	SEA 06H
Dedicated Cost Estimating Staff							
. Yes							X
. No	X	X	X	X	X	X	
. Number of Professional Estimators	0	0	0		0	0	2
Cost Data Banks Are:							
. Good					X		
. Mediocre		X		X		X	
. Poor							
. Computerized							
. In Contractors Custody					X		X
. Not observed	X		X				
Return Cost Data From							
. Contracts	X	X	X	X		X	X
. 7000.2					X		
. None							
. Manufacturer (not 7000.2)							X
Escalation & Inflation Predictions							
. Uses OSD						X	
. Applied by SEA 01G	X		X	X	X		
. Develops own							
. Uses Contractors/Manufacturers		X					X
Review Procedures							
. In-house					X		
. None observed	X	X	X	X		X	
. By Contractor							X
Cost Estimates Are Done							
. By updating SEA 02 contracts	X	X	X				
. By private contractor					X		X
. By contracting the manufacturer	X		X		X	X	
. In-house							X
. By updating SupShip data				X			

	SEA 65311	SEA 04	SEA 65322	PMS 399	PMS 404	SEA 661C	SEA 6524	SEA 06H
Cost Estimates Are Usually								
. Low								
. High	X			X		X	X	
. Vary			X					
. Within 10 Percent		X			X			X
Validation Of Cost Estimate								
. By Private Contractor					X			X
. Not Done	X	X	X	X		X	X	
. In-house								
Type Of Estimating Done By Navy								
. Analogy (update contracts)	X	X	X	X		X	X	
. Parametric					X			
. Engineering								
Type Of Estimating Done By Contractor								
. Analogy								X
. Parametric					X			X
. Engineering					X			X
Estimate Is For What Purpose								
. Development					X			X
. Budget	X	X	X	X	X	X	X	X
. Contract	X	X	X	X	X	X	X	X
. SPD	X	X	X	X	X	X	X	X
. SARS					X			X

such baselines and estimates and estimating rationale for these items cannot be found. Exceptions are NAVSEA 06H where data banks are in the custody of a private contractor and NAVSEA 01G where cost data is received in various formats but not to the detail required for tracking cost estimates or cost analysis.

- It is too soon to evaluate the effects of DOD INST 7000.2 regarding return cost information. Thus far, the only return cost information to be found was in SEA 02 -- Contracts.

- The source of escalation and inflation predictions varies; in most cases these factors are applied by NAVSEA 01G. There are some NAVSEA 06 codes which prefer to use inflation factors provided by the manufacturer while others will use DOD indices.

- No central review procedure was observed in SEA 06. If a review is made, it is made in NAVSEA 01G which has very limited capability or resources.

- Cost estimates provided by NAVSEA 06H and SEA 04, in most cases were within ten percent of actual costs. However, most of the cost estimates provided by other SEA 06 codes did not follow any consistent pattern.

- PMS 404 employs a private contractor to validate cost estimates for the PHALANX (CIWS) and PMS 403 does the same for the AEGIS System. Validation of cost estimates for other SEA 04 or 06 GFM is not common practice.

- Cost estimating is usually done by SEA 06/04 by updating contracts. This is a natural by-product of the many repeat buys for systems/equipments in production. For the cost of equipment modifications, the manufacturer is usually contacted.

- The SEA 06 and SEA 04 cost estimates are generated for new development, budget, Ship Project Directives, or contract bid purposes.

In SEA 06 alone, there are presently 24 different offices procuring GFM. They establish and initiate changes to technical baselines, are responsible for GFM life cycle costs and for the cost information that is forwarded to NAVSEA 01G as input for SCN budget estimates. These offices also keep current technical and cost data for Ship Project Directives and as required, provide cost data to SEA 02 to aid in selection of successful bidders. There is very little coordination of these activities, however, and as a result, there is no uniformity of cost data or documentation.

Without standards or published procedures to guide the GFM estimating process, the lack of estimating consistency will continue.

12. THE IMPORTANCE AND COMPLEXITY OF THE COST ESTIMATING FUNCTION WARRANTS GREATER NAVSEA COMMAND RECOGNITION

In preceding sections of this chapter, it has been shown that estimating for naval ships requires large amounts of information from a wide variety of souces. It has also been shown that good estimating requires adequate product definition and accurate assessment of shipbuilding market and building periods. In order for the Navy to keep abreast of this information, estimators must have meaningful work-oriented contact with the industry, project offices and other Navy departments as necessary. The present environment and organizational position of the estimating division does not provide these essentials to good estimating. There is also a lack of clear-cut responsibility on the part of project and budgeting officials to manage to the budget approved.

Although the Commander, NAVSEA is responsible for ship estimates, it is clearly understood that he must rely on NAVSEA 01, SHAPMs and other SYSCOMS for important input. Thus, when estimates are deficient, no single person or office can be held responsible to the Commander. In order to be assured that the cost estimating organization has the authority to coordinate and have access to necessary inputs and required data for estimates it produces, a single office in NAVSEA should be established which will be directly responsible to the Commander NAVSEA.

This office should at least include what is now NAVSEA 01G and the shipbuilding scheduling function(recently absorbed in NAVSEA 071). If it is to be a responsible organization, it must also have resources to validate estimates prepared within NAVSEA and other SYSCOMs, establish risk margins and task NAVSEC or contractors to assist in estimate preparation as required. It must have a free hand in judging market/building periods, and shipbuilding capacity without overriding influence from SHAPMs.

13. CONTINUAL EFFORTS HAVE BEEN MADE OVER THE LAST TEN YEARS TO IMPROVE COST ESTIMATING FOR SHIP PROCUREMENT

As part of this study the organizational history of NAVSEA 01G has been reviewed starting in 1969 when a staff of ten prepared ship cost estimates for the Navy. At that time, only estimating for ships was done -- neither Government Furnished Material nor economic factors were part of their responsibility.

(1) Professional Staffing Increased By Fourteen Estimators And Analysts Between 1969 and 1972

By 1972, the original staff of ten estimators had been raised to 24; at this writing, professional staff now stands at 21 (excluding clerical staff and trainees). Recommendations made in the 1969 SCN Study led to the creation of a Cost Analysis Branch which now has ten professionals and this is where most of the growth has taken place.

The estimating branch grew by only four (from 10 to 14) during this time. An increase of three resulted in 1974 when three NAVORD estimators were combined with the ship estimators to become SEA 01G. The NMARC study which was completed in January 1975 recommended additional staffing for the cost estimating function. However, the only staff increase was a result of the Assistant Secretary of the Navy transferring three billets from NAVCOMPT to SEA 01G. The overall gain in the comparable basic ship estimating staff has actually, therefore, been only one job.

(2) Additional Analytical Staff Has Made It Possible To Make A More Systematic Appraisal Of Economic Factors Impacting Estimated Costs

The newly formed cost Analysis Branch now reviews and analyzes economic data in a more regular and consistent manner than previously performed. In the past, individual estimators provided their own opinions on these matters. The new arrangement provides standardized guidance for all estimators.

(3) A Method Of Classification Was Developed To Identify The Degree Of Risk Associated With An Estimate

A series of estimate classifications was developed which identify for an estimate user, the degree of risk to be associated with the estimate. The classification series went from A (most accurate) through C (budget quality but not best estimate) to F (ball park) or X (directed estimate).

It was a step forward in that it provided a basis for the idea that estimates have varying degrees of credibility.

(4) NAVSEA 01G Has Initiated A Training Plan For Its Personnel

In 1971, NAVSEA initiated a long range training plan designed to give each of its staff training tailored to their individual needs. The substance of the training program is described as follows:

- A thorough examination of all cost estimating and cost analysis positions was undertaken and the specific skills and knowledge necessary for an employee to efficiently produce cost estimates, cost studies, analysis, escalation projections, budgeting data, etc., were determined. These skill and knowledge requirements were then weighted to reflect the degree of importance of individual positions to the organization as a whole.

- Each employee was interviewed to determine the extent he had acquired the skill and knowledge requirements identified for his position through formal training or practical experience.

- A schedule of training on a yearly basis was established which emphasized that training most needed to attain the skill and knowledge requirements for each position.

- Training was not restricted to formal classroom instruction, but included job-related training, homework, and job rotation.

Budget constraints have minimized expectations regarding the training in that only $75/year/employee has been available for training purposes. About one week per year is spent in training each employee.

14. <u>IN SPITE OF IMPROVEMENTS OVER THE LAST DECADE, THE COST ESTIMATING AND COST ANALYSIS FUNCTION IN NAVSEA IS NOT ADEQUATE FOR THE COMPLEX AND DIVERSE DUTIES ASSIGNED</u>

The preceding review of the cost estimating and cost analysis process led this study to conclude that the following problems exist.

- The modern naval combat ship is probably the world's most complex and certainly one of the most expensive military systems being constructed.

- The budgeting process requires that a commitment to Congress on the estimated cost be made approximately two and one-half years before construction contract award and six to ten years before ship completion.

- The lack of program stability characterized by change of ship types and numbers places a heavy demand on the estimating staff to produce good estimates in a constricted time frame and often with poorly defined ships.

- As many as 50 different organizations within the Navy prepare cost estimates with varying procedures and documentation that contribute to the total ship construction program cost.

- The ship's cost estimating procedure is based on a highly aggregated parametric cost estimating process using only nine line items. This procedure facilitates estimate preparation with a minimum of effort and time. This procedure is not, however, responsive to the complexities of naval ships and data available within the Navy that could enhance the sensitivity and credibility of the estimating process.

- The ship construction cost data bank is inadequate for estimating tasks required by the Navy as it is unstructured, does not provide for systematic entry of up-to-date bid and return cost data, or retrieval of this data in rapid and usable form.

- Since 1969, NAVSEA has taken useful steps to improve their ability to evaluate economic, industrial and market trends.

- Since shipyard overhead is as large an expense as direct labor or material, it should be given more careful analysis and the practice of expressing it in terms of a percentage of direct labor should be supplemented by an estimate of absolute overhead costs.

- The composite BLS index now being used as a basis for determining material cost escalation does not adequately reflect naval ships and a new more representative index should be developed.

- The evaluation of market factors utilized to adjust cost during budget preparation is difficult and warrants a greater degree of analysis and recognition than now being given due to its importance.

- Recent changes in labor productivity warrant a special effort on the part of the Navy to identify and quantify factors causing productivity change and to reflect these in the estimating procedure.

- NAVSEA 01G has been assigned some cost-related functions for which it does not presently have the resources to carry out.

- The capability of the NAVSEA 01G staff, from the point of view of training and experience, has been steadily declining since 1974.

- The NAVSEA 01G staff has very little shipyard experience.

- NAVSEA 01G has formulated a training plan that has not been fully implemented because of lack of time and funding. The program is intermittent, lacks emphasis on field experience and is not performance oriented.

- The cost estimators do not have regular work-oriented contacts with their counterparts in industry.

- NAVSEA has allocated very limited resources to the task of estimating the cost of GFM.

- NAVSEA relies heavily on contractors' and manufacturers' assistance to provide GFM cost estimates.

- The cost estimating function within NAVSEA should be afforded greater command recognition and responsibility.

IV COST ESTIMATING AS PRACTICED OUTSIDE NAVSEA

In order to place the NAVSEA estimating function in perspective with other DOD and industrial entities that have comparable cost estimating functions, the activities and capabilities of the following organizations were reviewed:

- Within the Navy.

- Naval Electronics Systems Command	(NAVELEX)
- Naval Air Systems Command	(NAVAIR)
- Naval Facilities Command	(NAVFAC)
- Military Sealift Command	(MSC)
- Office of Chief of Naval Operations Systems Analysis Division	(OP96D)
- Naval Ship Engineering Center	(NAVSEC)

- In DOD outside Navy.

- Army Directorate of Cost Analysis	
- Army Material Development and Readiness Command	(DARCOM)
- DOD Cost Analysis Improvement Group	(CAIG)
- Center For Naval Analysis	(CNA)

- Shipbuilding Industry.

- Newport News Shipbuilding & Dry Dock Co.	(Newport News)
- National Steel and Shipbuilding Co.	(NASSCO)
- Bethlehem Steel Co./Shipbuilding Division (Sparrows Point Baltimore)	(Beth Sp Pt)

The wide range of cost estimating/cost analysis responsibilities, approaches, capabilities and procedures of these other organizations are shown in Figure IV.1 (A thru D following).

1. THE ORGANIZATIONS REVIEWED HAVE COGNIZANCE OVER THE PROCUREMENT OF A WIDE RANGE OF PRODUCTS AND PROGRAMS

The purpose of this chapter is to draw comparisons between the cost estimating capability of NAVSEA and the capabilities of a variety of other groups with similar functions. Prior to making these comparisons, however, a description of the estimating charter for each of these groups is provided.

(1) The Cost Estimating Group Of The Naval Electronics Systems Command Has As Its Primary Objective, Support Of Contracting Activities

The Cost Analysis/Estimating Group (ELEX 504B) is responsible for all cost analysis and estimating policy and guidance. The estimating group prepares and reviews cost estimates which are the basis for Command planning, programming, budgeting, and acquisition in the research, development, and production of electronic systems.

Specifically, the NAVELEX estimating group's responsibility for cost analysis and estimating in the Command includes the following.

FIGURE IV.1A

COMPARITIVE ANALYSIS
NAVSEA VS. OTHER ESTIMATING ORGANIZATIONS

	NAVY (Outside NAVSEA Headquarters)						OTHER DOD			PRIVATE SHIPYARDS			NAVSEA		
ESTIMATING FACTORS	NAVELEX	NAVAIR	NAVFAC	MSC	OP96	NAVSEC	Army (DARCOM)	CAIG	CNA	Beth. St. Sp. Pt.	Newport News	NASSCO	SEA 01G	SEA 06	SEA 04
<u>Major Responsibilities</u>															
Development Estimates				1st	1st	1st	2nd	1st	1st				3rd		
Budget Est.	3rd	1st	1st										1st	3rd	3rd
SPD Est.	2nd													1st	1st
Contract Est.	1st	3rd	2nd										2nd	2nd	2nd
Life Cycle Cost		2nd				2nd	1st								
Bids/Proposals										X	X	X			
<u>Secondary Responsibilities</u>															
Development Estimates	X													Some	
Budget Est.							X								
Contract Est.							X								
LCC		X				X							X	X	
Should Cost	X	X					X						X	X	
DTC							X						X	X	
DCP							X						X		
Economic Analysis	X	X			X		X	X	X	X	X	X	X		
<u>Annual Value Product Estimated</u>															
Over 3 Billion		X					X						X		
Between 1 and 3 Billion					X			X	X						
Between 1 and 0.5 Billion	X		X	X		X									
Under 0.5 Billion										X	X	X		X	X

LEGEND:
NA - Unknown Quanity
X - Indicate Applicability

1st - Primary Consideration
2nd - Secondary Consideration
3rd - Tertiary Consideration

IV.1B

COMPARITIVE ANALYSIS
NAVSEA VS. OTHER ESTIMATING ORGANIZATIONS

	NAVY (Outside NAVSEA Headquarters)						OTHER DOD			PRIVATE SHIPYARDS			NAVSEA		
ESTIMATING FACTORS	NAVELEX	NAVAIR	NAVFAC	MSC	OP96	NAVSEC	Army (DARCOM)	CAIG	CNA	Beth. St. Sp. Pt.	Newport News	NASSCO	SEA 01G	SEA 06	SEA 04
Product Complexity															
Highly Complex	2nd	X					X							1st	2nd
Complex	1st				X	X	X	X	X		1st	2nd	1st	2nd	1st
Commerical State of Art			X	X			X			X	2nd	1st	2nd		
Types Of Estimates															
Analogy	1st			Some	2nd			1st					2nd	1st	1st
Parametric	2nd	Most		Some	1st	X	X	2nd	1st				1st		
Engineering			Most	Some						X	X	X			
Computer Usage															
Little				X	X								X	X	X
Moderate	X		X							X	X	X			
Extensive		X				X	X	X	X						
Primary Data Source															
Bid Data					1st	X		X	X				X		
Return Cost		1st								1st	1st	1st			
Past P.O. (Contracts)	1st									3rd	3rd	3rd		3rd	1st
Manufacturer	2nd	2nd		1st			1st			2nd	2nd	2nd		1st	2nd
Consulting Contractor	3rd		1st		2nd									2nd	
Published Data			2nd	2nd											

LEGEND:

NA - Unknown Quanity
X - Indicate Applicability

1st - Primary Consideration
2nd - Secondary Consideration
3rd - Tertiary Consideration

IV.1C

COMPARITIVE ANALYSIS
NAVSEA VS. OTHER ESTIMATING ORGANIZATIONS

ESTIMATING FACTORS		NAVY (Outside NAVSEA Headquarters) NAVELEX	NAVAIR	NAVFAC	MSC	OP96	NAVSEC	OTHER DOD Army (DARCOM)	CAIG	CNA	PRIVATE SHIPYARDS Beth. St. Sp. Pt.	Newport News	NASSCO	NAVSEA SEA 01G	SEA 06	SEA 04
Data Bank																
Scale of Completeness and Accessibility (1 = Highest)	1										X	X	X			
	2	X	X	X				X						X		X
	3					X	X		X	X					X	
	4				X											
	5															
Percent Procurement Repeat Purchase																
Over 75%		X	X				X	X				X			X	X
Between 25 - 75%											X		X	X		
Under 25%				X	X	X			X	X						
Primary Estimate Source (New Prod.)																
Governement Staff		2nd	1st	2nd	X	X	X		X	X				X	2nd	
Contractor (Cons.)				1st											1st	
Manufacturer		1st	2nd					X			X	X	X			
Shipyard Staff																
Time Allowed For Best Estimate											6-17 wk.	12-15 wk		1 wk.		
Staff																
Cost Estimators (CE)		8	50-60	55		Ships 2		±100	Ships 1	Ships 1	20	37	19	14	2	1
Cost Analyst (CA)							5	260						15	31	36
CE/CA Secondary Function		50+	NA	Very Few	5			NA						None		

LEGEND:

NA - Unknown Quanity
X - Indicate Applicability

1st - Primary Consideration
2nd - Secondary Consideration
3rd - Tertiary Consideration

IV.1D

COMPARITIVE ANALYSIS
NAVSEA VS. OTHER ESTIMATING ORGANIZATIONS

	NAVY (Outside NAVSEA Headquarters)						OTHER DOD			PRIVATE SHIPYARDS			NAVSEA		
ESTIMATING FACTORS	NAVELEX	NAVAIR	NAVFAC	MSC	OP96	NAVSEC	Army (DARCOM)	CAIG	CNA	Beth. St. Sp. Pt.	Newport News	NASSCO	SEA 01G	SEA 06	SEA 04
Estimator Staff Experience															
Government	Some	5-10 yr.	Extensive	NA	Not Extensive	3-11 yr.	6-10 yr.	Little	Extensive				6	5-10 yr.	5-10 yr.
Industry Allied	1-2 yrs.	Little	Extensive	NA						20-35 yr.	28 yr.	5-10 yr.			
Industry (Not Allied)	Some	Little		NA											
Staff Education Level															
Advanced Degree					X			X	X						
College	X	X		X		X	X						X	X	
High School			X							X	X	X			X
Staff Training															
Extensive															
Moderate													2nd		
Some														2nd	
Shipyard or Manufacturer															
On Job	X	X	X	X	X	X	X	X	X	X	X	X	1st	1st	X
Staff Pay															
(Journeyman Estimator)															
GS 15 or above					X				X						
GS 14								X							
GS 13		X		X		X	X							X	X
Less Than ($25,000)	X		X							X	X	X	X		

LEGEND:

NA - Unknown Quanity
X -- Indicate Applicability

1st - Primary Consideration
2nd - Secondary Consideration
3rd - Tertiary Consideration

- Cost estimates for POM/Budget and DCP/DSARC procedures; estimates in support of Life Cycle Cost (LCC), Design-to-Cost (DTC), Foreign Military Sales, Advance Procurement Plans, and Ship Project Directives.

- Analysis of direct costs presented in contractor's proposals to establish a fair and reasonable basis for contract negotiation.

- Implementation of Command responsibility for assuring Cost/Schedule Control System compliance in designated programs.

- Development and administration of training programs in cost analysis and estimating.

- Estimates to be used as DTC and LCC goals in designated programs.

- Preparation of economic analyses and program evaluations to support selection of cost effective alternatives.

The major portion of time spent by ELEX 504B is in assisting the contracting officer in placing new orders. It is in this connection that they visit manufacturers, examine their cost analyses in detail and perform estimating themselves. Budget preparation, although a natural development of the contract price, is of secondary importance and extensive use of previous contract data is made in checking estimates prepared by the NAVELEX Program Managers.

(2) <u>The Naval Air Systems Command Utilizes A Generalized, Computer-Based System For Estimating Activities</u>

The NAVAIR Estimating Group (AIR 506) collects estimates from various organizations within the Command in calculating aircraft flyaway cost including engines, ground support machinery, training equipment and facilities, catapults, etc. As with total ship estimates, all these cost elements are combined in a systematic way to arrive at the end cost of the aircraft.

The cost estimating and budget formulation process, though similar to that of ship estimating, has some unique characteristics of its own that should be borne in mind.

- The naval aircraft are unique in that the new programs are always incorporating features and requirements that crowd or exceed the current technological threshold. This leads to difficult cost prediction.

- The number of units produced each year are ten to twenty times more than naval ships.

- The aircraft industry is very sensitive to program changes with regard to numbers and technical change.

- There are a large number of sole source equipment suppliers whose performance can have an important impact on aircraft production.

- A change in one aircraft program could affect the costs in another. For example, if two aircraft programs were to use the same engine, cost would be lowered. If one program was canceled, the engine unit cost would increase for aircraft in remaining programs.

- The Navy is buying a manufacturer's design to meet stated performance requirements.

- The competition between aircraft manufacturers is based on both design and cost.

NAVAIR utilizes a parametric estimating technique that identifies, in a standardized format, all important elements of production cost. Figure IV.2 shows these elements.

The estimating process at all levels of confidence is primarily parametric, with extensive use of the computer.

- During conceptual design, NAVAIR will use a Rand cost model to arrive at a "rough estimate." These estimates are made in support of LCC cost exercises used to evaluate optimum characteristic/cost trade offs.

  NAVAIR 506 uses its own computer -- a Hewlett Packard System Model 9830. This system has the ability to process data by using multiple linear regression analysis on NAVAIR data so similar elements can be estimated using weights and degree of complexity as principal parameters.

- The Budget estimating is done by the central group with the assistance of other Codes mentioned earlier. Note was made during the interview that the learning curve for aircraft is much less apparent or predictable since the numbers of aircraft ordered have dropped from 3,000 in the 60's to 300 currently.

FIGURE IV.2

NAVAIR COST MODEL ELEMENTS

Aircraft Airframes/CFE Changes Allowance Engines Engine Accessories Electronics Armament Other GFE Non-recurring Cost	**Missile Hardware** G, C and A Propulsion Booster Safety & Arming Mechanism Target Detection Device Warhead Integration and Assembly Engineering Changes
Flyaway Cost Airframe PGSE Engine PGSE Avionics PGSE Peculiar Training Equipment Publications/Technical Data Fac. Training/Training Parts	**Procurement Support** Sys. Engr/Proj. Mgt. Contractor Gov't-in-house Special Tool & Test Equipment Inspection Gages Gov't. Test Program Data Containers
Support Cost Gross P-1 Cost Advance Procurement (credit) Advance Procurement **Other Program Cost** Spares/Spare Parts **Capital Investment Write-Off**	**Fleet Support** Peculiar Spt. Equipment Test Equipment Handling Equipment Training Equipment Training Services I.L.S. Data and Publications

- NAVAIR 506 does not prepare a contract estimate prior to award nor do they perform a TAR prior to award.

The NAVAIR estimating group has direct contact with manufacturers and, as a result, can form opinion as to market conditions, inflation factors, learning curve productivity, etc.

In broad terms cost for aircraft has gone up ten times in the last 15 to 20 years. The principle causes for this increase, according to NAVAIR, have been inflation, technical sophistication, reduced numbers and decreased productivity.

(3) <u>The Naval Facilities Command Is Responsible For The Estimating, Construction And Maintenance Of All Shore Facilities</u>

In contrast to weapons or ships which are manufactured in large numbers (weapons) and where design similarity is a goal (ships), most shore installations are one of a kind and must be estimated and contracted for on an individual basis over a widely dispersed geographical area. In order to come up with timely, knowledgable estimating on those projects where cost varies with the locality, the estimating is done in the field.

Little estimating is performed in NAVFAC Headquarters, but it does provide guidance to regional field divisions by publishing:

- Conceptual Military Construction Cost Engineering Data
- Historical Military Construction Cost Engineering Data

The conceptual data is background material to be used for the preparation of very preliminary cost estimates and budgetary costs in the conceptual or planning stage of public works construction. The costs are presented at the engineering estimate level and can be adjusted for geographic location and time element. The Historical Military Construction Cost Engineering Data provides information for the review of related Military Construction Programs by fiscal year. This document lists the costs for all projects at the time and location of award. Although the Engineering Field Divisions are responsible for estimate preparation as a matter of practice, most estimates are made by architectural and engineering firms.

NAVFAC procedures call for a project to be 30 percent complete before a budget estimate can be prepared. At the 30 percent design stage, the cost estimate is considered to be accurate within

10-20 percent. The responsible field division reviews the 30 percent design and costs, resolves differences with responsible line personnel and aids in the preparation of budget documents. The design effort continues with a goal to reach 100 percent design and final estimate preparation about six months before the President's Budget is presented to Congress. This also gives the Command about two or three months to adjust programs before they become locked in. This design effort is funded out of current year funds made available for this purpose amounting to 4.5 percent of total program cost.

Cost estimating procedures are those commonly used in industry. Substantial use is made of published data, handbook and contract award data. NAVFAC does not normally receive return costs as most projects are awarded on a fixed price basis and regarded in this industry as being proprietary.

The backup for the budget estimate can vary from a very abbreviated breakdown of some 15 line items to a detailed bottom-up estimate of 10-50 sheets with several hundred line items. A 100 percent estimate for a hospital was examined; it consisted of 128 sheets and approximately 2,000 line items.

Budget estimates prepared by NAVFAC carry a five percent margin. This cannot be exceeded. If a 100 percent estimate review indicated this margin would be exceeded, the scope of the project is reduced or it is postponed for re-evaluation in a following year. If the 30 percent design criteria is enforced, however, the chance of cost overruns is greatly reduced as long as inflation factors can be reasonably predicted. This is possible only because design has advanced to the point where the Navy is reasonably sure of what the project requires.

NAVFAC's contracting and specification requirements closely parallel commercial and civilian projects. The firming up of design prior to budget submittal and the dictated five percent growth limitation has almost eliminated cost growth except for unexpected inflation. The unexpected inflation from 1973 to 1976 caught NAVFAC unaware, as it did many others. Now, however, they are finding that estimates made one year ago include an allowance for inflation and market which is in excess of what is now being experienced.

(4) <u>The Military Sealift Command Has Responsibility For Estimating Acquisition And Operation Of A Variety Of Ships From Cargo Transport To Oceanographic Types</u>

The Military Sealift Command Engineering Office is responsible for the engineering, operations, maintenance, repairs, and alterations for the MSC fleet and secondarily such other projects and ships as are assigned to it. This function includes planning, supervising and approving the development, construction and conversion of ships to be operated by MSC, and supervising the Technical Materials Program of MSC.

The Ship Concepts Division has, as a primary responsibility, the definition of characteristics, early design activity and engineering support for construction of ships for the MSC. A secondary responsibility is estimating costs for these ships.

The major functions of the Division are:

- Reviewing Sealift program requirements and preparing feasibility studies
- Reviewing MSC operations to determine areas of potential improvement and economy through introduction of more efficient methods or new, more productive equipment

- Reviewing new construction plans and specifications proposed by:

  - Private operators for construction subsidies for ships which may be offered for charter to MSC

  - Naval organizations for MSC special project ships

  - Maritime Administration for national defense purposes

- Preparing contract specifications and supervising contracts for naval architectural firms to supplement MSC groups making engineering studies and developing ship concept designs into contract guidance plans and specifications for bid purposes

- Advising with respect to characteristics and costs of new construction and with respect to operating economies

There are two possibilities for adding to the MSC fleet -- by a privately financed "build charter" program or through the SCN budget. In the conceptual stage, MSC staff do not know how the financing will go, so they make preliminary estimates as part of feasibility studies to get an idea of how much a project might cost. This is more useful if financing will be by "build charter" than if by the SCN budget. If the ship is to be included in the SCN budget, an independent estimate made by SEA 01G is used.

MSC usually estimates from a conceptual design that will include an outline specification, basic characteristics, general arrangements and a preliminary weight estimate. With this data, informal contacts are made to shipyards building this type of vessel for their opinion on cost as a whole or for a major weight grouping such as steel, outfit and machinery. They maintain close contacts with equipment suppliers and solicit their help as well as keeping track of published cost data.

(5) <u>The Systems Analysis Division Is The Cost Validation Organization For The CNO</u>

This office uses a number of estimating techniques such as statistical comparison, regression analysis and parametrics. When using parametric techniques they are, if possible, applied to a basic nine group ship construction cost and weight breakdown. From a data point of view, the estimating procedure is very similar to that employed by NAVSEA 01G in that they also use bid data rather than return costs as their data base. The Rand model is used on occasion and it, too, is understood to be based upon bid data rather than return costs. For weapon test and integration, they use a cost which is a percent of the estimated weapon cost.

The Systems Analysis Group (OP 96D) has a close working relationship with SEA 01G. Upon request, OP 96D receives copies of SEA 01G cost analyses, guidance and any other information they specifically request. Construction periods used are similar to those utilized by NAVSEA. They do not make an independent evaluation of this important cost input.

With these tools, plus their own judgment regarding market conditions, cost trends, and economic variables, OP 96D develops an independent estimate. If the estimate is within eight percent of that developed by SEA 01G, it is considered a reliable estimate.

The credentials of the staff are impressive. The officers are full Commanders and the average civilian grade is GS 14. They have a basic engineering or scientific background. All have two Masters Degrees in such disciplines as econometrics, finance, statistics, etc. Three of the staff have Ph.D. Degrees. About 1.5 man-years of effort are devoted to ship construction programs per year.

In interviews with OP 96D staff, the following observations about their operations were offered.

- This office does not review budget estimates. It confines its review to estimates to be presented in the DSARC process.

- OP 96D attempts to spot unrealistic estimates in the DSARC process which, in the case of low project office estimates, could avoid the appearance of cost growth had the low estimate been established as a baseline cost. In their view, project office estimates tend to be low to help sell the program.

- Program instability is often considered to be responsible for cost growth by reducing numbers and pushing programs further into the future. Both of these actions will cause cost growth without technical change. It was pointed out that most of these actions were directed by the Secretary of Defense, the Chief Executive or the Congress.

- The point of view was expressed that overruns or cost growth could have a positive effect. It was theorized that if the cost estimates were not tight, all the margins would eventually get eaten up one way or another. The net effect would be to have total program cost in excess of one with a low budget and high overrun.

- OP 96D, at one time, used a 95 percent learning curve. Now they are seeing no evidence of learning.

- With respect to budgeting, OP 96D personnel indicated that ideally ship estimates should be expressed in ranges, rather than as finite amounts. Some personnel in the Congressional Budget Office and in DOD understand this. However, as a practical matter, it is necessary to have a finite estimate even if it only covers a planning wedge. Otherwise, the best that could be expected would be to be cut to the lower limit of the range.

(6) <u>The Naval Ship Engineering Center Has A Computer-Based Ship Construction Cost Estimating Capability</u>

The cost estimating and analysis function in NAVSEC resides in the Economic Analysis Section. This section is responsible for developing ship cost estimates for the internal use of NAVSEC in maintaining cost control during the development of ship design (such as "design-to-cost" programs) and to provide the SHAPM with the approximate ship cost impact of various design features and equipment (weapons, electronics, HM&E, etc.) alternatives. Very often, the cost impact of these design alternatives are used in LCC analysis to help determine final design selection.

The estimate for the base ship is done on a computer using seven weight groups. The data base is developed from bid data for selected shipyards specializing in certain ship types, i.e., DD's at Bath, CVN's at Newport News, etc. If the estimates are eventually to be used outside NAVSEC, computer developed CER equations are first validated by SEA 01G. The factors of particular interest to SEA 01G are labor rates, overhead rate, inflation, and profit. When estimating the impact of alternative equipments or features, the three digit weight breakdown is used. NAVSEC estimates are not in any way associated with or used by SEA 01G in the SCN Budget process and they are not subject to a formal review process.

The Economic Analysis Branch is staffed with five professionals. Two mathematicians maintain the computerized data base using information made available to them from SEA 01G. Engineers perform estimating using weight and design data prepared by NAVSEC and economic guidance from SEA 01G. Cost information on equipments is obtained from engineers in NAVSEC, SHAPMs, PARMs, and various equipment PMs.

The estimates, as produced by NAVSEC, are examples of state of the art, computer-based, parametric estimating and could serve as a model for future efforts by SEA 01G in this direction.

(7) <u>The Army Has A Well Conceived Total System For Estimating The Cost Of Weapons Acquisition</u>

In the past the Army, like the Navy, has had its problems with overruns and cost growth. In order to improve its estimating reliability the Army established a Cost Analysis Directorate in the Office of the Chief of Staff in 1973 and made assignments for a total staff throughout the Army of over 400 cost analysis and estimating professionals. Of this total, 260 professionals have been assigned to the Development and Readiness Command (DARCOM) which is responsible for Army materiel.

The Cost Analysis Program embraces the entire spectrum of considerations and resources needed to define the life cycle cost of a procured system, i.e., tanks, aircraft, etc.

According to the Army, a cost analyst is an individual qualified through formal training and work experience to provide credible and realistic cost estimates. The analyst is a broad-guaged, management-oriented, multi-disciplined professional who employs operations research, engineering and econometric techniques to prepare, evaluate and validate cost estimates. Their primary interest is in assuring that the overall cost to the Government of weapons systems, forces, units and activities is presented in ways which yield cost realism. A cost analyst is not a price analyst or budget analyst, nor is he a requirements planner; he must, however, have an understanding of these functions to fulfill his role.

Estimates for system acquisition costs are either derived from detailed, grass-root calculations (an industrial engineering approach) or based on the relationships between more aggregated components of system cost and the physical and/or performance characteristics of the system derived from cost histories on prior programs (a parametric approach). Two descriptors have come into common usage because of the clarity with which they capture the essential differences: Bottom-up for the detailed industrial engineering approach and Top-down for the parametric approach.

- Historically, defense contractors have employed the bottom-up approach in their proposal pricing estimates for the Government. Because of Program Manager (PM) responsibilities in connection with defense contractors, it has evolved that PM estimates of program costs mirror the detailed Work Breakdown Structure associated with contractor cost estimates. Thus the PM estimate, described as the Baseline Cost Estimate, usually reflects bottom-up estimating methodology.

- The advent of top-down cost estimating methods brought the opportunity for a genuine cross-check of detailed bottom-up cost estimates. The descriptor, Independent Parametric Cost Estimate, has been given to those estimates employing the top-down cost estimating methodology.

These concepts have become the foundation for the Army estimating procedure. Two estimates are made, then, for each system acquisition -- the Baseline Cost Estimate and the Independent Parametric Cost Estimate.

- The Baseline Cost Estimate (BCE) is a term denoting a complete, detailed and fully documented estimate of system life cycle cost accomplished by a system proponent (weapon system project manager). It is a dynamic document, appropriately refined and updated throughout the acquisition cycle. It serves, after review and validation, as the principal cost estimate for that system. If appropriate, the Comptroller of the Army will propose to ASARC principals a preferred Army program estimate through the mechanism of an Army Cost Analysis Paper or Cost Analysis Brief. In this event, the baseline estimate may require modification to reflect the will of ASARC principals prior to being documented in a Decision Coordinating Paper.

The baseline estimate (including subsequent updates) is used as

- The principal institutional source document for cost information related to the materiel system including design-to-cost goals.

- The basis for projecting funding requirements for acquisition and operation of the materiel system.

- A Materiel Developer is responsible for developing the initial BCE and for keeping it updated as the system progresses through acquisition phases. Further, the Materiel Developer is responsible for including a Requirements Specification as part of each BCE.

- BCE's reflect a variety of costing approaches. If the initial BCE is developed prior to contractor involvement in the program, system design will not be well defined and will usually permit costing only by parametric techniques. As system definition improves and contractor participation increases, BCE's reflect increasing use of detailed engineering cost estimates. As a minimum, the BCE will be updated for each major decision point in the acquisition cycle.

• The Independent Parametric Cost Estimate (IPCE) is a highly aggregated system life cycle cost estimate accomplished outside of the functional control of program managers. It utilizes a wide range of methodologies. This can vary from an industrial engineering approach to the use of cost estimating relationships and/or more advanced parametric methods. Usually systems in early and mid stages of development lend themselves to parametric estimating and as knowledge and experience with the system increases, engineering type of estimates become more feasible. The purpose of the independent estimate is to provide an unbiased, second estimate of a system's cost which can serve as a test of reasonableness of the BCE. It provides managers with an important tool at key decision points.

- In addition to its principal purpose of testing the reasonableness of the BCE, the IPCE is used for exploring cost sensitivities of the assumptions used in the BCE. This includes such factors as the probable impact of technical failures, changes in configurations, schedule changes, testing requirements, prototype quantities, inflation rates, deployment.

- It is system output related, examining cost in terms of what is being purchased and operated, such as the physical, performance or operational characteristics of the system, rather than in terms of what the funds are paying for (labor, material).

- Its scope encompasses the total life cycle of a system -- the resources required to develop, acquire, operate and support the system.

- It uses actual cost experience on similar, earlier systems (including that of other military departments and commercial firms) to the greatest extent applicable through statistical conversion of such experience to cost estimating relationships and cost factors. Nonparametric estimating methodology (analogy, detailed buildup, expert opinion) is used only for those cost elements for which inadequate data exists for statistical analysis.

A common framework is utilized by the Army for investment cost estimates. A general idea of how this framework is rationalized and implemented in practice is shown in Figure IV.3 at the end of this section.

The XM1 Battle Tank acquisition program is a good example of the system's viability. The XM1 Tank System was mandated as a Design-to-Cost system in 1972 and controls were written into the contract so that the Project Manager could monitor return cost data in managing to cost goals. The PM is staffed with professional engineers who track the schedules and have cognizance of the integration of the various assemblies for the XM1. The life of a tank is approximately 20 years and it will take about 10 years to build all the XM1 Tanks in the program. The XM1 Tank System Project Office has as its Program Manager, a Major General and is physically located in Warren, Michigan close to Chrysler Corporation, manufacturer of the XM1.

Upon the establishment of the project, a task force was organized composed of staff from the Project Manager's office, The Army Cost Analysis Directorate, and the Department of the Army Development and Readiness Command to prepare a cost study of the new tank. In 1972, the PM issued a study which provided a parametric, should cost estimate based on the Research and Development (R&D) program. Included in the cost analysis was the impact of a gas turbine versus diesel engine, different suspension tracks, and different guns. The study took approximately six months to complete, representing three man-years of effort.

The task force received help from the Cost Information and Analysis Branch within the Project Manager's Office, as well as from Chrysler and General Motors, the potential contractors. The Design-to-Cost goal developed by the task force was $507,000 (in 1972 dollars) for each tank with a total of 3,312 tanks. The program cost was accepted by Congress.

General Motors and Chrysler were given contracts to develop two competitive prototype versions of the XM1 Tank. During the advance development phase (prior to DSARC II), both GM and Chrysler at three different times verified that their costs were below the $507,000 DTC thresholds by making detailed unit hardware cost estimates based on the Work Breakdown Structure for the tank. The validated costs were subjected to a detailed study by the Project Manager, corrections made, and these costs then became the BCE.

The Chrysler version was eventually chosen, but certain aspects of the design are still not firm. For example, whether the gun will be 105 mm or 120 mm will not be decided until December

1977. However, the design is sufficiently flexible to permit either gun along with the different stowage requirements. Both GM and Chrysler had the leeway to change design within certain ranges for ten categories of performance (i.e., fire power and protection) but changes could not cause deviation from certain fixed criteria such as maintainability, reliability, or exceed the cost threshold of $507,000 in 1972 dollars.

The PM is of the opinion that competition between GM and Chrysler has been the main reason the $507,000 cost per tank threshold has not been exceeded and that a better tank has been developed. To maintain competition now that the contract has been awarded to Chrysler for 14 prototypes, the Army has established a Design-to-Cost award fee agreement. The award fee of $8,000,000 is, in effect, a bonus that will be paid Chrysler in five increments if the target cost is held down to the cost threshold established by the Army. The first increment of 10 percent ($800,000) will be paid in September 1977 with other increments given periodically. The last increment of $4,000,000 will be paid when a contract (fixed price incentive) for the first 110 tanks is signed. The Army will also go sole source for the second lot of 352 tanks. They already have signed ceiling options for the first and second lots and are presently negotiating a ceiling option for the third lot.

The following are distinct steps taken to hold down the costs for the XM1:

- Competition during development
- Design-To-Cost Award Fee during prototype phase
- Ceiling options signed well in advance, as the initial production contract award will be made in mid-1979.

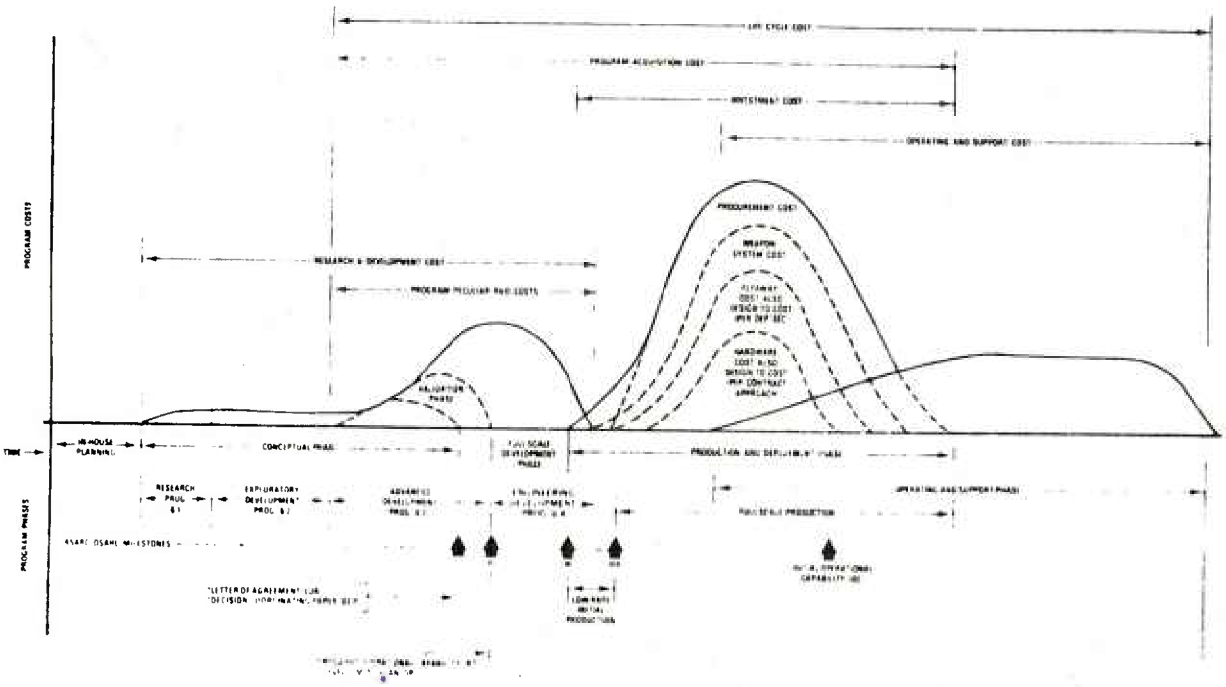
The principal cost review office for the XM1 Project Manager is the Material Development and Readiness Command (DARCOM) Cost Analysis Division. The Cost Analysis Division's function is to:

- Compare the Independent Parametric Cost Estimate (IPCE) generated outside the DARCOM to the Project Baseline Estimate (BCE) which is generated by the DARCOM. IPCEs for the big five (one of which is Main Battle Tank XM1) are provided by the Department of the Army Cost Analysis Directorate
- Review DARCOM IPCEs and BCEs
- Direct DARCOM's IPCE effort (non big five)
- Provide inflation guidance

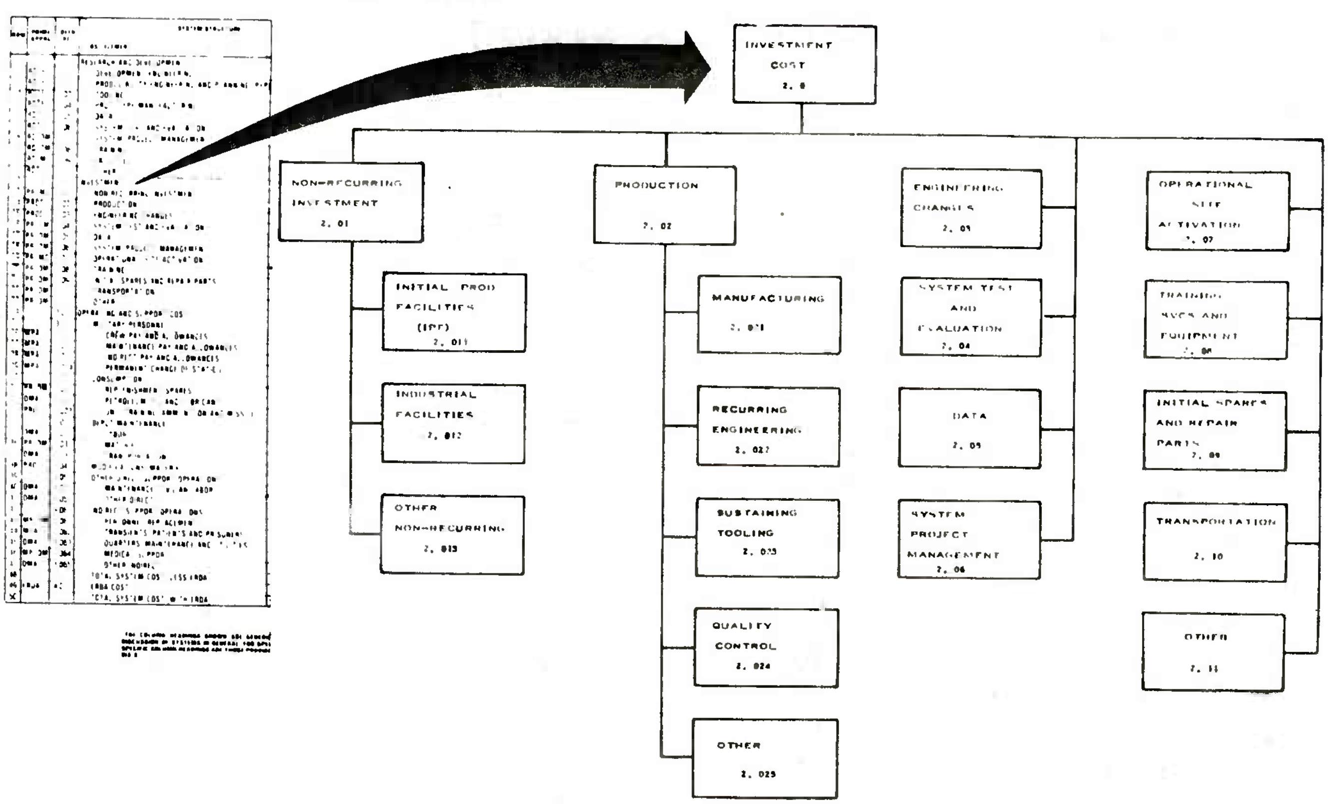
Basically, this Division is responsible for coordinating all cost analyses, data and factors relating to weapons system costing

FIGURE IV.3

LIFE CYCLE OF A MATERIEL SYSTEM



ARMY LIFE CYCLE COST MATRIX



SOURCE:
U.S. ARMY

and the Army feels that it is now preparing end cost estimates to within eight to ten percent of actual costs.

(8) The Cost Analysis Improvement Group Within Office Of The Secretary Of Defense Is The Principal Advisory Body To The DSARC On Cost Related Matters

The Cost Analysis Improvement Group (CAIG) was established in January 1972 as a result of weapon systems cost growth of a magnitude of 100 to 200 percent. The CAIG function is to review and interpret project manager estimates and make independent cost estimates at DSARC presentations. Each member of the CAIG represents functional areas which are in accord with the organizational role and mission of his office. Specific responsibilities include:

- Providing the DSARC with a review and evaluation of independent and program cost estimates prepared by the Military Departments for presentation at each DSARC. These cost reviews shall consider all elements of system costs, including procurement, operations and support as appropriate.

- Establishing criteria, standards and procedures concerning the preparation and presentation of cost estimates on defense systems to the DSARC and CAIG.

- Identifying to OSD functional offices and DOD components where efforts are needed to improve the technical capability of the DOD to make independent cost estimates of all major equipment classes.

- Developing useful methods of formulating risk information and introducing it into the DCP/DSARC process.

- Working with DOD components to determine what costs are relevant for consideration as part of the DCP/DSARC process and developing techniques for identifying and projecting these costs.

- Developing and implementing policy to provide for the appropriate collection, storage and exchange of information concerning improved cost estimating procedures, methodology and data necessary for cost estimating between OSD staffs, all DOD components, and outside organizations.

- Providing an assessment for the DSARC of all cost objectives prior to their inclusion in approved DCPs or similar documents giving direction to a DOD Component for the acquisition of a major defense system.

- Helping to resolve issues which arise over the comparability and completeness of cost data to be reported on new cost data collection systems.

The CAIG encourages the use of the parametric cost techniques for the preparation of independent cost reviews, rather than the industrial engineering or "grass roots" estimates used in industry. The parametric approach relates the actual historical cost of earlier weapon systems to their performance characteristics to make statistical projections of the most likely costs of new weapons. This approach is intended to capture the cost of setbacks and design changes encountered by almost all programs -- costs which are not usually anticipated in an industrial engineering approach. These most likely estimates are particularly useful in checking the reasonableness of the goals and thresholds used to manage and control weapon system acquisition programs as well as to ensure that adequate resources for major systems are provided for in the Five Year Defense Program.

Although independent analyses to date have tended to concentrate on the costs of acquisition, recent reviews have begun to emphasize collateral operating and support costs. The objective of these estimates has been to provide the DSARC principals with a perspective on the total impact of a given system on available resources and to properly distinguish between the costs of alternatives under consideration.

The CAIG staff consists of three civilians (GS 15s); one Navy Commander; two Navy Lt. Commanders; two Army Majors; and one Air Force Major for a total of nine. All members have Masters Degrees in various fields, two specifically in Operations Research and Systems Analysis, one member a Ph.D. in Mathematics. The naval officers are unrestricted line officers with a tour of three years with a possible extension of one year at the CAIG. The Army officers are from the Corps of Engineers.

The selection process for the military officers is very rigid. They must be nominated by their service; interviewed by the Chairman of CAIG, the Deputy Director of Resource Analysis, the Deputy Director for Strategic Programs and the team leaders in the directorate and finally an interview by the person the applicant would work with in the CAIG. The officers usually have not had cost experience before coming with the CAIG but have been outstanding students and officers.

Of the staff of nine, only five are full-time. This would seem to indicate that the level of effort placed on cost estimate review causes estimates to be made in a highly aggregated and approximate manner. With respect to ships, they review estimates prepared by Project Managers and the independent estimate by OP 96D. In a few cases, they make their own independent cost estimate by using historical data, analogy and regression equations. For example, they made an independent estimate on the FFG which took about 3-1/2 man-weeks of effort.

In DOD, the cost estimating process seems to proceed at two levels. The first level is concerned with new programs that must compete with one another to accomplish a mission on the basis of performance and LCC cost by way of the DSARC process. This is the stage where the CAIG has been performing its function. In this process, cost estimates are prepared without any direct regard for the Budget process. It is quite possible for a ship budget price to go forward to Congress for a program well in advance of DSARC II when a preliminary design should be completed and as a result, the SHAPM/SEA 01G estimate is never checked against an IPCE prepared by any organization.

The second level of estimates are those prepared for the POM/Budget. These are specifically reviewed at the prescribed administrative level, but are not checked against an independent estimate or validated by any independent group around the time of preparation.

(9) <u>Firms Interviewed In The Shipbuilding Industry Invest A Great Amount Of Time In Preparing Estimates Of Ship End Cost</u>

Any comparison of the estimating capabilities of the Navy with the shipbuilding industry would be invalid unless it recognizes the different demands placed on the respective estimating staffs.

The estimators for a shipyard are a key to corporate survival. They must be able to predict within a narrow margin of accuracy what a project "will cost." To do this, they have available a contract design, returned costs, vendor quotes and they invest time and manpower to turn out a detailed estimate. Furthermore, this estimate is recognized as being in effect for short periods, usually up to 90 days.

In contrast to this, Navy estimators must prepare an estimate which ultimately goes to Congress that should be accurate for two to three years not 90 days. The product description (for a new design) is usually not much better than shipyards use to give a prospective customer an "idea price." The shipyard devotes as much as 20,000 man-hours to prepare an estimate on which the Navy estimator may spend as little as three or four days each time the ship comes up for evaluation.

In the final analysis, however, the net impact of these two estimating philosophies is essentially the same. The estimates are a major factor in the generation of income to both a shipyard and the Navy.

Three shipbuilders were visited and their estimating capabilities analyzed.

- The Bethlehem Steel Corporation operates seven facilities in the United States and one abroad. Six facilities are dedicated to ship repair and conversion and two to ship construction. The largest and most modern is located at Sparrows Point, Maryland. Currently, this facility is building a series of 265,000 DWT tankers. In the past, it has been engaged in building large merchant ships, both tankers and dry cargo. They have also built naval auxiliaries, the last of which were two ammunition ships delivered in 1971. This shipyard is now doing about 150 million dollars worth of work per year and has total employment of about 4,000 people.

- The Newport News Shipbuilding Corporation is located in Newport News, Virginia on the James River. It has a current total employment of approximately 23,000 people and is currently building CVN, CGN, SSN and LNG ships. In addition, they have an extensive naval ship overhaul and repair capability.

  The original Newport News yard, now devoted to naval ship construction, is one of the oldest in the United States. In 1973, it started a new facility adjacent to the old yard designed to accommodate VLCC tankers up to 1,000,000 DWT as well as LNG carriers.

- National Steel and Shipbuilding Company is a relatively new shipyard in the large ship construction field. Since 1970, NASSCO has built numerous subsidized cargo ships, naval auxiliary ships, LSTs and tankers. Currently, it has commercial tankers under contract and two destroyer tenders (AD 41, 42).

  NASSCO is currently doing about 150 million dollars worth of work per year and employs approximately 6,500 people.

The first generalization that can be made concerning these three shipbuilding organizations is that the cost estimating function occupies a highly important place in the corporate structure -- generally close to the General Manager or Vice Presidential level.

Secondly, the basic estimating procedures of commercial firms are far more refined and exhaustive than those of the Government. The procedures used at Bethlehem Steel can be considered representative of commercial practice and are described in this section.

Estimates are prepared in accordance with Bethlehem's Job Number System. Material is accumulated by three digit account number and actual labor hours are projected by Department, by item number, as well as job number. This job number system has the flexibility of being used for almost any type of ship. It has been used in estimating and accumulating costs for naval ships as well as all types of commercial ships. The job number breakdown provides information from returned costs enabling the estimator to apply costs at various stages of construction.

The estimator concerns himself with weights, quantities of material required, present day material costs and actual man-hours to do the job or jobs as described by the job number book.

From specifications, general clauses are prepared which are attached to all vendor and subcontractor inquiries to explain general particulars such as:

- Standards of workmanship
- Regulatory body requirements
- Noise and vibration requirements
- Spare part requirements
- Instruction book requirements
- Guarantee or warranty requirements

The estimator generally takes off the material quantities and prepares the inquiry for purchased items. This assists the estimator in understanding the magnitude of the job and helps him in estimating labor while waiting for price information.

Inquiries for purchased items include:

- List of quantities required
- Applicable specifications and plans
- General clauses

Quotations, when received, are analyzed for price, delivery, conformance with specifications, guarantees, engineering features, freight allowances, etc.

Where information is not available from bidding plans and specifications, the estimator must layout or estimate by comparison to previous ships built for which he has returned cost information.

The estimator is responsible for maintaining returned costs -- the actual record of costs for ships previously built. The estimator establishes quantities from the working plans of ships previously built. These quantities are used in developing material and labor factors for each item or job as the case may be. Returned costs help the estimator to develop:

- Net to gross ratios
- Unit costs of items not normally sent for inquiry
- Cost items that represent miscellaneous type materials for each job
- Unusual items of cost that may or may not be considered on future estimates
- Separate fixed charge type items
- Comparisons with previous cost information to establish trends, learning curves, new requirements
- Unit rates for estimating

Returned cost information includes not only ships completed, but ships under construction. Information is received which compares hulls under construction to hulls completed at similar points of completion. The importance of returned costs to shipyard estimates cannot be emphasized enough.

In the case of a new item where factors are not available from returned costs, the estimator would first endeavor to apply any parts of returned costs from various ships to similar parts of the estimate under preparation. He would also estimate on the basis of the number of men and length of time required to accomplish the work.

In preparing the summary of material and hours, each job number or group of job numbers is totalled showing new weight, material dollars and labor hours. Reference to price source and other pertinent information is noted. Job number totals are then carried to the Hull and Machinery Summaries and totalled. This is then summarized on a sheet called a Summary of Material and Hours, in which:

- General characteristics are noted
- Total weight is estimated and comparison with the design agent information shown
- Weight, material and labor hour factors shown are used in overall checking and provide a ready basis for budget estimates
- Fixed charges or non-recurring items are added
- Unusual items or special considerations are added
- Adjustments are made for following ships as necessary

- Material listed on this sheet generally represents a particular base month and is so noted

- An allowance may also be made for a learning curve or drop curve. Years ago significant drop curves were provided.

Subsequently, an estimate summary is prepared in a less complicated manner in which:

- Material is broken down into items that lend themselves to the application of escalation.

- Labor rates are applied using a particular base month. (Usually normal straight time rate and overtime and shift work rate are shown.)

- Expense rate is computed based on a value for the construction period applicable to the particular estimate (considering the yard force that is anticipated to exist at the time this construction would be occurring). Expense dollars are developed by the shipyard with corporate Accounting Department assistance. The yard force that is anticipated to exist is developed by the shipyard with corporate assistance.

Key estimate elements are prepared in some detail, especially Labor, Material and Escalation. In preparing labor estimates, periodic rate projections are provided by corporate headquarters with current information consisting of the following:

- The Accounting Department record of actual rates which is compared with latest projections.

- Each estimate is weighted by shipyard divisions in establishing the total rate to be applied for each estimate. Divisions are structural, machinery/outfitting, material/service and loft/optical.

- Each element of a rate computation is reviewed for each estimate revised to suit conditions such as:

  - Will additional overtime or shift work be more or less?

  - Is there any indication of base rate creep, i.e., laying off or keeping high paid workers?

  - Was the effect of possible labor agreements assessed properly?

  - Are incentive payments following past trends?

Material estimates are based on delivered prices plus escalation and are computed as follows:

- An escalation factor for steel according to delivery schedules is applied based on the best judgment of Estimating Department, General Manager's Office, and Vice President's Office.

- Engineering services are escalated in a similar manner to yard rates.

- Fixed items would not be escalated provided they meet the required delivery schedule.

- On other quoted materials, if a vendor quoted to a different delivery schedule or expressed escalation conditions, increases are calculated as necessary.

- For all other material a percent is applied based on the best judgment of Estimating and Purchasing Departments at the time.
- Centroids for material are established based on historical information.

On Navy work further escalation must be computed due to:

- Navy escalation percent is usually low
- Navy formula provides for no profit on escalation
- NAVSEA indices are not currently weighted to suit most ship construction

The Chief Estimator presents his estimate to the Assistant General Manager. From there it is reviewed by the yard General Manager and is sent to the corporate office for pricing. The pricing is done by the Vice President's Office and involves adjusting the "will cost" estimate for overhead, profit, market and/or other margins for such risks which are not compensated for by escalation, etc.

All of these activities comprise the procedure followed by a private shipyard's estimating department in the 60 to 90 day period before bid opening. This task can consume up to 20,000 man-hours utilizing about 20 estimators with assistance from the production, accounting, and engineering departments. But, an estimate is not finalized by the estimating department. Rather, adjustments for capital improvements, productivity, escalation, market conditions, profit, technical risk, form of contract, etc., are done at executive levels after the Chief Estimator submits the "will cost" estimate.

The private shipyards have estimating staffs with personnel numbering --

. Bethlehem Steel	22
. Newport News	78
. NASSCO	24

Examples of time spent on proposals --

- NASSCO bid proposals take 18,000 to 23,000 hours.
- Newport News reports that time spent on engineering estimates for follow-on submarine is 20,000 to 25,000 man-hours; CVN is 50,000 man-hours; VLCC is 10,000 man-hours.
- Bethlehem detailed estimates for MarAd-type construction take six to eight weeks; Naval auxiliary takes eight to ten weeks; Naval combatant takes 13 to 17 weeks.

In spite of the difference in estimating objectives, it is instructive to see how detailed estimates are arrived at by industry. It must be said, however, that in many recent cases industry estimates did not accurately predict costs for one reason or another which is evidenced by the current volume of claims.

2. THE COMPARISON OF NAVSEA COST ESTIMATING METHODOLOGY AND CAPABILITY TO THAT OUTSIDE NAVSEA PROVIDES LEADS FOR POTENTIAL IMPROVEMENTS

Figure IV.1 shown previously shows the relative responsibilities, capabilities and resources of the twelve groups studied. The individual observations and comparisons outlined on the charts lead to the following statements.

(1) NAVSEA, The Army and NAVAIR Have Similar Responsibilities But Different Methodologies, Capabilities and Resources

NAVSEA 01G has a very broad range of responsibilities to develop estimates from conceptual stage to contract award. In the overall picture, these responsibilities with respect to investment cost estimating are similar in scope and program size to NAVAIR and the Army (DARCOM).

In carrying out these responsibilities, it is found that the Army is investing considerably more resources in cost estimating and analysis than either NAVSEA or NAVAIR with approximately 360 people involved, while NAVAIR and NAVSEA have around 55 and 26 respectively.

The Army has instituted a cost analysis program based on LCC techniques which is carried on uniformly through all levels of the service. Since a system's initial investment is only a part of total LCC cost, many of the 360 staff are dedicated to other elements in life cycle analysis. NAVSEA and NAVAIR, with smaller cost estimating staffs, are primarily concerned with initial investment cost, but the difference in staff resources is still dramatic.

The Army and NAVAIR make extensive use of manufacturer return cost data and computerized assistance for data storage and retrieval as well as for parametric estimating.

Staff of these three organizations are generally comparable in education and experience. The average staff member is young, has a college education and most of his experience has been with the Government. In general it was found that people with engineering background were in the minority in NAVAIR and Army but slightly in the majority in NAVSEA. The pay level of these organizations is about the same.

With respect to estimating methodology, some differences are found.

- Army - Extensive use of computer-based models for BCE and IPCE detailed engineering estimates.
- Army - Extensive use of manufacturer and contractor detailed engineering estimates which are validated by Army estimators for budget purposes.
- Army - Cost estimators maintain very close contact with counterparts in industry.
- NAVAIR - Extensive use of computer aided estimating with return cost data bank.
- NAVSEA - Manual parametric estimating
- NAVSEA - Informal and dispersed data bank based primarily on nine cost group bid data.

The important finding here is that the Army has rationalized the complete cost estimating procedure and made it an integral part of the acquisition process.

(2) NAVELEX Has As Its Strong Point Computer-based Estimating And Its Wide Contact With Industry

NAVELEX has a small annual budget compared to NAVSEA and correspondingly fewer and less experienced estimators. NAVELEX estimating staff spends a large part of its time in the manufacturer plants validating proposals. In contrast, NAVSEA estimators are relatively isolated from personal contact with industry.

NAVELEX is also conducting a Design-to-Price procurement for an ECM System which is reported to be proving quite successful.

This Command has a computerized system containing a complete record of past and current acquisition costs. The budget estimating process is usually relatively simple compared to NAVSEA since 90 percent of dollar value budgeting is for equipment that is now on order or for previous programs.

(3) The Key Lesson To Be Learned From NAVFAC Is That Of Requiring Levels Of Design Completion Prior To Budget Submission

A comparison of NAVSEA with NAVFAC is difficult because of the great difference in sophistication of their products. However, with respect to estimating procedure and approach, some meaningful observations can be made.

The first is with respect to product definition where NAVFAC develops its budget estimates only after 30 percent of the detailed design has been completed. These are engineering estimates in considerable detail as compared to the nine cost group estimates customarily prepared by NAVSEA. Second, the estimating staff is of grade GS 11-12 level, generally with high school education but usually with extensive experience in the commercial construction business.

NAVFAC headquarters develops estimating guidance but does not do estimating itself. Seventy-five percent of this is done by architectural and engineering firms and 25 percent done by the NAVFAC field offices. In contrast, NAVSEA headquarters performs both these functions.

(4) <u>NAVSEC's Capability In Computer Modeling Should Be Emulated</u>

NAVSEC has developed an estimating technique using a computer-based parametric ship estimating model. Further development of this program to accommodate updated return cost and bid data in greater detail would provide an excellent basis for a rapid response estimating capability. NAVSEA 01G does not utilize this type of capability at present.

(5) <u>OP 96D And The CAIG Are Basically Small, Elite Groups Performing Validation Functions</u>

OP 96 and CAIG have a very limited capability to do ship cost estimating due to the small staff, product identification and data banks. There is very little in capability or technique that these two validating organizations have that would be of any appreciable help to NAVSEA.

(6) <u>The Concept Of What Is Required To Make Estimates On The Part Of Industry Is Quite Different From That Of The Navy</u>

The shipyards have an entirely different estimating problem than NAVSEA. The shipyards must make accurate estimates as to how much it will cost them to build a ship. This price is normally valid for 90 days and usually 20,000 to 30,000 man-hours is devoted to developing this estimate. It must be accurate within five percent in order to maintain planned profit margins. NAVSEA is expected to do at least as well, two to two and one-half years before award, with 40 to 80 man-hours of effort often based on a conceptual design.

The lesson that can be drawn from reviewing shipyard estimating is that the industry believes accurate estimates must be based on:

- Return cost data
- Good product definition
- Engineering detail
- Vendor quotes

- Limited price exposure (making offer good for limited time)

- Estimators having shipyard experience

NAVSEA does not follow this procedure, partly because the system under which it operates does not permit it and partly because shipyard estimating techniques are not recognized as being essential to quality budget estimating.

3. A NUMBER OF OBSERVATIONS CAN BE MADE AS A RESULT OF THESE COMPARISONS

The review of the estimating functions outside of NAVSEA provides a basis for the following conclusions.

- Within the Navy, NAVSEA 01G is considered to have greater overall cost estimating capability than

  - SEA 06
  - SEA 04
  - NAVELEX
  - NAVSEC
  - MSC
  - OP 96

- NAVAIR and NAVFAC are considered to be somewhat superior to NAVSEA in overall capability to do their assigned basic estimating tasks.

- The Army (DARCOM), in the case of the XM1 Tank project, appears to have superior estimating and analysis capability to NAVSEA.

- The shipyards are superior to SEA 01G in preparing engineering estimates.

- NAVAIR, NAVSEC, Army, CAIG, CNA, NAVELEX and the shipbuilding industry make greater use of the computer for data storage and estimating than SEA 01G.

- NAVAIR, Army, and the shipbuilding industry make extensive use of return costs as a basis for estimating while SEA 01G relies primarily on bid data.

- NAVSEA has the smallest estimating and analysis staff relative to the dollar volume of estimates and collateral duties than any of the other organizations that prepare budget estimates.

- The NAVSEA 01G estimating staff is at the GS 12 average level which is less than NAVAIR, Army, NAVSEC, CAIG, OP 96, SEA 06, SEA 04 and MSC. It is about the same as NAVFAC but greater than the shipyards.

- NAVSEA 01G is the only organization studied that has a training program.

- NAVSEA 01G appears to be the only Government office, except NAVAIR, that does not depend heavily upon industry estimates as the primary source.

- All the DOD offices reviewed rely heavily on parametric estimating. The Army and NAVFAC also rely heavily on engineering estimates prepared in-house and by private industry.

- The quality of the NAVSEA 01G data bank would seem to be only average. Organizations considered to have superior data banks are:

  - Shipyards
  - NAVELEX
  - NAVAIR
  - Army

Organizations having lesser quality data banks are:

- OP 96
- CAIG
- CNA
- MSC
- SEA 06
- NAVSEC

. NAVSEA 01G is required each year to estimate more new products in dollar value than any other organization.

* * * * * *

These are conclusions based on an extensive organization study. Paralleling the organization study, case studies have been made on ships, weapons and other GFM as well as an in-depth study of ship cost estimates for two fiscal years. The findings in terms of actual performance will add other points for consideration of NAVSEA estimating capability.

V ESTIMATING PERFORMANCE OF THE NAVY

The study has thus far examined NAVSEA cost estimating from an organizational point of view. Additionally, to gain perspective on the strengths and weaknesses of NAVSEA, other organizations were examined and comparisons drawn.

What remains to round out the study is an assessment of the performance of NAVSEA and that is covered in this section. Estimates prepared for all new or modified ships during FY 1975 and FY 1976 have been studied. Beyond that, studies of three representative ship programs and eight items of GFM are discussed. The objective in these case studies was to determine how estimates were arrived at and what events followed that contributed to cost growth.

1. OVER THE LAST EIGHT YEARS, FUNDS REQUESTED FOR SHIPBUILDING PROGRAMS, WHICH TOTALLED $18 BILLION, HAVE GROWN TO $22 BILLION

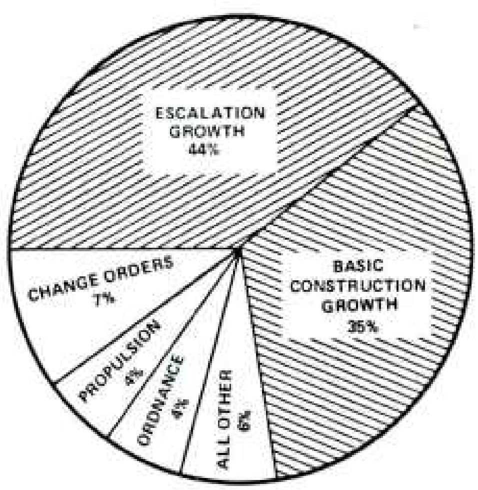
Between the FY 1970 and FY 1977 budgets, the Navy requested funding for 132 new ships of 13 major types totalling some $18.8 billion. In late 1976, the Navy estimated that to maintain this program in a fully funded status, $22.2 billion would be required -- an 18 percent increase over the years amounting to $3.4 billion.

The 18 percent may be somewhat misleading, however, since cost growth in 1976 and 1977 is minimal, if any. These programs have just started construction or in some cases are in the bidding process and, therefore, tend to distort cost growth if recent history repeats itself.

As is pointed out in Chapter I, the largest cost increase by far is growth in unanticipated escalation and basic construction. Very weak third, fourth and fifth causes are unanticipated growth in change orders, ordnance and propulsion. Figure V.1 following shows this.

FIGURE V.1

ELEMENTS OF TOTAL PROGRAM COST GROWTH



In terms of dollar values, the following relate to the percentages shown in the figure:

V ESTIMATING PERFORMANCE OF THE NAVY

- Escalation $1,500,000,000
- Basic Construction........ 1,200,000,000
- Change Orders 238,000,000
- Propulsion................ 136,000,000
- Ordnance 136,000,000
- All Other 204,000,000

It is clear that the Navy shared with many organizations -- public and private -- the probelm of unanticipated escalation. Over $1 billion of unanticipated inflation can be shown to have occurred on the big ticket programs (SSN, TRIDENT and FFG) constructing during recent years. This problem is further compounded by government-directed escalation rates which were often unrealistic. Also a factor is the difference in escalation and inflation-related factors between industries where shipbuilding, for example, seems to have been affected to a greater degree than some other industries.

It is another matter, however, with regard to overruns in basic construction, ordnance and electronics. It is the responsibility of the Navy to be equipped to make reasonable predictions in these areas. As a procurement "giant", knowledge of the shipbuilding industry, expertise in product engineering, experience in project management are areas in which the Navy should excel. Case studies and estimate tracking, however, have shown this to be open to question.

2. NAVSEA BASIC CONSTRUCTION ESTIMATES -- WHEN COMPARED WITH CONTRACT AWARD AND END COST FIGURES -- SHOW WIDE VARIANCES

The reasons for cost growth in basic construction are not highly visible. It can be caused by such varied factors as inflation, design development problems, poor estimates, lowered productivity, fluctuating overhead, market changes, building period misestimates, etc. It is this portion of the end cost estimate that depends most upon the skill and capability of the NAVSEA Cost Estimating Group in that basic construction cost can vary from 30 to 70 percent of the end cost of a ship. It is the portion of the end cost that is calculated solely by NAVSEA 01G and can usually be compared directly to the shipyard contract price, i.e., target price. Thus, the comparison of the basic construction figure to the contract price can demonstrate, to a large degree, performance on a specific ship case.

Table V.1 shows NAVSEA 01G estimating performance for FY 1975 and FY 1976 (excluding program awards based on option agreements of prior year procurements). In FY 1975, NAVSEA estimates supplied to Congress were 35 percent below the contract or low bid price. In FY 1976, their figure was 12 percent lower than contracts awarded.

In order to determine why basic construction experiences such growth, the following cases were examined in detail for the FY 1975 program:

TABLE V.1

BASIC CONSTRUCTION ESTIMATES

Fiscal Year	Ship/Class	Original Budget Figure (000)	No.	Original Estimate Date	Contract Award Price (000)	Contract Award Date	Dollar Difference (000)	Percentage Increase	Time Between Budget Est. & Award (in months)
75	SSN 688	254,400	3	7/73	309,488	8/75	55,088	21.7	25
75	FFG 7	148,650*	3	8/74	193,205	2/76	44,555	30.0	18
75	AD	90,400	1	3/73	162,660	12/75	72,260	79.9	33
75	ARDM	16,350	1	3/73	24,427	10/75	8,077	49.4	31
Total		509,800			689,780		179,980	35.3	
76	SSN 688	188,500	2	7/74	189,970	2/76	1,470	00.08	19
76	FFG 7	251,710	6	1/75	320,699	2/76	68,989	27.4	13
76	AD 42	134,700	1	1/74	143,511	3/76	8,811	6.5	26
76	AO	147,420	2	8/75	153,050	8/76	5,630	3.8	12
Total		722,330			807,230		84,900	11.8	

* The original budget figure is $110,940,000 made in June 1974 for three ships based on an average unit cost of a seven ship buy. The figure shown is a revised estimate made in August 1974 for a three ship buy which reflects the increase in cost per ship for a reduced number of ships plus changes, etc.

- SSN 688 class -- three Submarines
- FFG 7 class -- three Frigates
- AD 41 -- one Destroyer Tender
- ARDM 4 -- one Floating Dry Dock

(1) The SSN 711,712 And 713 Budgeted In FY 1975, Although Repeat Ships, Were Underestimated By 22 Percent

The SSN 711, 712 and 713 are the 24th, 25th and 26th of the SSN 688 class submarines and were awarded to Newport News on August 1, 1975. The SSN 688, the first of the class, was awarded to the same builder over four years earlier on January 8, 1971. Subsequent to January 1971, eight ships had been awarded to Newport News and 18 to General Dynamics - Electric Boat Division.

The basic construction cost estimate for the FY 1975 ships made on July 10, 1973 was $254,400,000 for the three ships or about $84,800,000 each. The total end cost for the program of three ships was estimated to be $580,500,000. The most recent budget document, dated June 1, 1977, estimates basic construction at $309,493,000 for three ships or $103,164,000 each based on the contract price. The increase in basic construction from July 1973 to August 1975 is approximately 22 percent.

The initial estimate prepared for the FY 1975 budget made in July 1973 was based on General Dynamics-Electric Boat bid data of

November 1970, adjusted for construction learning and inflation. The estimate considered only three large aggregations of cost -- engineering manhours, production manhours, and material. All the notations on the estimating back-up sheets indicate that the $84.8 million is for each of five ships, regardless of the fact that only three were in the budget.

The revised estimate of $103,164,000 was based on Newport News bid data of January 30, 1975. The major elements of cost growth related to the basic construction estimate were labor manhours and material. The material increased by 47 percent and labor and overhead cost was 20 percent greater than the NAVSEA estimate.

On hindsight, this overrun in material could be expected since it bridged the years of highest inflation. In fact, between the time the estimate was made in mid-1973 and the materials were purchased in 1975 and 1976, material costs increased by as much as 100 percent according to the NAVSEA index. It is unlikely that this aberration would have been foreseen by anyone.

After granting this exception, however, it must be noted that the procedure used in estimate preparation would in most cases tend to provide less than adequate data. The guide to material costs utilized in mid-1973 was bid data from late 1970. Data from a time period about four years prior to the material purchase period was used when return data from other partially completed SSN 688 class ships was available. This four year difference could have been reduced to two years and in almost all cases (except 1974 and 1975) material trends would have been recognized.

A summary of cost growth for the program follows:

TABLE V.2

SUMMARY OF SSN COST GROWTH
ON FY 1975 BUDGET
(3 - SSN 688 Class)

Breakdown of Estimate	Orig. Est. Approved By Congress (000)	4/77 Current Estimate (000)	Estimate Change (000)
Plan Costs	12,000	15,000	3,000
Basic Construction	254,400	309,493	55,093
Change Orders	21,000	24,707	3,707
Electronics	55,410	54,900	(510)
Propulsion Equipment	105,900	105,900	-
Hull, Mechanical, Electrical	55,707	51,000	(4,707)
Other Costs	5,400	3,600	(1,800)
Ordnance	8,550	9,000	450
Future Characteristics Change	6,000	5,100	(900)
Escalation Budgeted	33,885	160,200	126,315
Escalation Earned	-	-	-
Project Managers Growth Factor	22,248	-	(22,248)
Total Ship Estimate (3 Ships)	580,500	738,900	158,400

The above table shows two primary areas of growth -- basic construction (21.7 percent), escalation (372 percent) which along with other increases and decreases makes for an overall increase for the total ship of 27 percent.

(2) <u>The FFG 8, 9 and 10, Which Are First Production Hulls, Have Thus Far Experienced A 30 Percent Cost Growth</u>

The FFG ships in the FY 1975 program are the FFG 8, 9 and 10, and were awarded to Todd Shipbuilding (both San Pedro and Seattle yards) and Bath Iron Works on February 27, 1976 for a total $165,665,753 target price including profit. The original basic construction budget estimate is recorded on the budget document as $110,940,000. This reflects the proration made by Congress when the program was reduced from seven ships to three. The records of NAVSEA 01G show that the basic construction cost estimate for three ships at that time to be $129,140,000. The $165,665,753 does not include the gas turbine propulsion system and generators as does the $129,140,000 because it was decided in the period between estimates and contract award to procure this equipment as Government Furnished Equipment in lieu of CFM. A comparable figure of $193,205,753 is then obtained by adding $27,540,000 for this equipment to the $165,665,753 figure. According to this record of cost estimating, the Navy underestimated the FY 1975 FFG program by 52 percent.

Records in NAVSEA 01G indicate that the back-up data for the contract price of the FFG 8 exceed the corresponding Navy estimates as follows:

- Labor hours....... 37 percent
- Overhead .... 73 percent
- Material .... 47 percent
- Profit............ 77 percent
- Total Basic Ship... 52 percent

TABLE V.3

1977 NAVY BUDGET ESTIMATES FOR FY 75 FFG FOLLOW SHIPS (3)
(Dollars in Thousands)

Breakdown of Estimate	6/74 Orig.Est. Approved By Congress	8/74 NAVSEA Revised Estimate	4/77 Current Estimate	6/74 Estimate Change	8/74 Estimate Change
Plan Costs	1,020	2,580	2,580	1,560	-
Basic Construction	110,940	148,650	164,680	53,740	16,030
Change Orders	3,360	3,720	20,900	17,540	17,180
Electronics	13,110	16,300	30,680	17,570	12,380
Propulsion Equipment	-	-	27,540	27,540	27,540
Hull, Mechanical, Electrical	4,170	6,180	8,740	4,570	2,560
Other Costs	330	840	1,180	850	340
Ordnance	37,110	60,870	75,730	38,620	14,860
Future Characteristics Changes	-	-	-	-	-
Escalation Budgeted	11,100	44,500	55,510	44,410	11,010
Escalation Earned	-	-	3,000	3,000	3,000
Project Managers Growth Factor	4,860	9,660	13,060	8,200	3,400
Total Ship Estimate (3 ships)	186,000	295,300	403,600	217,600	101,300

The conclusion that is drawn from the review is that official budget documents show an overrun for the total ship estimate (three ships) to be 117 percent or 37 percent depending on the base used.

It would appear, based on documentation made available, that the underestimate for basic construction was about 52 percent. This basic construction estimate of $129,140,000 (three ships) was revised substantially in August 1977, two months after the seven ship estimate was developed, which increased the cost to $148,650,000. This new estimate includes what is described as

- "Reflects experience learned on lead FFG"
- "Includes additional (fourth) SSDG*"

The cost growth from this revised basic construction estimate to the current estimate of $164,680,000 is approximately 11 percent.

(3) The AD 41, Which Is A Repeat Of The AD 38 And 39, Is Being Overrun By 80.5 Percent

There have been only two Destroyer Tenders (ADs) built since World War II. The AD 37 and AD 38 were built in the Puget Sound Naval Shipyard and delivered in September 1967 and August 1968. The AD 41 is the third of a new class destroyer tender with the capability to service nuclear ships. The original budget estimate to Congress, prepared October 11, 1971 for the FY 1973 budget was based on

* Ship Service Diesel Generator

return costs of the first two ships -- the AD 37 and 38. It was estimated that the basic construction cost for a third AD in the FY 1973 SCN program would be $81.9 million if built in a naval shipyard and $64.6 million if built in a commercial shipyard.

This FY 1973 estimate took into account Headquarters Modification Requisitions and other changes not included on the AD 37 and 38 design such as an accommodation change from a Type Command Ship to a Flotilla Command Ship. For all changes, however, the light ship weight increased only 72 tons to the current estimate of 13,271 Light Ship Tons.

The AD was dropped from the FY 1973 program due to fiscal constraints but reappeared in the FY 1975 program. NAVSEA 01G re-estimated the AD 41 on March 23, 1973 for the FY 1975 program on the basis of bids received on similar ships -- the AS 39 and 40 received from Litton and General Dynamics in June 1972. Using the nine group breakdown from these bids, the basic construction costs in FY 1975 were re-estimated at $90.4 million. Table V.4 following details the estimate and subsequent cost history.

TABLE V.4

AD 41 ESTIMATE HISTORY

	FY 73 Budget (10/71)	FY 75 Budget (3/73)	08/74 SCA	04/75 OSD Approved	Budget Estimate (6/76)*
Manhours**	3,844	3,900	5,838	5,838	6,342
Labor Rate (direct and overhead)	$8.26	$10.24	$10.04	$10.61	$11.74
Labor Cost**	$31,738	$ 39,916	$ 58,610	$ 61,967	$ 14,447
Material Cost**	$26,998	$41,255	$ 51,750	$ 54,015	$ 70,953
Profit Rate	10%	11%	11%	12%	11.87%
Basic Construction **	$64,610	$90,400	$122,500	$129,900	$162,737
Contract Esclation **	$ 3,576	$ 5,460	$ 38,500	$ 40,054	$ 44,375
Change Orders Allowance**	$ 3,000	$ 4,525	$ 6,100	$ 6,500	$ 22,300
GFE**	$10,160	$ 9,202	$ 13,958	$ 17,303	$ 8,700
Other **	$ 5,554	$ 7,113	$ 6,442	$ 6,943	$ 8,188
End Cost **	$86,900	$116,700	$187,500	$200,700	$246,300
Estimate Classification	"C"	"C"			

* Based on NASSCO Bid of December 1975

** Expressed in thousands

In August 1974, the AD basic construction cost was re-estimated in a Ship Cost Adjustment review and increased to $122,500,000 with an associated end cost of $187,500,000. This estimate was based upon a re-bid of the AS 39 and 40 by Lockheed in November 1973. Lockheed was the sole bidder and was given a cost plus fixed fee contract for the AS 39 and 40 in November 1974.

The AD 41 estimate was again revised on March 31, 1975 to reflect a three month delay in award which increased the end cost to $200,700,000 from $187,500,000. Finally, the last estimate shows $162,737,000 for basic construction and $246,300,000 for end cost based on the NASSCO bid and subsequent award of the AD 41 on December 15, 1975.

The cost growth in basic construction between the March 1973 estimate of $90.4 million and the bid estimate of $162,737,000 is summarized in Tables V.5 and V.6.

TABLE V.5

ESTIMATED VERSUS ACTUAL COST GROWTH
BY MAJOR CATEGORY

	Percent Growth
Light Ship Weight	1.4
Labor and Engineering Manhours	62.5
Labor Costs	118.5
Material Costs	75.5
Overhead Costs	74.5
Profit	95.5
Basic Construction Cost	80.0

Table V.5 shows the percent growth that took place between March 1973 and June 1976 by major cost category. The significance of this comparison is the remarkable consistency of miscalculation of all major estimating categories when the physical changes were minor -- increasing the ship's weight by only 72 tons. This may have been due to a rapid change in productivity and material costs. Table V.6 below shows the same cost differences in the form of the nine cost group breakdown.

TABLE V.6

ESTIMATED VERSUS ACTUAL COST GROWTH BY NINE COST GROUPS

	---- Growth Percentage---------		
	Manhours	Material *	Ship Changes **
Hull Structure	53.5	48.0	-
Propulsion Plant	25.7	113.0	-
Electric Plant	-25.5	6.0	-
Command and Surveillance	24.0	111.0	-20.0
Auxiliary Systems	63.8	102.0	+3.0
Outfit and Furnishings	54.8	94.0	+8.0
Armament	38.1	-28.0	-50.0
Integration Engineering	142.3	-56.3	-
Ship Assembly and Support	74.2	233.0	-

* Dollars
** Weights

According to the Navy Material Index, material prices grew 55 percent between March 1973 and December 1975. The material inflation growth shown in Table V.5 (by comparing the March 1973 estimate to the current estimate) is 75.5 percent. This may be due, in some degree, to the NASSCO practice of extensive subcontracting. The difference in labor hours of 62.5 percent then becomes even more difficult to explain when the characteristics of the ship remained essentially unchanged. In fact, the weight growth was only 1.4 percent. This is either the result of bad estimating or a rapid deterioration of productivity that could not be predicted. The succeeding table shows variations in labor estimates among the nine cost groups from -25.5 percent to 142.3 percent, a range of 168 percent.

From records in NAVSEA 01G, it would appear that no attempt has been made to record the results of the contract negotiation to reconcile these wide differences as a protection against similar discrepancies in the future. Possible explanations of these differences may be:

- The effect of a seller's market where the shipbuilders were willing to take Navy work only if they had sufficient manhours to cover all possible contingencies such as:
  - Quality control and rework
  - Hidden specifications requirements
  - Disruption caused by changes or late GFM
  - Unexpected engineering documentation
  - Compliance with DOD INST 7000.2
  - Productivity considerations
- The AS bids of June 1972 by Ingalls and General Dynamics may have been very low and NAVSEA 01G reflected this data in the AD 41 estimate.
- The NASSCO bid may have been high due to a backlog

of commercial work and due to its loss experience on the AOR 7. NAVSEA 01G, again, did not have sufficient data or insight to detect it.

- Since Puget Sound Naval Shipyard delivered a very similar ship in 1967 for considerably less manhours, something dramatic happened to productivity and/or it had become increasingly difficult to work with the Navy.

NAVSEA had demonstrated in this instance that they have the capability to extrapolate experience from similar ships to derive a cost estimate, but in budget preparation during that period, the group did not detect the impact of rapid changes in productivity, market conditions and inflation.

NAVSEA was(and is)not prepared to question a shipyard estimate by individual cost group which deals with manhour and material details. This is due to lack of readily retrievable current bid and return cost data. This type of information is needed to detect productivity and other general trends -- which under any conditions is most difficult. Currently, NAVSEA is increasing labor estimates by 18 percent to reflect changes in productivity.

(4) <u>The ARDM 4 Has Experienced A Cost Growth Of 52.4 Percent</u>

The ARDM 4 is the first drydock to be built by the Navy since World War II. The basic construction estimate dated March 13, 1973 was $16,350,000 and carried a "D" classification. This estimate for a fixed price contract was included in the FY 1975 budget submission to Congress. About two years later, on February 14, 1975, a contract estimate was prepared prior to receipt of bids and the cost was re-estimated at $18,640,000 on an adjusted price basis which took into account unanticipated inflation that took place from 1973 to 1975. On July 29, 1975, bids were received from a single bidder -- Bethlehem Steel Company -- for $24,996,000 on an adjusted price basis (i.e., to be adjusted for labor and material escalation during contract). A reconciliation was attempted to account for the difference between the Navy estimate and Bethlehem's. This review led to a voluntary price reduction of $569,000 by Bethlehem and an award was then made on October 23, 1975 for $24,427,000.

A comparison of the end cost breakdown prepared for the FY 1975 budget on March 13, 1973 and the most recent estimate of June 1977 is shown in Table V.7.

The $16,350,000 estimate of March 13, 1973 was classified by the estimator as "D" quality and, in doing so, indicated that it should not be considered budget quality. Nevertheless, it was used for the budget submission and the record does not provide further explanation.

TABLE V.7

ARDM 4 COST GROWTH
(Dollars in Thousands)

	Budget Estimate 3/13/73	Estimate as of 6/77	Percent Growth
Construction Plans	500	-	-
Basic Construction	16,350	24,300	48.6
Basic Changes	1,650	2,000	21.2
Future Delivery Charges	800	-	-
Escalation Budgeted	-	2,600	-
Other Costs	440	500	13.6
Grand Total	19,740	29,400	48.9

As can be seen, the major contributor to cost growth is in the estimate for basic construction (49 percent). One cause of this difference is in the area of labor rate. It is shown in Table V.8 that the quantity of labor was 22 percent less than the NAVSEA estimate and further that Bethlehem used $9.44 per hour compared to the Navy's $5.40 per hour. Bethlehem presented back-up that finally convinced the Navy that this rate was reasonable for the Bethlehem shipyard.

The breakdown of percent differences in the basic construction estimate is shown in the following table. It is a comparison of the Navy manhours and material estimate of March 13, 1973 and the accepted Bethlehem bid dated July 29, 1975.

TABLE V.8

COMPARISON OF ARDM 4 ESTIMATE VERSUS BID

Estimated Group		Percentage Growth Labor Man-hours	Material
100	Hull structure	- 57	+ 12
200	Propulsion Plant	-	-
300	Electric Plant	+ 37	+ 154
400	Command & Surveillance	- 45	+ 171
500	Auxiliary Systems	- 38	+ 159
600	Outfit and Furnishings	- 26	+ 144
700	Armament	-	-
800	Integration/Engineering	- 41	+ 1,650
900	Ship Assembly/Support Services	+ 140	+ 382
	TOTAL	- 22	+ 162

The record does not indicate that the dry dock design changed in the intervening time so that when comparisons of estimated manhours and material costs are examined, differences are so large that one can conclude that either the Navy greatly under-estimated the job or Bethlehem had greatly over-priced it. The ship is now under construction on a fixed price contract, hence it will be some time before the reason can be known. In any event, since the Navy did accept the Bethlehem bid, the overrun is real and as far as budgeting is concerned, it was under-estimated.

Bethlehem did submit a detailed estimate to back-up their bid but since NAVSEA uses only a nine group breakdown in their estimating, a sole source award was considered without benefit of knowing in detail why manhour and material cost differences were so large. NAVSEA 01G subsequently examined the Bethlehem bid back-up, met with Bethlehem officials, and decided that the price was reasonable. Upon this advice, the contracting officer negotiated the contract.

In retrospect, several considerations should be kept in mind.

- Market conditions were such that Bethlehem was the sole bidder. If the market had been such that several bids had been received, it would not have been unreasonable to expect a low bid up to 25 percent less than that submitted by Bethlehem.

- NAVSEA made its budget estimate 31 months prior to award. During this period, the NAVSEA "Cost Group" Index increased 60 percent, which is twice what might have been reasonably expected in 1973.

It could be concluded that had the market conditions of 1973 continued into 1975 and had material inflation remained within reasonable limits, the Navy's March 31, 1973 estimate of $16,350,000 would still have been on the low side -- but not as seriously as it seems now.

(5) <u>NAVSEA 01G Estimating Performance On Ships Contracted For In The FY 1975-1976 Budget Averaged 30 Percent Below The Contract Price</u>

Table V.9 shows NAVSEA estimating performance in relation to design status (i.e., new or repeat), time lapse between the budget estimate and award, and the difference in estimated values used by Navy and low bidder for labor hours, material dollars and overhead cost.

TABLE V.9

BASIC CONSTRUCTION COST GROWTH
FY 1975 and FY 1976

Fiscal Year	Program	Basic Construction Cost Growth (percent)	Design Status	Time Between Budget Est. and Contract Award (months)	Increase in Basic Estimate Between Budget and Award		
					Labor Hrs. (percent)	Material (percent)	Overhead (percent)
1975	SSN 688	22.0	Repeat	25	(1)	47.0	(1)
1975	FFG 7	52.0	Repeat	18	29.0	47.0(3)	73.0(2)
1975	AD 41	80.5	Repeat	33	62.5	75.5	74.5
1975	ARDM	48.0	New	31	(22.0)	162.0	(10.0)
1976	SSN 688	0.1	Repeat	19	*	*	*
1976	FFG 7	27.4	Repeat	13	*	*	*
1976	AD 42	6.5	Repeat	22	*	*	*
1976	AO	3.8	New	12	*	*	*

* Not analyzed.
(1) Overrun for labor and overhead dollars combined -- 20 percent.
(2) Profit margin exceeded Navy estimate by 77 percent.
(3) Includes main propulsion units, etc., @ $9.19 million per ship now GFM.

In FYs 1975 and 1976, the only new designs were the ARDM 4 and the AO. The remainder consists of repeat designs with no changes in design which would affect price after the initial estimate to any great extent.

With regard to labor hours, the Navy estimates were substantially less than the bidder except for the ARDM 4 and the SSN 688. In the case of the ARDM 4, the labor rate used by the bidder was 75 percent higher than that used by the Navy; however, the number of manhours used by the bidder was 22 percent less. Overhead estimates (in two cases) were about 74 percent low. The most consistent difference is with respect to material costs.

The effort to quantify the estimating capability of NAVSEA was complicated by the fact that the continuity and quality of estimate records in NAVSEA over the 33 month time span are completely inadequate. This was demonstrated by the inordinate amount of time spent by study staff and NAVSEA personnel to track this relatively small sample of estimating performance. A more comprehensive analysis of performance was precluded by inadequate estimate documentation. The limited examples included, however, do represent almost all of NAVSEA's estimating activities for the 1975 program.

What has been found is that the Navy failed to recognize, in the 1972 through 1974 time frame, the magnitude of changes taking place which were changing the character of the industry.

- Increasing labor costs
- Skyrocketing material costs
- A rapid drop in labor productivity
- Rapid growth in overhead cost
- Effects of a seller market in the industry

This is not to forget the difficulties in predicting prices and costs two to three years in advance of contract award even under the most favorable circumstances. Navy estimators have even greater difficulty, however, because of late program changes and poor product definition. In addition, the allowances by OSD for future inflation have proved in the past to be inadequate.

Considering this environment, the Navy should have a particularly strong and capable Cost Estimating and Analysis Group to cope with these conditions -- perhaps an elite group might be the term.

This study of the FY 1975-1976 program has brought to light a number of problems that can be noted.

- Cost estimates were calculated in too aggregated a manner (nine cost groups). Greater accuracy and familiarity with design features and weapons systems could be expected if estimates were to reflect available detail of the design development.

- Data banks were insufficient. They are still not in a form that facilitates rapid retrieval of data in usable form. Neither does it contain the mass of pertinent cost data that is available within the Navy or properly available to it.

- Estimate documentation setting forth the rationale behind an estimate, data source, purpose, design data, etc., in most cases, was incomplete and often non-existent.

- No systematic effort was made to monitor and analyze return costs in on-going programs to keep Cost Estimating Relationships up-to-date or to determine current productivity trends.

- The estimating and cost analysis staff had very limited contact with shipyard and industry counterparts. As a result they did not have an opportunity to keep abreast of current developments and trends until it was too late.

- The cost analysis and estimating staff are a dedicated group who have implemented many previous study recommendations, but on the whole, has been insufficient in numbers, experience, training and budget resources to adequately estimate complex Navy ships.

- In addition to the lack of estimate documentation, recordkeeping in the Division was poor. No records were kept, for example, of where time is spent on the numerous functions assigned to the Division.

- Supervision was insufficient in that all supervisors through GS 15 were working supervisors and often could not give adequate guidance to subordinates or give their work adequate review.

3. A NUMBER OF SHIP AND GFM CASES WERE SELECTED FOR MORE IN-DEPTH STUDY TO PROVIDE FURTHER CLUES AS TO THE CAUSES OF COST GROWTH

The ship cases selected demonstrated cost growth between the Congressional budget and estimated (or actual) end cost of

- 52 percent for the AOR 7
- 20 percent for the SSN 678
- 41 percent for the FFG 7

These ships are vastly different in terms of program development status, engineering sophistication, economic and market influences during building periods and priority within the shipbuilding program.

To illustrate one of these differences -- economic influences during building period -- Figure V.2 shows shipbuilding material and labor inflation indexes between the years 1965 and 1977. Superimposed on these indices are the development periods for each of the three ships. The difference in economic environment is obvious.

Before describing the ship programs examined, however, a brief discussion on the method of selecting the ship and GFM items to be tracked.

(1) A System Was Devised To Select Three Ships From The 1970-1977 Programs For Detailed Analysis

The review included 108 ships of 12 different types in the following five Budget Activities: 1) Ballistic Missile Ships; 2) Other Warships; 3) Amphibious Ships; 4) Mine Warfare Patrol; and 5) Auxiliaries and Craft. Programs that were not included are those that were considered as being not representative of typical ship construction. These were the SSBN POSEIDON conversions wherein major sections of the ships were not involved. Also, four T-ATF tugs and smaller craft were not considered because of their relatively small impact in the SCN appropriation.

Table V.10 summarizes the ship classes and numbers of ships authorized over the study period and which formed the population from which ships were to be selected.

FIGURE V.2

MATERIAL COST GROWTH AND KEY PROGRAM DATES FOR SHIP CASES

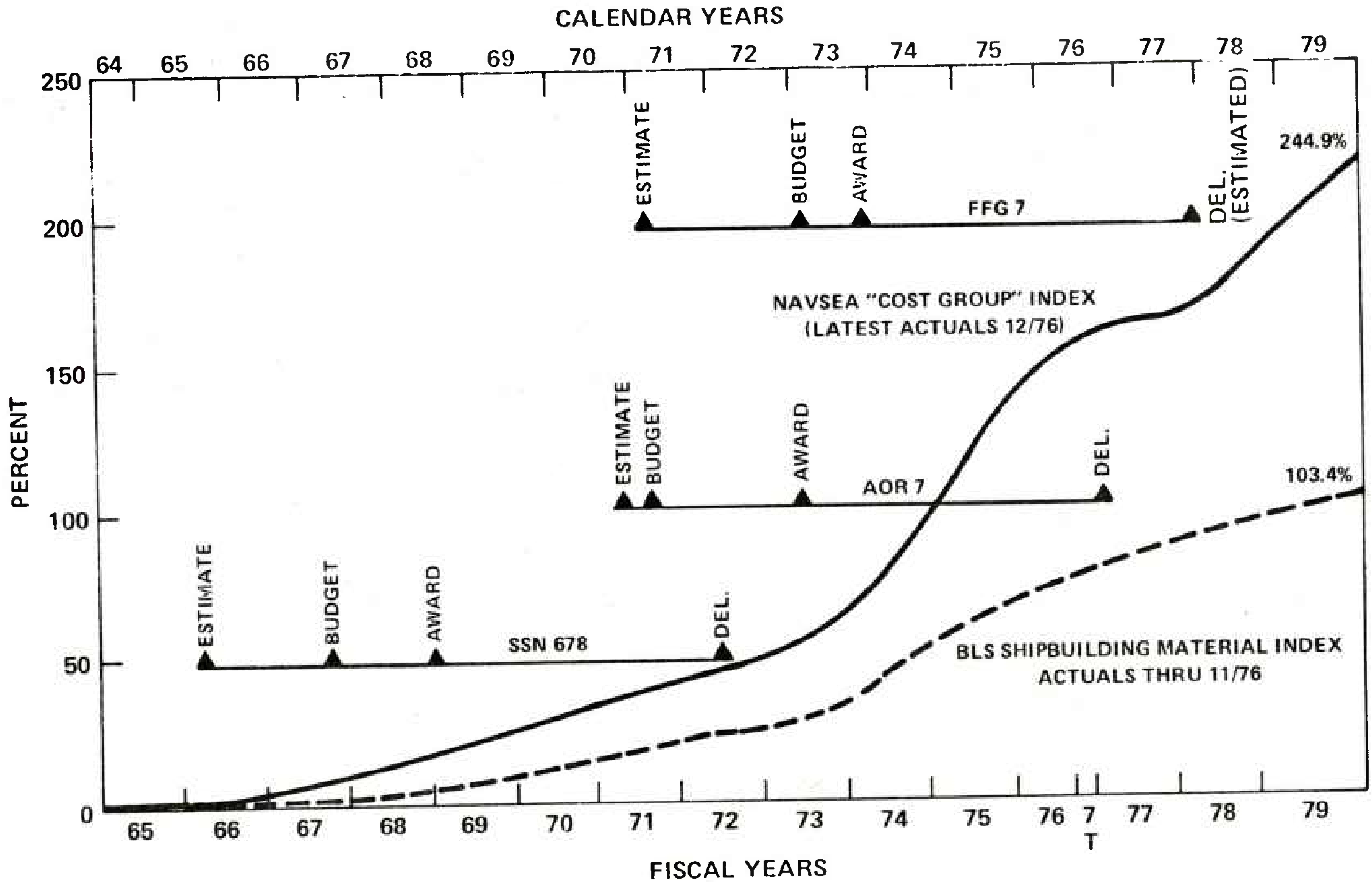


TABLE V.10

SHIPS AUTHORIZED AND FISCAL YEAR OF AUTHORIZATION

Type	1970	1971	1972	1973	1974	1975	1976	1977
SSN	3	4	5	6	5	3	2	3
TRIDENT	-	-	-	-	1	2	1	1
DD	3	6	7	-	7	7	-	-
FFG	-	-	-	1	-	3	6	8
CVN	1	-	-	-	1	-	-	-
CGN	1	1	1	-	-	1	-	-
LHA	2	2	-	-	-	-	-	-
AD	-	-	-	-	-	1	1	1
AS	-	-	1	1	-	-	-	1
AO	-	-	-	-	-	-	2	1
AOR	-	-	1	-	-	-	-	-
PHM	-	-	-	-	-	4	-	-

Many factors were considered in the initial review process before a recommendation could be made as to the ships to be selected for in-depth study. The written record, particularly reports of Congressional hearings, discusses in some detail the problem of cost growth from original estimates, the rapidly rising cost of naval ships (aside from obvious economic problems), the quality of Navy estimates, the diminishing number of shipyards in which naval ships are being constructed, shipyard attitude toward Navy and vice versa, contract administration procedures and the like. These kinds of problems are covered in the many documents reviewed in preparation for the report. They provided a basis for focusing on important criteria requiring review prior to selection of specific ships to be studied. The criteria that were considered pertinent and on which selection was based follows:

- Size of the program -- This criterion was used to weight the larger of the ship programs with the view that it was best to direct effort to areas consuming the larger amount of Navy resources.

- Size of cost growth -- Since the study was prompted by the amount of cost growth being experienced on SCN programs, this factor was important in the selection process.

  As has been previously discussed, the size of cost growth is considered in this study to be a function of the current estimated cost versus the "original estimate". The original estimate is defined as the estimate made available to the Congress on which funding actions for advance procurement and/or authorization of a new ship or class of ships were based.

- Ship type -- The type of ship was considered in that an insight might be gained regarding impact on overall cost growth in understanding estimating difficulties related to all types of ships.

  From the point of view of ship type alone, the ships authorized for construction in Fiscal Years 1970-1977 provide a suitable mix from which to select three types for detailed review. Within each of the categories indicated in the study specification, i.e., a nuclear ship, a non-nuclear combatant ship and an auxiliary ship, there are at least three types from which to make selections.

  The combatant ships cover a broad spectrum of size, configuration, manning, armament and mission. They range from aircraft carriers (measuring almost 1,100 feet, carrying over 5,700 people for whom living and working accommodations must be provided, as well as complex systems for operating aircraft) to the 132 foot hydrofoil (which carries 21 people and conducts offensive warfare while traveling at great speeds) as well as various types and classes of surface combatants.

- Follow program -- This criterion relates to the possibility that findings of the study will have additional value if the ship on which findings are based is to be followed by a ship class having features similar to the case study ship. Similar or identical hulls or similar weapons systems are examples.

- System integration complexity -- Because difficulties encountered in integrating weapons systems into the total ship control system have caused significant cost growth, it is considered that ships with more complex weapons systems should be given preference in the selection process. The more complex the system, the greater the probability of integration problems, and the greater the estimating problem.

- Design -- Within the population of ships there are a number of different design processes being followed. They range from a simple repeat design to design-to-cost. Ships having more extensive or complex design requirements were given preference in the selection.

- Number of shipyards involved -- There is a potential advantage in having two or more shipyards involved in the construction of ships of the same class as the specific ships selected for in-depth review because cross-checking of estimates, proposals and performance reports should be possible.

- Acquisition status -- The purpose of this criterion is to insure that ship programs in their infancy are not selected because, for these programs, the amount of useful data is limited. Comparisons of estimates to actuals would not be possible on very new programs.

- Contract data -- The contracts under which the ships being considered are procured usually cover more than one ship. This makes data analyses more difficult, especially if a lead ship is included in the lot. Preference is given to single ship contracts and, then, to contracts including only follow ships.

- Potential problems -- It is considered that some of the ships in the population are more apt to experience problems which will affect cost and delivery after this study is completed than are other ships. This could tend to reduce the usefulness of the study results. Accordingly, preference was given to ships that give promise of having fewer problems as they near completion.

- Claims -- Preference was given to ships with the fewest claims and to ships being constructed in shipyards having lodged claims on only one ship type. The purpose is to reduce the impact of claims on the analysis of actual cost data.

The process of selecting ships based on these criteria was an iterative one. The first step was to eliminate from the sample those ship types which presented particular analysis problems. On this basis, the following ships were eliminated in the first cut.

- TRIDENT since it was managed by a project office under NAVMAT; not a party to the contract and also not a mature program.

- LHA since it was the first Navy ship of its class constructed at a completely new building facility; too many start-up problems could confuse issues.

- PHM as too unique and not built at typical shipyard.

- AO 177 since progress against completion is minimal.

- AS ruled out as too closely connected with other potential nuclear ships.

- CVN since armament not complex -- as compared with nuclear submarines, for example.

The final selections were made between two ship types within each of the categories by close analysis of the criteria. The choices were as follows.

- The SSN 688 class was chosen over the CGN 38 class. It met the criteria of program size, cost growth, number of ships, complexity and number of shipyards. Other criteria were either not germaine or favored the CGN.

- The FFG 7 class was chosen over the DD 963 class. This was a difficult choice but the major influences were program size, apparent cost growth, design-to-cost experiments, number of shipyards, follow-on potential and fewer problems.

- The AOR 1 class was chosen over the AD 41 class. The choice here was driven by the fact that the AOR class had a relatively complete record of events over seven ships which would provide an opportunity for detailed review of acquisition phases.

To summarize the selection choices, then,

TABLE V.11

SUMMARY OF SHIP CLASS SELECTION

Selection Criteria	------Ship Classes------		
	SSN 688/ CGN 38	DD 963/ FFG 7	AOR 1/ AD 41
Program Size	SSN	FFG	AD
Cost Growth	--	FFG	AD
Ship Type	SSN	--	--
Follow Program	CGN	DD	AOR
System Integration Complex	CGN	DD	AOR
Design	--	FFG	AD
Number of Shipyards	SSN	FFG	AOR
Delivery Status	--	DD	AOR
Contract Data	--	FFG	AOR
Potential Problems	SSN	FFG	AOR
Claims	SSN	--	AD
Consensus	SSN	FFG	AOR

(2) Three Ships Were Selected, Two Were Approved By The Navy, The Third Rejected And A Substitute Directed

The SSN program is under construction in two shipyards, Newport News Shipbuilding and Dry Dock Company and General Dynamics Corporation, Electric Boat Division. The first consideration was the shipyard. In consideration of the claims situation that prevails between Newport News and Navy, on prior programs as well as the SSN, opinion was that one of the ships under contract with Electric Boat could be tracked more thoroughly, with input provided by the shipyard as well as the Government. The selection process then concerned itself with which of the boats at Electric Boat to recommend. Since there was little choice but to track the lead ship in the non-nuclear combatant category and a single ship in the auxiliary category, study of a follow ship would round out the mix of lead yard/lead ship and follow yard/follow ship. The group, therefore, recommended SSN 696 for tracking. The construction schedule for SSN 696, at the time, was about one year behind SSN 690; the first ship of this class is under construction and nearing completion at Electric Boat and about 1-1/2 years behind the SSN 688. The SSN 696 is approximately 70 percent complete and is projected for delivery in April 1978. The selection of the SSN 696 was not approved by the Navy, however. A boat in the 637 class -- SSN 678 -- was directed.

The FFG 7 was the logical choice for tracking in this category. It is the lead ship of the class, being constructed in the lead yard. There are two other yards involved in the program in follow ship construction. FFG 7 is estimated to be approximately 90 percent complete, with delivery estimated in December 1977.

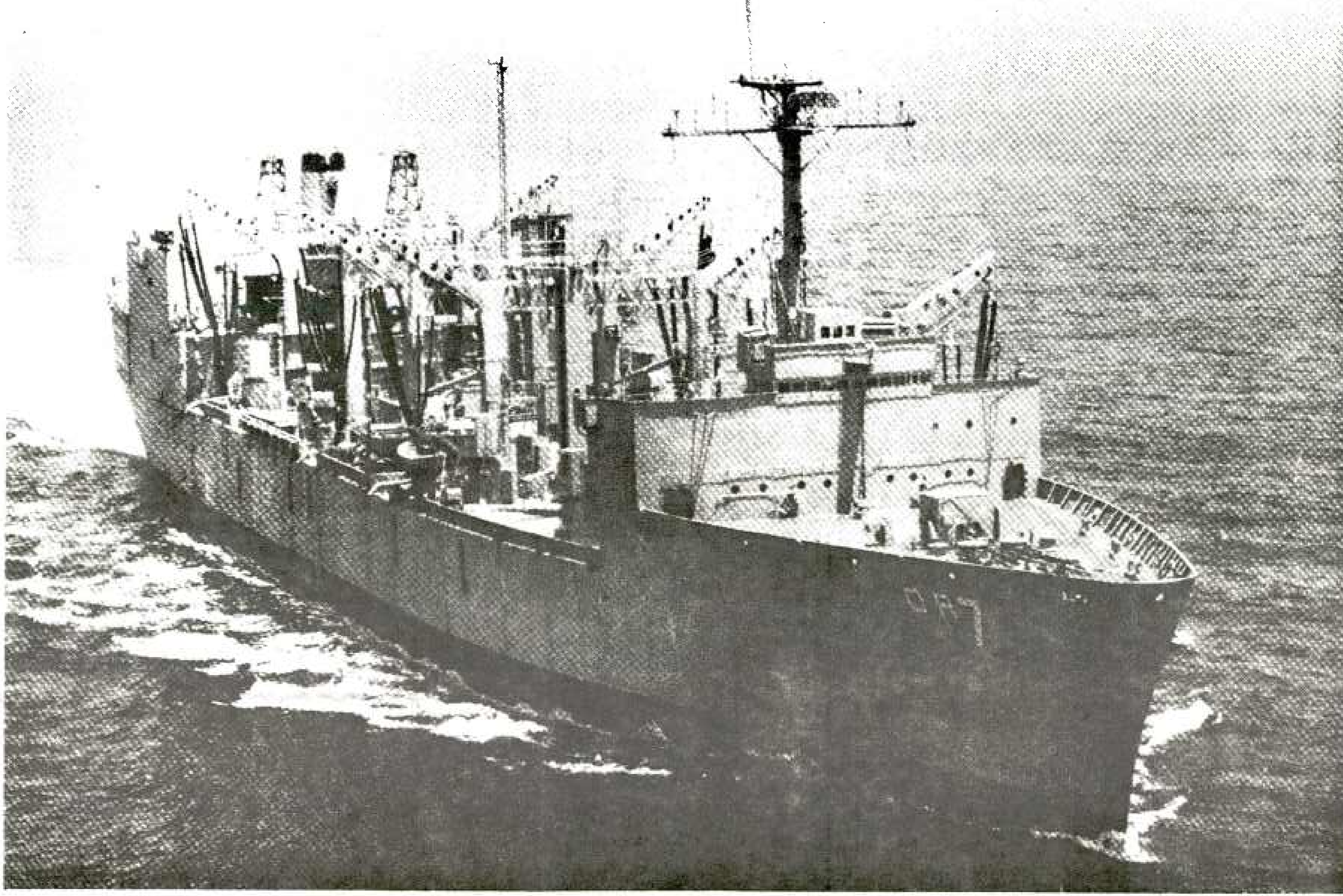
The AOR 7 is the only ship of this type authorized in the period covered. It was constructed by National Steel and Shipbuilding Company and delivered on October 14, 1976. It is of the AOR 1 class constructed by General Dynamics, Quincy Division in the late 1960's.

(3) Eight Items Of GFM Were Selected By The Navy As Being Interesting Tracking Candidates

The following items of GFM have been researched as part of this report:

- AN/SPS-55 Surface Search Radar -- A conventional x-band radar capable of detecting medium and large line-of-sight targets and small targets at close range.
- PHALANX Close-In Weapons Systems -- A unitized, completely automatic gunnery weapon designed to recognize, track, fire on and destroy a missile within its operating area.
- MK-45 Lightweight Gun -- A fully automatic, lightweight, shielded single-barrel weapon firing 5"/54 caliber projectiles at about 20 rounds per minute.
- MK-86 Gun Fire Control System -- A gun fire control system for surface to surface and surface to air (aircraft and missile) weapons.
- AN/UYK-7 Digital Computer -- A modular, general purpose digital computer for shipboard applications in the weaponry and administrative computing areas.
- AN/SPS-40 Air Search Radar -- A lightweight air search radar for detection of high and low flying targets.
- AN/SQS-53 Sonar -- A surface ship sonar providing detection, classification and localization of underwater targets as part of the ASW mission.
- LM 2500 Gas Turbine Engine -- An advanced propulsion unit developed from aircraft technology. It is a simple cycle, two shaft, high performance engine generating 27,500 horsepower with necessary support subsystems.

THE AOR-7 REPLENISHMENT OILER



4. THE AOR 7 WAS BUDGETED AT $56.5 MILLION IN 1970; BUT UPON DELIVERY IN 1976, THE COST WAS $86.3 MILLION

The AOR 7 is a multipurpose replenishment ship designed to provide rapid replenishment of petroleum products, selected ammunition items, limited amounts of chilled and frozen provisions, repair parts, consumable stores, and fleet freight to operating forces at sea.

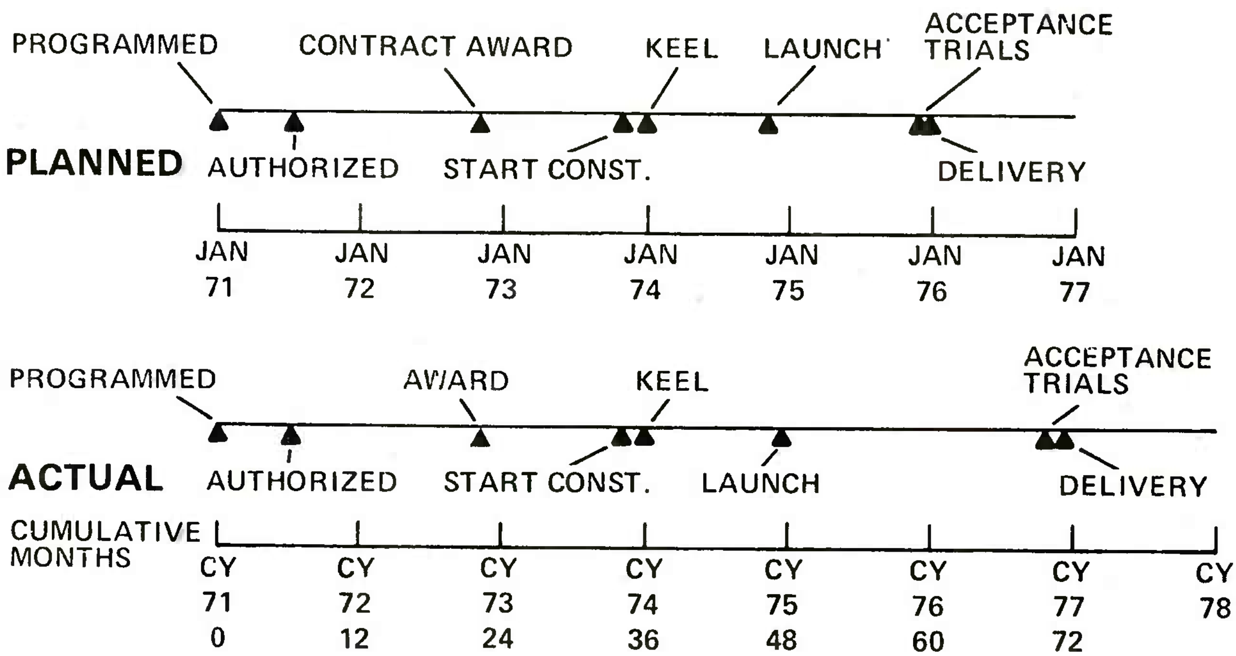
When first authorized in FY 1965, the AOR was a new type of ship which was designated a Replenishment Oiler and it is now one of five ship types classified as Underway Replenishment Ships in the Auxiliary Ship group. Subsequent AOR class acquisitions are summarized below:

- Contracts for AORs 1 through 6 were awarded to General Dynamics-Quincy. The U.S.S. WICHITA AOR 1, the lead ship of the class, was delivered in May 1968, thirteen months behind schedule at a cost of $41.0 million.
- The last of the class built by General Dynamics-Quincy, the U.S.S. KALAMAZOO AOR 6, was delivered in July 1973, thirty months behind schedule at a cost of $43.7 million.
- The AOR 7 was authorized in June 1971 with the FY 1972 shipbuilding program to replace an older ship of questionable reliability which was then approaching 36 years of service.

An overview of the AOR 7 development follows:

FIGURE V.3

AOR 7 ACQUISITION PROGRAM



(1) <u>The Replenishment Oiler AOR 7 Was Included In The FY 1972 Shipbuilding Program</u>

An estimated end cost of $56.5 million for AOR 7 was forwarded to the Congress in January 1971. This estimate, including escalation growth and other contingencies was derived as a result of a series of program planning and budgeting reviews, the results of which can be summarized as follows.

TABLE V.12

COST HISTORY OF AOR 7
(Dollars in Millions)

Date	End Cost Estimate	Estimated Basic Construction Cost	Estimate Classi-fication	Remarks
2 April 1970	70.9	46.7	F	POM Preparation
12 June 1970	68.5	44.7	D	POM Submit
28 Sept. 1970	65.5	44.7	D	SECNAV to OSD Budget Submit
19 Nov. 1970	56.5	41.7	F	PBD Reclama
17 Dec. 1970	58.5	43.4	F	NAVSHIPS to OP-NAV Budget Reclama
18 Dec. 1970	56.5	41.7	F	Approval and Budget Submit
14 Dec. 1972	68.0	48.1	F	Reprogramming Action
14 Oct. 1976	86.3	61.4	-	End Cost

These planning and budgeting reviews are characterized by continual testing of options to best utilize resources provided by OSD guidance for the POM and Budget submissions. Many elements -- cost per ship, number of ships, characteristics lists, current year or out year programming -- are evaluated to achieve the best program within resources available. The objective, finally, is to put forward a program which has high probability of Congressional approval. The compromises attendent to such a process necessarily impact over the life of the ship procurement. This was evident in the AOR 7 acquisition.

Estimating problems during the early period were caused chiefly by changing and sometime confusing characteristics lists for the ship. Beyond that, constant pressures were exerted to settle on a lower end cost figure. CNO guidance for the AOR 7 was issued in September 1969 and requested five ships (two in FY 1973 and three in FY 1974) of a modified, repeat design based on AOR 5 and 6 specifications. All changes in the AOR class developed over the three previous flights such as class items, field and headquarters-initiated changes and operational evaluation items were to be included in the design baseline. Further, new characteristics were specified in ordnance, habitability, pollution abatement, helicopter handling, refrigeration compartments and electronics.

In reviewing estimating activities during this period, a question arises as to whether AOR 7 was a new class ship or actually a routine modification of a current or existing class of ships. The answer to this question impacts the estimate classification. If the changes accumulated on prior ships had been routinely incorporated in the class design, one might expect a class "B" estimate; however, these changes were thought by NAVSEA estimators to be substantial and precluded extensive utilization of cost experience from past ships.

The first estimate for the AOR 7 was $70.9 million and implies, by its class "F" designation, an initial reaction that ship changes and updates as approved were sufficient to consider it almost a new class which would cost substantially more than any of the first six AORs -- the last of which cost $43.7 million at completion.

In the time between the POM estimate and the NAVCOMPT budget submission, more refinement took place and a class "D" estimate of $68.5 million for a FY 1973 award was arrived at. A breakdown of the original POM estimate is found in the Table below.

TABLE V.13

BREAKDOWN OF AOR 7 ORIGINAL VERSUS REVISED BUDGET ESTIMATES
(Dollars in Millions)

Cost Category	Original POM Submit Class "D" (5/22/70)	Revised POM Submit Class "F" (9/28/70)
Plans	1.9	1.9
Basic Construction	44.7	44.7
Change Orders	3.6	3.6
Electronics	1.2	1.3
H/M/E	1.8	1.8
Ordnance	8.0	8.0
Escalation	4.6	1.5
Future Characteristics Changes	1.7	1.7
Other	1.0	1.0
Total	68.5	65.5

During the Budget cycle, the NAVCOMPT, CNO and SECNAV Hearings produced a revised plan and, in the last days before the OSD Budget submission, a repricing of the AOR 7 for FY 1972 was requested by CNO.

This price-out came during a time of great pressure in the budget process. The Navy hearings mentioned all take place within the same month and, to further complicate matters, OSD budget guidance is published during this period. The total time between the last hearing (SECNAV review) and the OSD submit is typically only a few days. Consequently, the revised AOR 7 estimate for the FY 1972 budget year was completed in about one day. The resulting revised end cost estimate, shown in Table V.13, was reduced to $65.5 million by a two-thirds reduction in the escalation allowance. This estimate was forwarded for OSD/OMB review on September 28, 1970.

During the Program Budget Decision process, PBD #81 dropped the FY 1972 AOR from consideration. This was responded to by OP-NAV on November 19, 1970 with a reduced end cost estimate of $56.5 million and a request for re-inclusion in the FY 1972 budget. Further, it was asserted that the estimate was a class "C" estimate. This view by OPNAV was addressed in a November 30th internal memo by the NAVSEA estimators in which they stated an objection not only to the amount, but also the "C" classification. The resultant $9 million reduction was considered to be arbitrary and undocumented with regard to characteristics changes. It was further recommended that approximately $4.5 million be reinstated to provide for Integrated Logistics Support, NAVSEC customer funding, and change order growth. Table V.14 summarizes the estimate reduction.

TABLE V.14

BREAKDOWN OF AOR 7 RECLAMA ESTIMATE

	Sept. 1970 FY 72 POM Class "F"	Nov. 1970 PBD #81 Reclama Class "F"	Difference
Plans	$ 1.9M	$ 1.8M	$0.1M
Basic Construction	44.7	41.7	3.0
Change Orders	3.6	2.7	0.9
Electronics	1.3	1.0	0.3
H/M/E	1.8	1.6	0.2
Ordnance	8.0	4.9	3.1
Other Cost	1.0	0.3	0.7
Future Char. Chngs.	1.7	1.0	0.7
Escalation	1.5	1.5	-
Total	$65.5M	$56.5M	$9.0M

One of the contingency issues discussed during the PBD process was the inclusion of long-lead funding for an aircraft carrier. When the carrier funding was eventually dropped the AOR 7 funds, apparently then falling within available resources, were reinstated at the reclama end cost estimate of $56.5 million. This figure prevailed and was included in the President's Budget for Fiscal Year 1972. It thus became the standard against which bid figures and actual costs are measured.

Looking ahead to what the AOR 7 would ultimately cost, it must be concluded that the players in the program planning and budgeting process were in a large measure responsible for changing an estimate which was within 18 percent ($70.9 million) of the end cost to one which was within 35 percent ($56.5 million) of the eventual end cost ($86.3 million).

(2) The Construction Contract Was Awarded To National Steel And Shipbuilding Company On 15 December 1972 As A Fixed Price Incentive Type Amounting To $51.5 Million

The AOR 7, which was to be a modified repeat design after an AOR construction hiatus of more than five years, incorporated numerous design modifications and characteristics changes which in retrospect may have warranted designation as a new class of AOR.

Potential bidders were invited to visit General Dynamics-Quincy during the period 13 to 16 March 1972 for the purpose of reviewing approximately 1,500 plans and drawings from the AOR 5 and 6. The contract requirements for the AOR 7 directed that the detailed working drawings prepared by General Dynamics-Quincy for the AOR 5 and 6 were to be utilized to the maximum extent possible in the AOR 7. This requirement also provided that the successful bidder would modify the subject plans and drawings for compatibility with the involved yard's construction methods. The five days provided for plan review was later confirmed by the Navy claim analysis group to be wholly inadequate for a detailed analysis and review of the working drawings. There is no record, however, of any bidder requesting additional time to review the plans. Thus, bids were based on contract drawings, contract guidance drawings and specifications supplied as part of the RFP with only limited review of the working drawings.

Prior to the submission of bids, General Dynamics informed the Navy that hardware and software changes specified in the AOR 7 contract/design package would involve a large cost increase over the AOR 6. The cost information submitted by General Dynamics showed a $55 million cost baseline for an AOR 6 design with potential increases of $8-11.5 million for hardware and $2-6 million for software for the new AOR 7 baseline. General Dynamics' maximum estimate was in excess of $70 million. NAVSEA agreed that perhaps $2.0 million more was needed, but disagreed with General Dynamics pessimistic outlook regarding budgeted funds.

The Navy's independent estimate of the contract price for the AOR 7 was calculated just prior to the bid closing date. This estimate which is used to judge the reasonableness and accuracy of contractor's bids, was $55.5 million or $12 million above the original amount ($43.5 million) budgeted for basic construction and plans.

As of June 13, 1972 three offerors had submitted bids on the AOR 7, including National Steel and Shipbuilding Company (NASSCO), Todd Shipyards, and General Dynamics-Quincy.

The bid from NASSCO was $51,465,000. The bid from General Dynamics was $69,440,000 and the bid from Todd Shipyards (Los Angeles) was $60,603,991.

General Dynamics, builder of the first six AORs, submitted a bid almost $18 million higher than NASSCO; Todd's bid was almost $9 million or 18 percent higher than NASSCOs. General Dynamics' estimate, capitalizing on experience with AORs 1 through 6, detailed knowledge of the AOR 5 and 6 baseline design plus a knowledge of the AOR 7 characteristics changes, caused them to submit a bid which in the final analysis turned out to be closest to the final contract cost of $71.1 million.

In September 1972, a $10 million increase was requested by the Navy to cover probable higher cost of the AOR 7. The requested increase was attributed to a stated under-estimation of material, labor and overhead costs. Approval for the $10.0 million reprogramming action was given on December 14, 1972 -- one day before the construction contract was awarded.

On October 16, 1972 the Source Selection Advisory Council recommended the awarding of the AOR 7 contract to NASSCO. On December 15, 1972 NASSCO was awarded the AOR 7 contract for $51,474,347. The contract was a fixed price incentive type with material and labor escalation clauses. A summary of the contract costs at award follows:

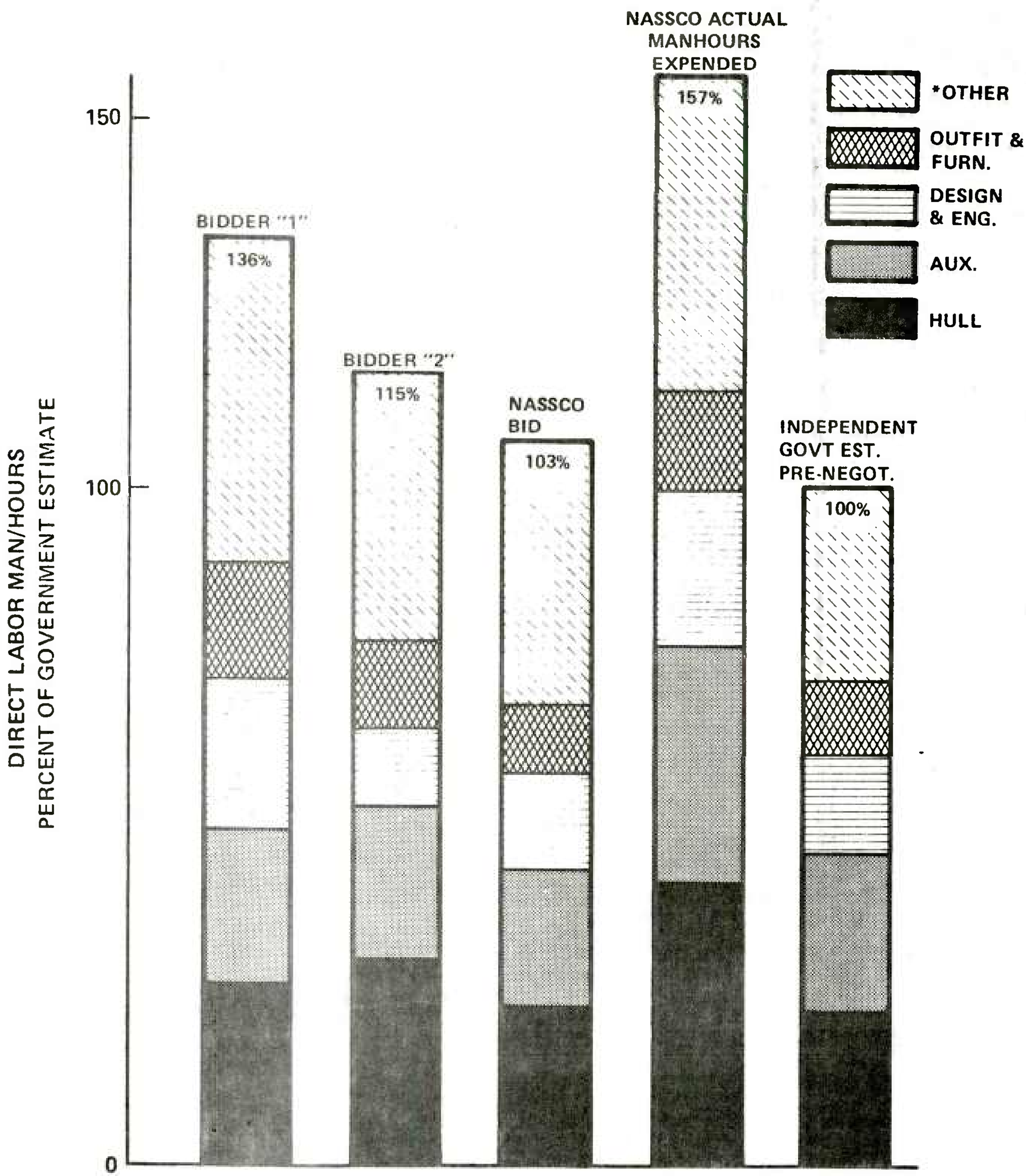
- Target Cost....... $47,125,383
- Target Profit 4,348,964
- Target Price 51,474,347
- Ceiling Price...... 58,906,727

Delivery was scheduled to be 36 months from award date.

A comparison of the manhours bid with regard to major cost categories is shown in Figure V.4 along with the Independent Government Estimate and actual manhours expended.

FIGURE V.4

COMPARISON OF AOR 7 BID DATA



*OTHER INCLUDES PROPULSION, ELECTRIC PLANT, COMMUNICATION AND CONTROL AND ARMAMENT

(3) <u>The Building Period Can Be Characterized By Manhour Overruns, Late Equipment And Schedule Delays</u>

NASSCO had built and delivered, prior to the AOR 7 contract, twenty-four ships for the Navy since 1966. During 1963, in conjunction with the Navy, NASSCO developed the prototype combat stores ships, the U.S.S. MARS AFS 1 and subsequently delivered seven AFS type ships to the Navy (the last of which delivered in 1970). This was followed by a $250 million contract for seventeen 1179 Class LSTs, the last of which was delivered in August 1972. Additionally, NASSCO had built and was still building a number of large ocean-going commercial ships.

Review of previous Navy ship deliveries reveals that of the 24 ships delivered to the Navy prior to the award of AOR 7, the contractor had averaged eight months delay in ship deliveries -- five months of excusable delay, three months non-excusable delay. This was a better than average record -- especially compared with the average 17 month delays on AOR 1 through 6.

The following Table identifies key milestones and delays during the AOR 7 building period as a reference for later comments.

TABLE V.15

SLIPPAGES IN AOR 7 KEY EVENTS SCHEDULES

Description	Schedule Date	Actual	Months Late
Start Construction	10/01/73	10/06/73	-
Keel	01/05/74	01/19/74	-
Launch	11/02/74	12/07/74	1
Ship Service Gen. Tests	08/01/75	05/12/76	9
Boiler Light Off	06/27/75	04/26/76	10
Preliminary Dock Trials	08/25/75	07/13/76	11
Official Dock Trials	09/08/75	07/14/76	10
Builder Sea Trials	09/29/75	08/01/76	10
Acceptance Trials	11/03/75	09/13/76	10
Contract Delivery	12/15/75	10/14/76	10

Schedule slippage started early in the building period due to late delivery of contractor furnished equipment. This was caused primarily by vendor market problems such as shortages of valves, compressors, pumps, etc. Late deliveries impacting construction schedules occurred mostly in the main propulsion area. Also, late arrival of equipment and material resulted in slippages in the Master Machinery Erection Schedule of from three to twelve months.

- Boiler light-off was ten months behind schedule primarily due to slipped hull erection schedules and delivery of critical valves.

- Due to non-receipt of critical valves, the contractor proposed on December 17, 1975 that the contract delivery date of July 15, 1976 could only be met if Navy approved the substitution of commercially-available replacements. Following discussions regarding valve substitution, the contractor advised on January 22, 1976 that barring unconditional approval for valve substitutions, the delivery date would slip to September 30, 1976. (Approval was denied.)

The majority of deviations from planned manpower allocation came before launch when massive efforts were made to meet the launch date. As shown in the preceding table (V.15), launch was accomplished within one month of the original schedule. Figure V.5 illustrates the magnitude of changes in planned manpower scheduling. Figure V.6 which follows indicates the magnitude of other work in the contractor's yard and might explain the rigid adherence to the planned AOR launch date.

Major overruns in manhours occurred in construction of the hull, decks, bulkheads, foundations and other structural members. Other significant manhour over-expenditures were in auxiliary systems, design and engineering services and construction services. A comparison of total manhours expended (planned versus actual) is shown in Figure V.5 and also in Table V.15 As seen in the table actual total manhour expenditures exceeded the bid estimate by 71 percent and the Government's independent estimate by 76 percent. A key category, hull structure -- which should prove little problem for estimators -- shows a large growth.

FIGURE V.5

SCHEDULE MANPOWER LOADING vs. ACTUAL MANPOWER LOADING

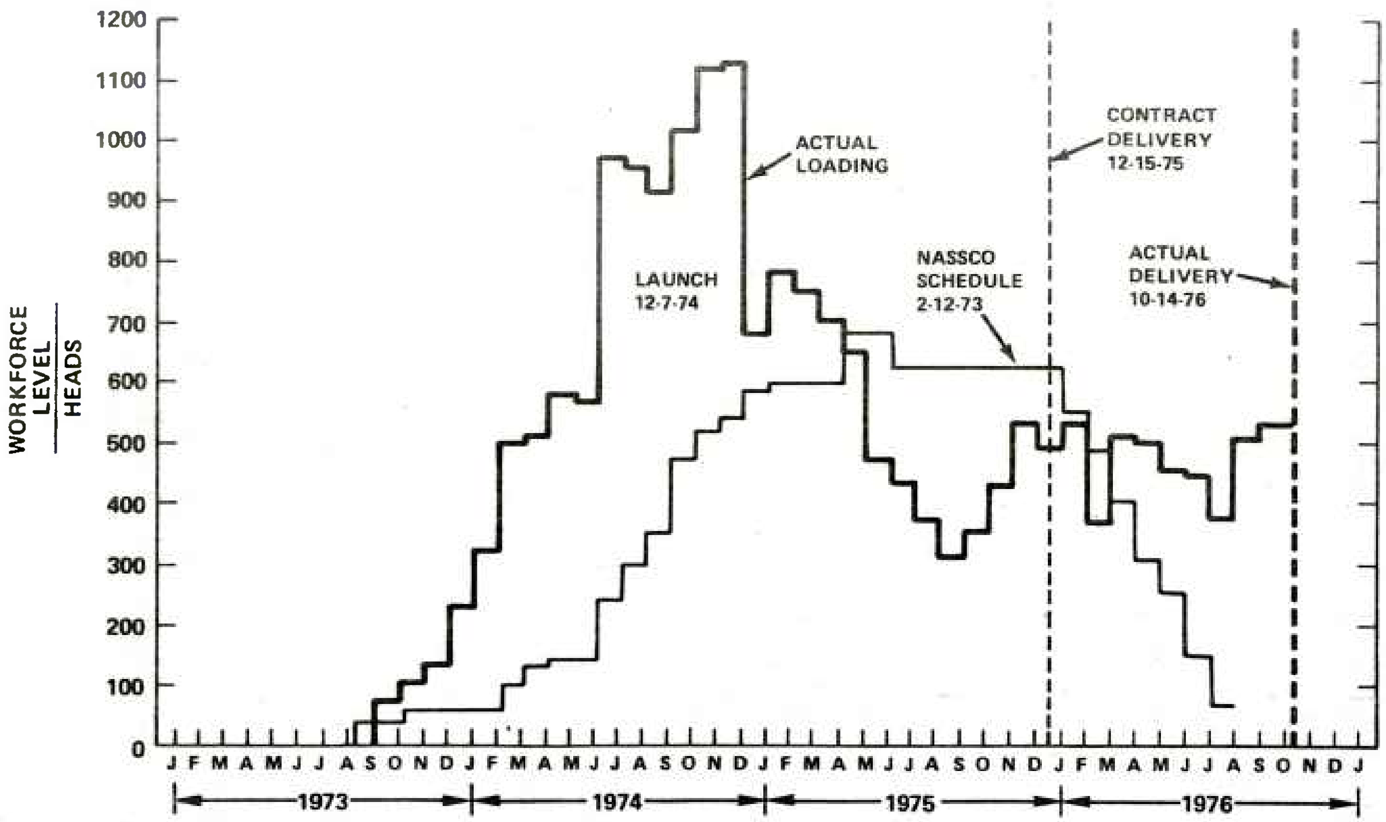
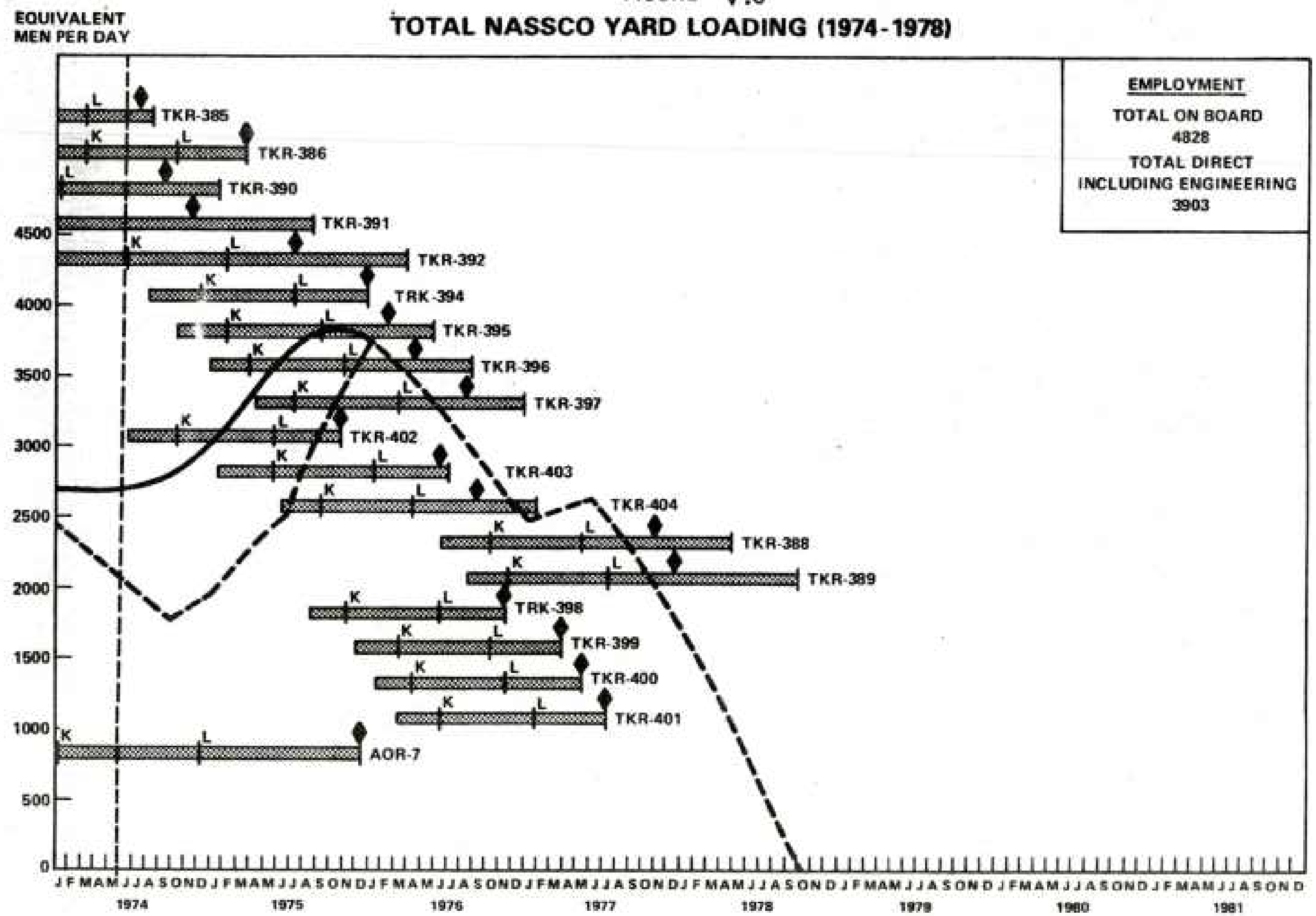


FIGURE V.6

TOTAL NASSCO YARD LOADING (1974-1978)



SOURCE: NAVSEA OSP (JUN, 1974)

TABLE V.16

NASSCO BID/INDEPENDENT GOVERNMENT ESTIMATE VS. ACTUAL MANHOURS PERCENTAGE VARIATION BY CATEGORY

Category	NASSCO	Government
Hull Structure	171	197
Propulsion	33	60
Electric Plant	(4)	(5)
Communication and Control	(21)	65
Auxiliary Systems	44	29
Outfitting and Furnishing	39	7
Armament	147	(66)
Design and Engineering Services	55	60
Construction Services	61	108
Total Manhour Overrun	71	76

(4) In The Final Analysis, Delivery Of The AOR 7 Was Delayed Ten Months

All delay was adjudicated as excusable in contract modifications with actual delivery taking place on 14 October 1976 vice the originally scheduled date of 15 December 1975.

- In January 1975, the contractor affirmed 15 December 1975 as the then current contract delivery date.
- In mid-February 1975, however, the contractor asserted that the ship would be delayed as a result of stated causes, primarily late CFE, which he considered excusable and proposed that 15 April 1976 be accepted as the guaranteed delivery date of the ship.
- Government rejected proposed new guaranteed delivery date on the grounds that stated causes were present

prior to January 1975 when the contractor reaffirmed the 15 December 1975 delivery date.

- Government, by contract modification dated 21 July 1975, agreed to extend the delivery date of 15 December 1975 to 15 June 1976 for stated considerations, which included full and final settlement for all claims arising out of delays in delivery of GFE which previously occurred. The considerations did not include late GFI.

- Government, by contract modification dated 17 September 1976, agreed to extention of contract delivery date to 14 October 1976.

  - Considerations included contractor acceptance of full responsibility for cost of additional Builders Trial held during August and September 1976.

  - Contractor further agreed to correct certain Government-responsible trial item deficiencies.

Over the life of the AOR 7 contract, a total of $900 thousand was paid to NASSCO for adjudicated changes reflected in FMRs and HMRs. By contract modification, the contract billing price was increased to cover allowable cost increases related primarily to increased labor expenditures for a total of $6.7 million. Table V.17 summarizes the contract cost growth.

TABLE V.17

SUMMARY OF AOR 7 CONTRACT COST GROWTH
(Dollars in Millions)

Original Contract Target Price	51.4
FMRs and HMRs (excluding REA-related)	0.9
Increased Billing Price via Contract Modification	6.7
HMR #58 (REA settlement)	2.9
Escalation Paid	9.2
Final Adjudicated Contract Price	71.1

The majority of the final cost increase was incurred as a result of the settlement of a Request for Equitable Adjustment submitted by NASSCO in November 1975. The original REA totalled over $20 million and contained 19 separate items. The settlement negotiations are outlined below:

- The REA was examined by a team from SupShips-San Diego in order to analyze the facts and aid settlement.

- In October 1976, the original REA was formally modified to nine items as follows:

Replenishment-at-Sea	$ 748,893
Hotel Space Arrangement	2,698,654
Machinery Space Interferences	1,595,997
Growth in Electrical Dist.	278,756
Degaussing Systems	22,647
Pollution Holding Tanks	116,833
Thermal Insulation	65,647
Shafting Calculation	34,420
Grounding of Electrical Equip.	28,877
	$5,590,724

- Subsequent technical and cost evaluations substantiated that NASSCO had incurred reimbursable costs as a result of Government changes and defective ship construction plans and drawings.

- Following review, the Government proposed a settlement of $2.9 million. Extensive negotiations took place between NASSCO and Government representatives and agreement was reached on November 12, 1976 in the amount of $3.5 million. This included $581 thousand for outstanding FMRs (repairs to GFM, etc.) and $2,919,000 covering items specified in the REA.

- The $9.180 million escalation paid ($4.017 million related to labor and $5.163 million to materials) equals approximately 40 percent of the total contract growth. The escalation provision had reached the maximum permitted number of quarterly payments eleven months prior to delivery. The approved budget baseline allowed for only $1.475 million for escalation growth. The most significant increase in escalation results from revisions in the rates upon which the escalation payments are computed. This amounted to a $4.331 million adjustment to the escalation funds as reported in the August 1974 Ship Cost Adjustment Report.

(5) The AOR 7 Experienced An Overrun Of 53 Percent On The Original Budgeted End Cost Estimate Forwarded To The Congress In 1971

Program tracking was able to identify an overrun of $29.8 million during the six year period from authorization to ship delivery. Several areas contributed to the overall cost growth.

- Costs attributable to basic construction accounted for 66 percent ($19.7 million) of the growth caused by:

- Incorrect plans
- Defective specifications
- Inadequate time to estimate
- Changing market conditions
- Low productivity
- Delay in government action
- Scheduled event delays

- Costs in other areas including escalation, changes and GFE/GFI accounted for the remaining $10.1 million related to:

  - Constraints on estimates
  - Program uncertainty
  - Unanticipated escalation
  - Low productivity
  - Insufficient definition
  - Characteristics changes
  - Incorrect plans and defective specifications
  - Poor estimates
  - Inadequate time to estimate

The tracking uncovered the following problems relative to the AOR 7 experience:

- The numerous pre-authorization budget reviews caused a pressuring of the estimating process which resulted in lower estimates.

- Budget ceilings, real or self-imposed, seriously inhibited allowances for reasonable contract growth especially as seen in the overrun in escalation.

- Budgeting decisions were made without budget quality estimates and characteristics changes were made during the contract design process, thus invalidating the budgeted amount. (See Table V.18)

- Completed prior ship drawings were not updated in a systematic or disciplined manner.

- The time allowed to review AOR 5 and 6 working drawings was not adequate and provisions to ship check AOR 5 and 6 for "as-built" conditions were not made.

- AOR 7 characteristics changes were used as a wedge for inflating or deflating end cost estimates. The cost impact of these changes was underestimated.

- Productivity factors were in error.

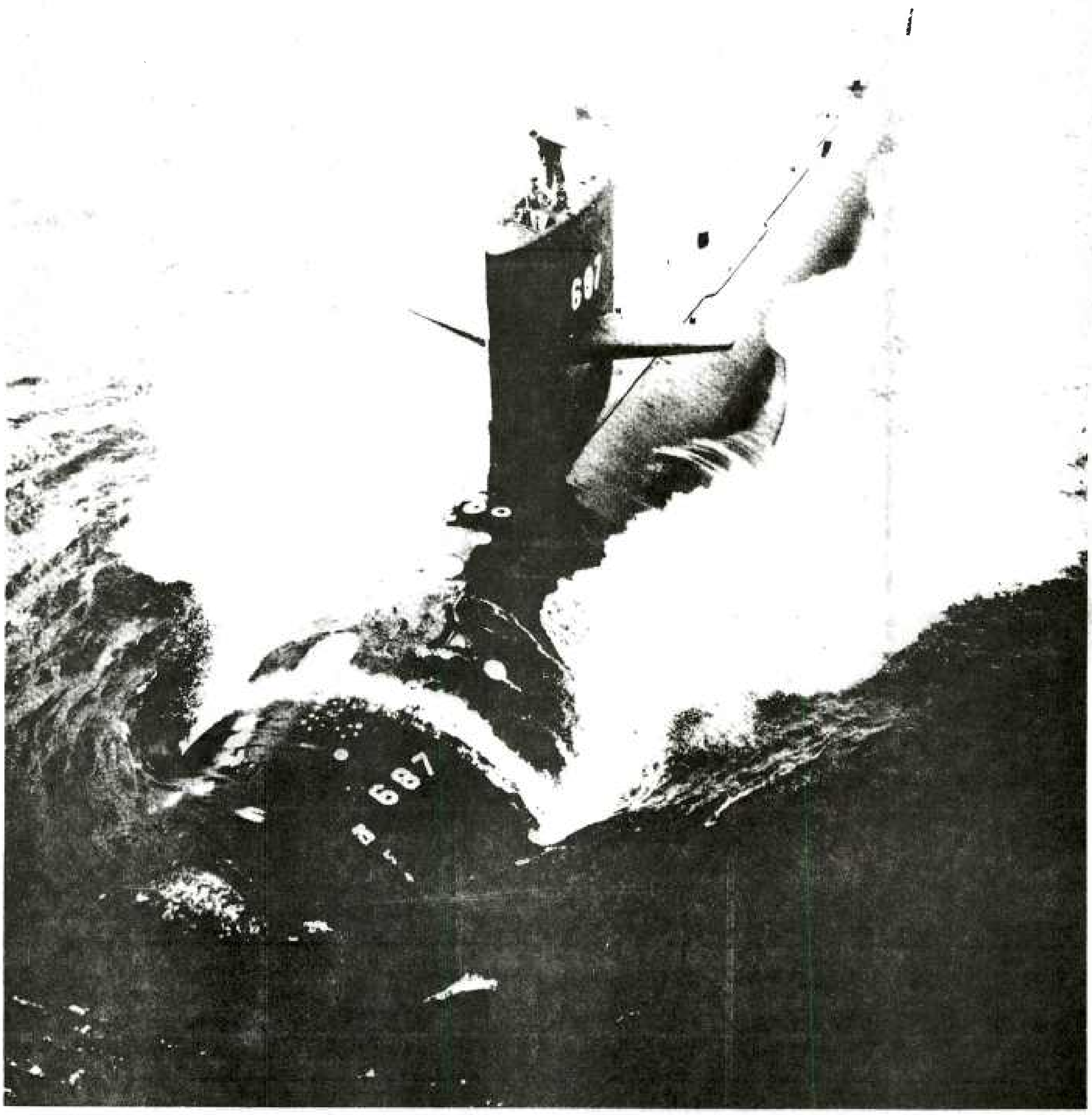
- CFE lead times were inadequate.

- Lack of an adequate budget quality ("C") end cost estimate for a modified repeat design cannot be justified.

TABLE V.18

SUMMARY OF AOR 7 COST MOVEMENT

Cost Category	$68.5 Million Class "D" May 1970	Reductions	$56.5 Million Class "F" Nov. 1970	Final Estimate Oct. 1976
Plans	1.880	(.055)	1.825	3.527
Basic Construction	44.700	(3.000)	41.700	61.425
Change Orders	3.600	(.900)	2.700	2.313
Electronics	1.145	(.190)	.955	.985
H/M/E	1.790	(.214)	1.576	2.190
NAVSEC Tasks	1.000	(.750)	.250	1.098
Ordnance	8.055	(3.036)	5.019	5.000
Future Charact. Changes	1.700	(.700)	1.000	.456
Escalation	4.630	(3.155)	1.475	9.306
Total	$68.500	$(12.000)	$56.500	$86.300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5. ALTHOUGH THE SSN 678 HAD A COST OVERRUN OF 20 PERCENT, IT WAS DELIVERED EARLY AND EARNED A BONUS FOR ITS BUILDER

This class of nuclear attack submarines has as its mission the location and destruction of enemy submarines and surface ships. They are designed to conduct radio, radar and sonar reconnaissance, as well as coordinated anti-submarine warfare operations with other anti-submarine warfare units. It is the largest single class of nuclear-powered submarines in the fleet.

This chapter will briefly trace the acquisition of the 37 ships of the STURGEON Class of submarines and the ARCHERFISH SSN 678 (the 24th ship) in some detail from the original end cost estimate as submitted to Congress through contract award, construction and delivery.

(1) The Development Of The STURGEON Class Submarine Was Evolutionary Rather Than A Major Departure From Previous Designs

Nuclear-powered attack submarines built over the last decade and a half have followed a developmental path which began with the SKIPJACK, then to the THRESHER/PERMIT Class, then to the STURGEON Class, and finally to the current SSN 688 LOS ANGELES Class. The STURGEON or SSN 637 Class technology was based on the improved depth and silence capabilities of the THRESHER/PERMIT Class. The need for immediate incorporation of designated SUBSAFE requirements hastened the introduction of these development improvements in the case of the STURGEON Class.

The SSN 637 Class procurement was characterized by year-to-year authorizations rather than a pre-planned 37 ship program as Table V.19 shows.

TABLE V.19

SSN 637 CLASS PROCUREMENT SCHEDULE

Fiscal Year	62	63	64	65	66	67	68	69
# Authorized	3	8	5	6	6	5	2	2

The SSN 637 procurement contracts from FY 1962 through 1965 were fixed price. Fiscal Year 1966 contracts, also fixed price, included a special bonus provision for early delivery -- a feature which carried through the remaining program years.

(2) Over The Entire Thirty-Seven Ship Program Actual Costs Exceeded Predicted Costs By 13.1 Percent With An Average Delay Of About 13 Months

Over the nine year period during which all the SSN 637 Class submarines were constructed, the average cost per ship was $76.5 million. An initial cost growth occurred with the lead ships of the FY 1962 buy and was attributed to the SUBSAFE requirements and associated design changes brought about by the U.S.S. THRESHER accident in 1963.

TABLE V.20

SSN 637 CLASS PROGRAM COST HISTORY
(Dollars in Millions)

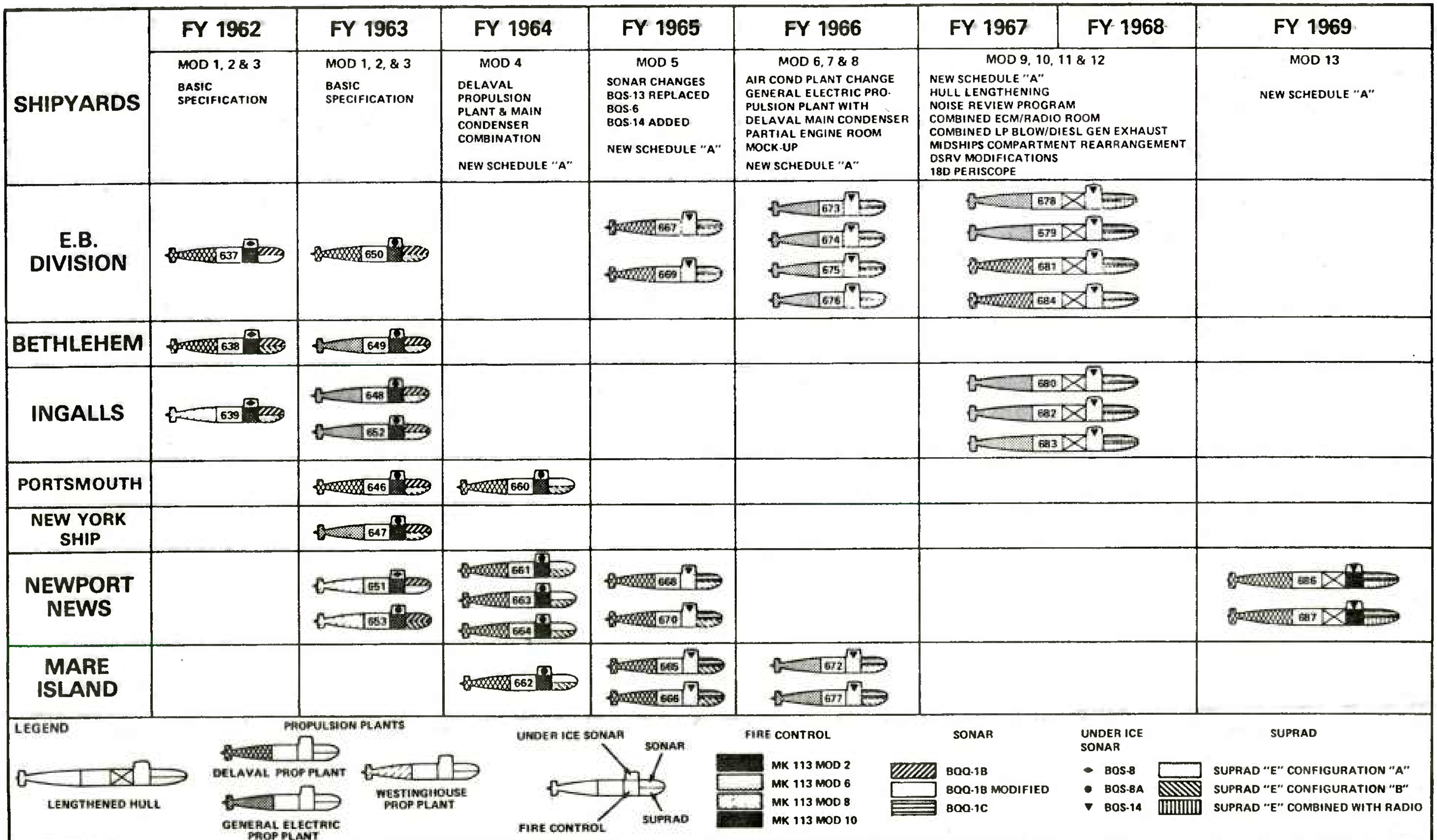
Approved Congressional Budget vs. Actual End Cost

Fiscal Year	Number of Ships	Approved Budget	Budget Cost Per Ship	End Cost	End Cost Per Ship	Cost Variance By Fiscal Year
62	3	$ 183.9	$61.3	$ 225.0	$75.0	$ 41.1
63	8	505.9	63.2	612.4	76.6	106.5
64	5	337.3	67.5	363.9	72.8	26.6
65	6	441.0	73.5	426.5	71.1	(14.5)
66	6	400.9	66.8	437.2	72.9	36.3
67	5	341.0	68.2	396.6	79.3	55.6
68	2	143.2	71.6	176.0	88.0	32.8
69	2	162.6	81.3	196.4	98.2	33.8
	37	$2,515.8		$2,834.0		$318.2

As seen in the Table above, overall cost growth of $318.2 million or about 13 percent has been experienced. Additionally, claims totalling approximately $200 million have been filed and are still outstanding. However, it should be pointed out that this nominal cost increase supported a program which accommodated a systematic update of class characteristics. The diversity of changes is seen in Figure V.7.

Delivery delays averaged 13.1 months over the acquisition period. Electric Boat Division – General Dynamics built 32 percent of the program's ships and experienced no overall delay. On average they bettered delivery dates by one month.

FIGURE V.7



TOTAL — 37 SHIPS

(3) <u>The SSN 678 Grew In Cost Over Budgeted Amount By 20 Percent But Was Delivered Ahead Of Schedule</u>

The original end cost estimate forwarded to Congress in 1966 for the SSN 678 was $70.0 million and was included in the FY 1967 SSN 637 Class budget request for five ships. A summary of the approved budget for the SSN 637 Class (FY 1967) follows:

.	SSN 678	$70.0 million
.	SSN 679	70.0
.	SSN 680	67.0
.	SSN 681	67.0
.	SSN 682	67.0
.	Total	$341.0 million

A construction contract for four ships was awarded to the Electric Boat Division - General Dynamics in June 1968, including the ARCHERFISH which was delivered to the Navy three months ahead of schedule on 23 December 1971 at an end cost at delivery of $84.3 million. This amount represents an apparent cost growth of approximately 20 percent which included an earned bonus for early delivery.

The early delivery incentive appears, in this case, to have provided motivation to complete the construction of these ships ahead of schedule. The progress evident in this instance is particularly noteworthy when compared to that exhibited for earlier ships of this class constructed in other private or public yards -- in some cases four extra years were required to effect delivery.

The CNO requested a price-out for the FY 1967 SSNs during September 1964. This request produced a response in October 1965 of $68.2 million per FY 1967 ship based upon the characteristics of the FY 1966 SSN 637 Class ships. This estimate was forwarded to OSD for inclusion in the FY 1967 budget.

In March 1966, however, CNO directed NAVSHIPS to undertake a study relative to the inclusion of additional space and weight for the Acoustic Information Gathering System. The findings of the May 1966 study showed that the length of the ship's hull would have to be increased by eight feet, which for the five FY 1967 ships would add an estimated $3.7 million. Changes in the estimate between original CNO price-out and budget approval are seen in Table V.21. It is noted that the initial estimate for hull lengthening increased ship end cost by $0.7 million (total $68.9 million) and FCC reserves by $1.1 million (total $70.0 million).

TABLE V.21

BUDGET ESTIMATE CHANGES
(Dollars in Millions)

Date	Estimate	Remarks
October 1965	68.2	Price-out per CNO request
May 1966	68.9	Increase for lengthening hull by eight feet
September 1966	70.0*	FCC reserves for additional characteristics

* Budget Estimate, SCA dated March 1966

The Congressionally authorized baseline end cost for SSN 678 was $70.0 million which included an estimate of $31.5 million for basic construction (contract price). However, a review of available data shows that significant characteristics changes approved in February 1967 were incorporated into the FY 1968 STURGEON Class submarines. The estimates approved by Congress did not include these changes as they were approved over one year after the estimates were submitted. Accordingly, an analysis of Ship Cost Adjustment Reports shows a difference of $7.0 million between the $31.5 million estimate and the $38.5 million contract award.

The independent government estimate prepared in March 1968 to provide guidance for proper evaluation of bid proposals was based upon average labor, material, overhead and profit factors from prior year SSN procurements. While allowing for a moderate increase of approximately $2.5 million for escalation, specifications, and GFM changes, this estimate fell $4.5 million short of the actual award price.

An examination of available SCAs indicates that the budgeted end cost as forwarded to Congress did not allocate funds to cover plans costs, however, between September 1966 and contract award in June 1968, a total of $4.95 million was added to this cost category. As previously pointed out, the costs in the basic construction category also increased by $7.0 million during that period to allow for the difference between estimated and awarded basic construction contract price. The SCA report of August 1968 indicates that an additional $2.3 million was reprogrammed into the basic construction category and an additional $4.1 million was reprogrammed into the construction plans category. The increases in the plans and basic construction categories are summarized in Table V.22 below.

TABLE V.22

SSN 678 PLANS AND BASIC CONSTRUCTION COST INCREASES
(Dollars in Millions)

	Plans	Basic Construction	Related End Cost Estimate
Congress Baseline	-	31.5	70.0
March 1968 SCA	4.9	38.2	75.9
Est. Cost at Del.	9.2	40.5	84.3

While the record indicates that all plans costs were charged to the SSN 678, the overall increase from the originally quoted $0.7 million to about $18 million which included allowances for increased contractor labor, overhead and profit rates illustrates the significant impact upon estimate credibility and apparent cost growth brought about by changing characteristics/design subsequent to estimate preparation. The scope of these characteristics changes is shown below:

- Hull lengthening -- 8 feet, 3 inches
- Space and weight for:
  - Acoustic Information Gathering System (AIGS)
  - Improved PUFFS array and equipment
  - Satellite Navigation System AN/SRN-9
- Increase accommodations (three enlisted)
- Deep Submergence Rescue Vehicle capability
- Periscope change
- Rearrange ECM room
- Update electronics suite
- Stowage for expendable bathythermograph
- Improved VHF/UHF/IFF system
- New weapons launch console and switchboard
- Revised noise goals

While some of the cost growth can be attributed to changing market conditions or award delay and higher profit margins, the magnitude of the cost increase in basic construction, following analysis of available records, can be traced to significant changes other than those associated with hull lengthening which could not have been considered by the estimator in late 1965.

(4) ARCHERFISH Experienced Minimal Cost Growth After Contract Award

The ARCHERFISH shows a net cost growth of $14.3 million (to $84.3 million) over the originally authorized $70.0 million including $7.0 million incurred at contract award. However, tracking shows that before considering several costs which fell below budgeted amounts, thus negating some of the increase, cost growth in the plans and basic construction categories at delivery totalled $19.9 million. Of this, nearly $9.2 million was required for construction plan changes associated with the hull lengthening and other interior rearrangements. The increases by cost category are shown in Table V.23.

TABLE V.23

SSN 678 BUDGETED VERSUS ACTUAL END COST
(Dollars in Millions)

	Original Approved Estimate	End Cost At Delivery	Difference
Plans	-	9.2	9.2
Basic Construction	31.5	42.2	10.7
Change Orders	2.5	1.1	(1.4)
Electronics	7.4	6.8	(0.6)
HME	17.3	18.5	1.2
Post Delivery	1.4	-	(1.4)
NAVSEC	0.4	-	(0.4)
Ordnance	2.9	2.2	(0.7)
Escalation	2.4	4.3	1.9
Future Char. Changes	1.9	-	(1.9)
Other	2.3	-	(2.3)
Total	70.0	84.3	14.3

From Table V.23 it can be seen that GFE costs were actually less than originally budgeted, even while supporting the update of various equipments. The decrease in GFE funding requirements aided somewhat in reducing cost growth in the plans and basic construction categories. Escalation growth in the case of the SSN 678 amounted to $1.9 million or only 13 percent of the total dollar growth.

In summary, while some of the cost growth can be attributed to changing market conditions, award delay and higher profit margins, the majority of the increased costs are apparently related to design changes which included hull lengthening, equipment updating and various interior rearrangements.

(5) The SSN 678 Experienced A Post Authorization Program Growth Of Approximately 20 Percent.

Cost growth for this ship totalled $14.3 million which included $1 million as a bonus for early delivery. The general causes were:

- Basic construction costs were increased through characteristics changes approved after budget and approval.
- Government estimated labor, overhead and profit rates were lower than negotiated.
- GFE cost growth was negative.

No factors such as fast-paced material escalation, decline in productivity, availability of potential builders or shortage of skilled labor seemed to influence the construction process.

THE FFG-7 GUIDED MISSILE FRIGATE

6. THE FFG 7, LEAD SHIP OF A 74 SHIP PROCUREMENT, SHOWS SIGNIFICANT COST GROWTH WHICH MAY BE EXPLAINED BY ITS PURPOSE AS A "PROTOTYPE" SHIP

The end cost of the FFG 7 is currently estimated to be $270,100,000 as of scheduled delivery in December 1977. Since the budget approved by Congress in 1973 for lead ship construction was $191,500,000, a cost growth of $78,600,000 has been experienced resulting in a percentage increase of 41 percent. This growth is comprised of increases in almost all categories of cost with significant growth in basic construction and GFM costs.

In addition to the rise in costs on the lead ship, total FFG program costs have risen significantly. The average unescalated unit cost per ship has risen approximately 55 percent since the approved development estimate and escalation has increased over 1,100 percent. Program size has risen from 50 to 74 ships which will be built through FY 1988. The average escalated unit cost for each ship in the FFG program is now estimated at $187 million. Total program through 1988 now is predicted to be $13.8 billion, making it the largest combatant shipbuilding program -- both in number of ships and planned expenditures.

(1) The Requirement For The FFG Arose From The Need For An Escort Type Ship To Replace World War II Destroyers Being Phased Out

In the late 1960's, several trends were apparent which led to decisions related to the creation of a new patrol escort ship class. The trends were:

- The declining inventory of World War II destroyers -- the majority of which were over 20 years old and deficient in modern weaponry.
- An increasing requirement to upgrade the Anti-Air Warfare (AAW) and Anti-Submarine Warfare (ASW) capabilities for protection of sea lines of communication.
- The need for not only weapons-capable platforms but numbers of ships to "cover" the water, increase visibility and bring inventory levels up to more reasonable levels of risk.
- The need for a low-cost ship, large numbers of which could be financed in a period of increasing demand on available resources.

These trends and needs caused the CNO in January 1970 to order a Cost and Feasibility Study relative to the development of an escort type ship design.

Approval for conceptual activities were included in PBD #507 (December 31, 1970) and on January 1, 1971 the FFG Conceptual Phase was begun.

Assumptions made at the outset were as follows:

- Ship design would take into account a $50 million limitation on cost.
- Two designs would be implemented -- one ASW and another, AAW -- with similar hull and operational characteristics.
- Total inventory would be about 50 ships.
- To accomplish these goals, the ship would be "austere" with extensive use of off-the-shelf items and only thoroughly tested weapons systems.

The SHAPM organization determined in March 1971 that a lead ship contract could be awarded in 1973. All plans were, therefore, oriented toward that goal.

(2) A Number Of Management Techniques Were Adopted During Early Project Phases To Optimize Performance And Minimize Costs

Plans made to implement a program to meet the stated mission requirements were comprehensive and ambitious. The number of ships planned implied a degree of cost control, intensive management and standardization that was not common to many other programs. Since various problems common in ship construction could be multiplied time after time in such a large program, a number of efforts were made to eliminate to the maximum extent possible causes of engineering and construction problems.

The first objective of the planning was to define ship configuration(s) that would meet the dual objectives of mission capability and cost. Several hundred configurations were analyzed -- both from a technical and cost point of view during the conceptual planning period. By the end of the conceptual phase, a single ship platform was selected to incorporate the required AAW and ASW characteristics. Table V.24 shows the evolution from two ship to a single ship design. For reference in later sections, characteristics changes are listed through 1976. It can be noted in passing that -- with the exception of the Sonar, Oto Melara Gun and Gun Fire Control System -- major characteristics have remained relatively stable.

The trade-off studies required that a number of estimated costs be produced. These varied widely, but did provide evidence that a lead ship could be built for $125 to $146 million; follow ships at a cost starting at $34 million and $53 million for ships with increased capability. When the single ship platform decision was made, the lead ship cost was estimated at $185 million; follow ships at $49.2 million.

In order to provide an increased assurance that the cost and military capability equation could be solved, program management outlined a number of techniques that would be utilized throughout the program to assure optimum performance.

TABLE V.24

EVOLUTION OF MAJOR CHARACTERISTICS

	January 1971 Initial Presentation to CNO: ASW	January 1971 Initial Presentation to CNO: AAW	April 1971 Recommended Alternatives: ASW: Basic	April 1971 Recommended Alternatives: ASW: Basic w/SQQ-23 vice SQS-505	April 1971 Recommended Alternatives: AAW: Basic	April 1971 Recommended Alternatives: AAW: 1	April 1971 Recommended Alternatives: AAW: 2	Common Ship	CNO Selected Characteristics May 1971 Common Ship(4)	Preliminary Design Submit October 1971	Congressional Budget Submit January 1972	Present Characteristics November 1976
Propulsion	Twin Screw w/2 LM 2500s, 2 TYNE; or Twin Screw w/ 2 LM 2500s, 2 Diesels; or Single Screw w/ 2 LM 2500s, 1 TYNE	Twin Screw w/ 2 LM 2500s, 2 TYNE; or Single Screw w/ 2 LM 2500s, 1 TYNE	Single Screw COGAG (3)	Single Screw COGAG	Single Screw COGAG	Single Screw COGAG	Single Screw COGAG	Single Screw COGAG	Single Screw w/ 2 LM 2500s, 1 TYNE (with cruise and take home)	Single Screw w/ LM 2500s, (2) 1 TYNE (with cruise and take home)	Single Screw w/ LM 2500s, (2) 1 TYNE (with cruise and take home)	Single Screw w/ LM 2500s, (2) 1 TYNE (with cruise and take home)
Launchers	MK-16 ASROC/ HARPOON, or MK-26	MK-26	SEASPARROW	SEASPARROW	MK-22	MK-13 Mod 1	MK-22 MK-16	MK-26 Mod 0	MK-13 Mod 1	MK-13 Mod 1	MK-13 Mod 1	MK-13 Mod 1
	2 MK-32 TT	MK-32 TT	2 MK-32 TT	2 MK-32 TT	2 MK-32 TT	2 MK-32 TT	2 MK-32 TT	2 MK-32 TT	2 MK-32 TT	2 MK-32 TT	2 MK-32 TT	2 MK-32 TT
Gun Missile FCS	MK-87	MK-74 or 2 Channel TARTAR D	MK-87 CWI/ STIR	MK-87 CWI/ STIR	MK-87 CWI/ STIR	MK-87 CWI/ STIR	MK-87 CWI/ STIR	MK-87 CWI/ STIR	MK-87 CWI/ STIR or MK-74 Fallback	MK-74 (TARTAR C) or MK-92 MK-87 with CWI	MK-92 (with CWI and SPG-60 STIR)	MK-92 (with CWI and SPG-60 STIR)
UFCS			MK-114	MK-144			MK-114	MK-114	MK-309 Control Panel	MK-309 Control Panel	MK-309 Control Panel	MK-309 Control Panel
Weapons	LAMPS HARPOON SEA SPARROW Oto-Melara Gun or 5"/54 Gun	HARPOON Standard Missiles 2 CIWS	35 mm Gun ASROC AIM 7F HARPOON LAMPS	35 mm Gun ASROC AIM 7F HARPOON LAMPS	35 mm Gun SM-1 Missile HARPOON	35 mm Gun SM-1 Missile HARPOON	SM-1 Missile HARPOON ASROC	35 mm Gun SM-1 Missile HARPOON ASROC	LAMPS; HARPOON and Standard Missiles; 35mm Oto Melara Gun or 76 mm Fallback MK-46 Torpedo	LAMPS HARPOON 35mm Oto Melara Gun 76mm Oto Melara Gun	LAMPS(1) CIWS (Sp. & Wt.) HARPOON 35mm Oto Melara Gun	LAMPS LAMPS III (Sp. & Wt.) HARPOON, CIWS (Sp. & Wt.) 76mm Oto Melara Gun MK-48 Torpedo
Radar: Air Surface	SPS-58 SPS-10	SPS-52 SPS-10	SPS-49 SPS-55	SPS-49 SPS-55	SPS-49 SPS-55	SPS-49 SPS-55	SPS-49 SPS-55	SPS-49 SPS-55	AN/SPS-49 AN/SPS-55	AN/SPS-49 AN/SPS-55	AN/SPS-49 AN/SPS-55	AN/SPS-49 AN/SPS-55
Sonar	ED 0610E SQS-26 TACTLASS (and Prairie Masker)	ED 0610E	SQS-505 TACTLASS	SQS-505 (pair) TACTLASS	SQS-505	SQS-505	SQS-505	SQS-505 TACTLASS	AN/SQQ-23 (pair) TACTLASS (Sp.&Wt.)	AN/SQQ-23 (pair) TACTLASS (Sp.&Wt.)	AN/SQQ-23(1) TACTLASS (Sp.&Wt.)	AN/SQS-56(2)
Countermeasures	Passive EW	Passive EW	WLR-8 or WJ-1007	WLR-8 or WJ-1007	WLR-8 or WJ-1007	WLR-8 or WJ-1007	WLR-8 or WJ-1007	WLR-8 or WJ-1007	WLR-8 or WJ-1007	WLR-8 or WJ-1007	WLR-8	WLR-8

SOURCE: NAVSEA 01G files, July 1971 Concept Exploration Report; budget information.

(1) CNO modified PF characteristics in May 1972 to reflect:
- 2 LAMPS Helicopters
- 76 mm Oto-Melara Gun
- SQS-505 Sonar

(2) The SQS-505 Sonar was dropped in June 1973 and replaced with the SQS-56.

(3) COGAG includes:
- 2 LM 2500s
- Four 75 KW s/s Diesel Generators
- 2 Distilling Plants
- 2 Auxiliary Boilers

(4) Used in the Conceptual Report dated July 1971.

- A Design-to-Cost technique was to be utilized to a achieve maximum capability at minimum cost. The concept is most critical during the early design phases and it assures that cost is as important an element in development thinking as capability, engineering, etc.

- A life cycle cost technique was to minimize costs in such areas as:

  - Acquisition cost -- reduced building and growth margins, close configuration management, and reduced test requirements.

  - Manning -- reduction of normal personnel requirement.

  - Availability and maintainability -- extended periods between overhauls and on-board maintenance improvements.

  - Fuel -- selection of low fuel rate systems.

- A lead ship/follow ship concept would provide for the elimination of engineering and equipment problems on a lead ship. Also provided for was a detail design period which would last over the construction period of the first ship so that follow ships would have validated, as-built drawings. All testing, on ship and land-based, would be accomplished on the lead ship.

- The validated drawings technique was to be implemented at a substantial investment, to assure detailed and accurate drawings for use in building follow ships. The goal was to increase producibility in a number of shipyards and reduce production risk.

- Industry participation in ship system design was planned so that two shipbuilders would be involved:
  the first as primary design agent and potential lead builder; and the second as secondary design agent (verifier) and potential follow ship builder. The goal of this technique was to produce better quality design, enhance producibility and encourage competitive

bidding. The Navy hoped to have a number of bidders for production ships and to be able to finally choose three. The technique of early shipbuilder participation would also encourage, later in the detail design phase

- More realistic estimates for basic construction by the designated lead ship builder.
- The safety factor of having the secondary design agent (follow ship builder) as an alternate lead ship builder.
- Added pressure for the lead ship builder to negotiate realistically.

. The land-based test site concept was to involve the design, integration and testing of all combat system and propulsion system equipment. The defined purpose of the LBTS was to help alleviate integration and testing problems on lead and follow ships, and to provide early crew training.

. A standardized, centrally procured equipment technique would be utilized to enhance class equipment standardization and control costs. In this technique the lead ship builder would purchase options on approximately 60 pieces of equipment. Life cycle cost benefits through increased availability of spares and lower maintenance costs were also anticipated.

Having defined the techniques to be used in ship development, program milestones were projected as follows:

. Release RFP for SSD	11/71
. NAVSEC start SSD	11/71
. Shipbuilder start SSD	02/72
. Start LLT GFE buys	06/72
. Start Detail Design	06/72
. Deliver lead ship	12/76
. Deliver first follow ship	04/78
. Deliver last follow ship	04/82

This schedule assumed that the lead ship could be constructed in 32 months and follow ships in 24 months. Three yards would each build four ships per year so that an average of one ship per month could be delivered to the Navy.

The last important activity during the pre-implementation period was the preparation and submission of the budget for the lead ship. The preliminary design phase was in progress during the last half of 1971 when budget data was assembled. Although the Functional Baseline was not to be published until December 1971, preliminary versions were available to estimators.

(3) Budget Reviews Reduced The Original FFG 7 Class "D" Estimate By $12.5 Million

Initially, a class "D" budget estimate totalling $204 million for construction of the lead ship was forwarded to NAVCOMPT. This estimate was immediately adjusted down by $7.1 million after initial NAVCOMPT review. A revised budget of $196.9 million was subsequently submitted by NAVSEA. The reduction was accompanied by a reprogramming of FY 1972 funds involving GFM such as the MK-92 FCS, Oto Melara 35 millimeter gun, MK-13 Launcher and SQQ-23 Sonar so that necessary design and development activities could start sufficiently early.

The lead ship budget, in three separate Program Budget Decisions (PBDs), was reduced from $196.9 million to $191.5 million. The net $5.4 million reduction was effected by further reprogramming of FY 1972 RDT&E funds and adjusting escalation down to OSD rates offset by charging the Universal Hot Plant to SCN.

Construction of the lead ship was, therefore, officially estimated at $191.5 million and the average price of a follow ship (scheduled for initial award in FY 1975) was $47.2 million. The $191.5 million estimate included not only construction of the ship, but detail design activities and Land-Based Test Site procurement activities.

The key components of the Congressional Budget estimate were as follows:

- Major categories

  - Plans............... $63.2 million
  - Basic Construction ... 39.8
  - Ordnance 38.0
  - Electronics.......... 8.8
  - H/M/E 6.8
  - Escalation 6.2
  - All Other Costs 28.7
  - Total.............. $191.5 million

- Plans at $63.2 million was uncommonly high because design and engineering during construction of the lead ship was to be intensive. Changes were apt to be higher than normal and activities related to validated drawings would continue until contract trials were complete.

- Basic construction was estimated at $39,800,000 and was comprised of:

  - Labor Hours 1,568,247
  - Labor Dollars.............. $ 6,747,384
  - Overhead Dollars 4,858,116
  - Material Dollars 22,629,331
  - Profit and Weight Margins ... 5,608,963

  The original NAVSEA 01G estimates for basic construction rose from $25.1 to $39.8 million when the propulsion system was designated CFE vice GFE and costs were transferred from H/M/E (GFE) into basic construction. The propulsion equipment for the land-based test site is also included in the higher basic construction estimate. In addition to costs for the LM 2500, other items such as reduction gears, CRP propeller, and start-up costs amounted to $14.7 million.

- Ordnance was estimated at $38 million and included land-based and ship testing of all weapons plus integration.

- Escalation, which was originally estimated at $9.9 million or a rate of five percent, was finally submitted at $6.2 million or a 3.2 percent rate.

Table V.25 identifies the key estimates prepared during the pre-implementation phase.

TABLE V.25

EVOLUTION OF COST ESTIMATES
(Dollars in Millions)

	Initial Proposals Jan. 1971		Recommendations to CNO March to May 1971			Concept Exploration Report 7/71	Sept. 1971 NAVCOMPT Submission		OSD Submit 10/71	Congressional Submit Jan. 1972	Current Estimate April 1977
	ASW	AAW	ASW	AAW	Common Ship		Budget Prior to Reprogramming	Revised 1973 Submit			
Plans			87.0	55.0			72.3	69.3	69.3	63.2	56.8
Basic Construction			28.8	24.8			25.1	25.1	25.1	39.8	79.5**
Change Orders			2.0	2.5			2.0	2.0	3.0	2.0	16.2
Electronics			13.7	6.2			11.5	10.5	9.7	8.8	10.3
Propulsion Equipment										0.9	
H/M/E			8.2	8.2			16.2	14.1	14.1	6.8	43.2
NAVSEC (Other)			1.2	1.2			20.0	20.0	21.9	19.9	12.5
Escalation			10.5	7.7			9.9	9.9	9.9	6.2	
Ordnance			22.2	18.8			40.7	39.9	43.9	38.0	51.6
Electronic Growth			1.4	0.6			1.2	1.1			
Change Order Growth							1.0	1.0			
Ordnance Growth							4.1	4.0			
Project Managers Growth										5.9	
Total Cost of Lead Ship High: / Low:	146.6* / 124.3	146.1* / 138.0	175.0	125.0		185.1*	204.0	196.9	196.9	191.5	270.1
Follow Ship Costs (Unescalated) High: / Low:	46.7 / 33.8	53.5 / 46.8	47.6 / 45.6	43.5 / 40.6	47.7	49.2	47.8	45.0	44.4	45.0	126.9 (for follow ships through FY 1979)

* Unescalated

** This estimate is over $10 million higher than Bath Iron Work's estimate. The SCAs show this increase is mostly due to growth in the lead ship contract.

SOURCE: NAVSEA 01G Files; July 1971 Concept Exploration Report; Budget data.

(4) <u>The Pre-Production And Design Phase Began Early In 1972 And Has Progressed To The Point Of 90 Percent Completion On Lead Ship Construction</u>

Common practice in the Navy calls for contract design to be developed by NAVSEC, with the final product being an Allocated Baseline on which contractors can bid for award of a construction contract. In the case of the FFG, an attempt was made to produce a ship design which represented not only the best the Navy could develop, but which also reflected ideas of shipbuilders and engineering firms that would eventually participate in production phases.

An RFP for Ship System Design participation was sent to a number of shipbuilders. While responses were being prepared, NAVSEC began activities directed toward preparation of an Allocated Baseline. Four shipyards submitted bids, but only bids from Bath Iron Works and Todd Shipyards were accepted. The other two shipyards submitted bids which, in the opinion of the Navy, were too high. Bath Iron Works was awarded a Cost Plus Fixed Fee contract for $3.15 million as the primary design agent and potential lead ship builder and Todd Shipyards was awarded a contract for $1.78 million to review the lead ship baseline and was considered to be a potential follow ship builder.

In normal acquisition procedure, DSARC I is held to review program concept and approve proceding with preliminary design;

DSARC II determines whether to proceed with full scale development and specifically, contract design. In the case of the FFG program, DSARC I and II were combined. An independent cost estimate was prepared by OP 96 for the combined DSARC meeting scheduled for August 1972 and it was determined that cost projections for the lead ship and production ships were reasonable and within acceptable risk. Program plans were approved and acting on the DSARC recommendations, DEPSECDEF (in September 1972) authorized a 56 ship program, lead ship construction and land-based test site development.

Ship system design activities continued with Bath Iron Works (BIW), and Gibbs and Cox as BIW's subcontractor, developing design and engineering specifications based on NAVSEC plans. Todd played its role as a reviewer of specifications for producibility and came up with over 200 recommendations for design and engineering improvements. Since the decision had been made earlier as to lead ship builder, negotiations took place with BIW during the period with regard to lead ship construction.

In June 1973, Bath Iron Works submitted a non-competitive bid for detail design and lead ship construction. Negotiations continued until October 1973 when a contract was awarded. It called for two separately priced tasks:

- A Cost Plus Fixed Fee task for detail design leading up to Validated Follow Ship Drawings, lead ship planning, special studies and procurement of propulsion systems for the lead ship and LBTS; awarded for $42,914,000.

- A Cost Plus Incentive Fee task for construction of the lead ship and central procurement of certain standard items; this task awarded for $49,500,000.

Detail design began at BIW subsequent to completion of the Ship System Design phase which had provided a Lead Ship Allocated Baseline. The objective was to proceed from the Lead Ship Allocated Baseline and associated specifications and drawings to arrive at a guide to build the lead and follow ships. To assure that drawings would always represent the latest information, great pains were taken to update drawings at each change and prior to performance of any shop or yard work. All work on the lead ship was to be done from as-built drawings and in that way, there would be a higher probability of assurance that the validated drawing concept would operate in practice successfully by eliminating most drawing "bugs".

Certain engineering problems became apparent quickly and contributed to a six month delay in lead ship delivery right at the outset. Several reasons can be given for this delay and the negotiations it caused to modify contract costs.

- The subcontractor to Bath for design work, Gibbs and Cox, increased its estimate at completion because

  - Defective specifications and information resulted in inaccurate information being sent to vendors.

  - Additional manpower and hours were required to make up lost time on material and equipment procurement.

  - Backlogs in drawing activities occurred due to the preceding factors.

- Design and engineering activities did not progress adequately and some rather basic changes had to be implemented.

  - A fourth diesel generator

  - Longitudinal bulkheads below the second deck to eliminate vibration

  - Space and weight provisions for fin stabilizers

  - The ships firefighting capability had to be redesigned

  - A fifth fire pump

  - Additional computer memory modules

  - Some several hundred other items.

Throughout the construction process, engineering changes have been numerous. Table V.26 which follows identifies the scale and number of contract modifications that have taken place.

TABLE V.26

HMR'S/FMR'S
SUMMARY

Total Modifications (According to Dollar Value)

Individual Mods	Number of Mods	CPFF	CPIF	Total
> 1M	6	$10,914,856	$4,922,747	$15,837,603
> 500K	7	1,101,213	2,293,418	3,394,631
> 100K	23	2,725,968	1,367,575	4,093,543
	36	$14,742,037	$8,583,740	$23,325,777
< 100K	327*	11,154,810	2,229,524	13,384,334
Total Changes Recorded		$25,896,847	$10,813,264	$36,710,111
Increases in Contract Price Estimate at Completion as of March 1977		$ 20.9M	$18.3M	$39.2M

* Of the 327 other contract modifications (as of April 1977), only 109 involved changes in dollar amounts according to SupShips.

SOURCE: SupShips Bath

The numbers of changes that took place can probably be justified for a lead or prototype ship. The primary objective of the lead ship construction concept is to eliminate design and engineering problems and fully test equipment in order to minimize problems on follow ships. The net result of all this has been, however, a delay of at least nine months in delivery, with an associated estimated increase in cost of construction and design activities exceeding $39 million. In general, the cost increases can be attributed to:

- Labor hour overruns caused by a misestimate of the complications of outfitting a complex ship with a smaller than normal hull.
- Increased material costs driven by increased reliability assurance requirements giving rise to the view that the

ship is "gold-plated" and not austere

- The propulsion system at the LBTS has required numerous engineering changes necessitating attendent cost increases and delays.

- Late GFM at the Combat System Land-Based Test Site and increased GFM testing required have been factors of delay and cost increases in the construction process, mainly in the case of the AN/SPS-49 Radar, SQS-56 Sonar, and MK-92 FCS.

Regardless of the cost increase and engineering change experienced, prospects are good that the selected lead ship design and construction techniques have provided the necessary foundation for construction of follow ships -- the initial awards of which took place in 1975. A high degree of confidence has been noted at both Bath Iron Works and Todd Shipyards with respect to follow ship production.

(5) Cost Growth On The Lead Ship Has Exceeded 40 Percent And Provides Evidence Of Consistently Low Estimates

The FFG 7 is scheduled for delivery in December 1977. Comparisons of estimates versus actual costs are therefore based on return costs through March 1977 and estimates of cost to complete which are indicated on Quarterly Progress Reports and Ship Cost Adjustment Reports.

Current percentage cost growth with respect to original estimates versus current end cost estimates in major categories is as follows:

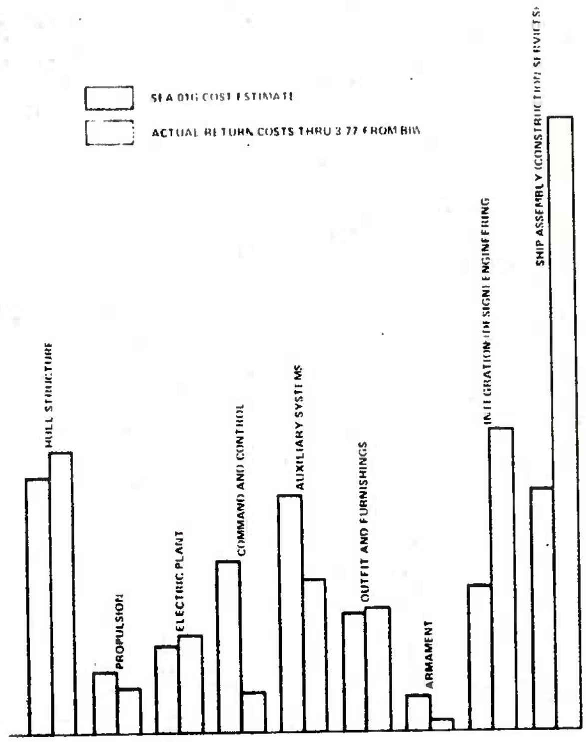
- Basic Construction
  - Labor Hours 91%
  - Labor Dollars....... 175
  - Overhead Dollars ... 252
  - Material Dollars 27
- Plans 1%
- H/M/E 535%
- Ordnance 36%

Note: Basic construction and plans increases are based on March 1977 Estimates at Completion from Bath Iron Works and H/M/E and ordnance increases are based on March 1977 budget documents.

As can be seen cost increases in basic construction are significant. The following chart, Figure V.8, shows labor hours estimated for various basic construction components as compared to return costs when the ship was 81 percent complete. Although the relationships may change when the ship is complete, it is notable that two components have been underestimated, due perhaps, to faulty engineering data provided estimators or other information-related problems during early phases.

FIGURE V.8

ANALYSIS OF BASIC CONSTRUCTION LABOR HOURS



SOURCE
BIW COST PERFORMANCE REPORTS

- Integration engineering estimates have been exceeded thus far by 174,000 labor hours, a 104 percent labor hour growth.

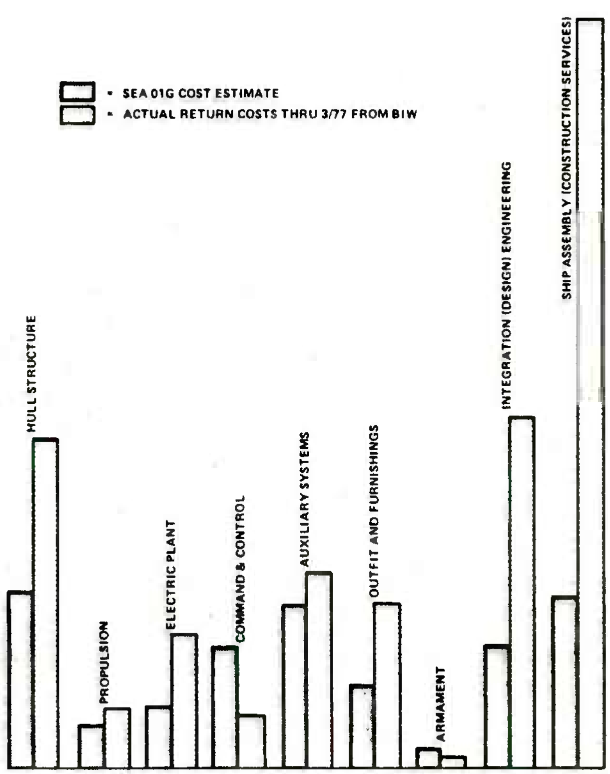
- Ship assembly estimates have been exceeded thus far by 420,000 labor hours or 153 percent.

Both labor hours and labor rates were low so that a large labor dollar increase occurred. NAVSEA 01G based lead ship labor estimates on a rate of $4.30/hour. BIW currently projects the rate through completion of construction to be over $6.00/hour. Analysis shows, therefore, that labor rates were under-estimated by almost 44 percent. There was a labor rate increase at Bath Iron Works during lead ship construction, and it is suspected that NAVSEA 01G should have included projections of such rate change in their estimates. No documentation exists which substantiates the use of the original labor rate.

Overhead estimates follow the pattern of labor hour estimates, tending to be mostly on the low side. The return cost data shows over-

FIGURE V.9

ANALYSIS OF BASIC CONSTRUCTION OVERHEAD COST $



SOURCE:
BIW COST PERFORMANCE REPORTS

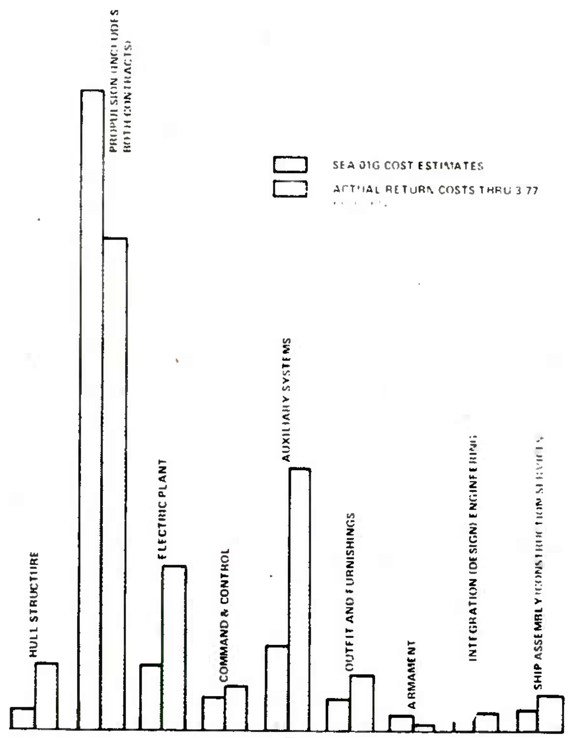
head charges of $10.3 million through March 1977 whereas SEA 01G estimated $4.8 million. The March 1977 estimate at completion projects total overhead charges to be over $17 million. Figure V.9 identifies overhead overruns and underruns.

The NAVSEA lead ship material estimates were exceeded in mid-1976 when the lead ship contract was approximately 50 percent complete. The following figure shows the comparison of SEA 01G estimates versus return cost data through March 1977. As can be seen, SEA 01G estimates, although exceeded in many sub-accounts, were fairly close in the overall estimate of material costs.

- An estimate at completion of $28.7 million vice SEA 01G estimate of $22.6 million shows a difference of $6.1 million -- a 27 percent overrun.
- The BIW bid showed estimates of total material costs at approximately $23 million as a comparison.

The most significant overrun in material cost has occurred in auxiliary systems. The SEA 01G estimate was $2.1 million and return costs through March 1977 exceed $6.4 million for a $4.3 million overrun.

FIGURE V.10
ANALYSIS OF BASIC CONSTRUCTION MATERIAL COSTS



SOURCE
BIW COST PERFORMANCE
REPORTS

GFM cost growth has reflected problems in the propulsion area and costs associated with weapon and sensor testing. The largest single increase occurred in the area of Hull, Mechanical and Electrical in 1973 when estimates increased from $6.8 million to $29.7 million. The majority of this increase can be attributed to test and instrumentation at the propulsion system land-based test site, including increased design activity, new construction at test site, hardware installation, and lengthy testing. The bulk of the remaining increase to the present budget estimates is also due to additional test and instrumentation costs at both Land-Based Test Sites (i.e., $13.6 million).

In May 1972, the CNO issued several changes to the ship's characteristics:

- Utilize two vice one LAMPS helicopters
- 76 millimeter Oto Melara Gun vice 35 millimeter gun
- SQS-505 Sonar vice SQQ-23 Sonar, later changed to SQS-56 Sonar

Other than these changes, the weapon and sensor characteristics have remained relatively stable. It would appear, however, that testing costs of the magnitude experienced were not foreseen in the original estimate for GFM.

TABLE V.27

HARDWARE COST INCREASES
(Millions of Dollars)

Equipment Designation	Budget Estimate (1/71)	Current SPD Estimate	Dollar Difference	Percent Difference	Reasons for Change
MK-92 Mod 2 Fire Control System with STIR	11.5 for one 15.7 for two	19.5(3) for two	3.8 (3)	24 (3)	1 LBTS System ($4.2M), additional GFE, INCO spares, systems engineering, console modifications, refurbish to "as new condition", portion of reliability testing.
MK-13 GMLS	5.4 for one	6.3 for one	0.9	17	Low estimates due to smaller initial quantity (one) buy than anticipated originally (50).
AN/SPS-49 Radar	0.825 for one	1.6 for one	0.775	94	Low estimates, undefined cost growth, engineering services, contract increase to ceiling price.
HARPOON Command and Launch Sub-system (1)	0.100 for one	0.963 for one	0.863	863	Originally low estimates, poorly defined initial requirements, escalation.
AN/SQS-56 Sonar	1.5 (2)	2.3	.80	53	Additional testing or equipment modifications, low estimates.

(1) No documentation available to support changes.
(2) Planning estimates
(3) Includes procurement of two MK 92 systems.

Equipment hardware costs and related charges for software and testing have increased significantly as shown in the accompanying tables. The explanations for increases in hardware and software costs are sometimes overlapping and somewhat general due to the limited data available.

TABLE V.28

SOFTWARE AND TESTING COSTS
(Dollars in Millions)

Equipment Designation	Date of Increase	Amount of Increase	Reason for Increase
MK-92 FCS	late 1975	2.1	Reliability and qualification testing
	1976	1.3	Computer program support and engineering change proposals
MK-13 GMLS	since 1973	0.019	RMA testing
	late 1975 and 1976	1.6	Engineering support, strike impact, increase in scope, i.e., heat exchanges, spares, etc.; b blast test vehicle, MK 60 testing
AN/SPS-49 Radar	After 1973	0.65	Deficiency correction, i.e., receiver noise, memory cards, additional operational testing, drawing revisions
	Total	5.7	

It has been reported that the FFG SHAPM originally requested Research and Development funds to finance additional testing and reliability efforts for such items as the MK-92 Fire Control System, AN/SQS-56 Sonar and AN/SPS-49 Radar. Also, R&D funds were requested for the land-based test sites since they could be considered a form of research and development. These funds were not forthcoming, however, and therefore, a great deal of testing was charged to lead ship construction -- much more than was originally estimated.

(6) <u>The Growth In Total Program Costs Has Resulted From An Increased Unit Price Per Ship, An Increased Inventory Requirement And Escalation</u>

In late 1972 during FFG 7 budget reviews within the Navy, projected total program costs for the 50 ship buy were $2,717,400,000. The FY 1978 budget shows a total program cost of $13,793,400,000 -- an increase of about 400 percent. Table V.29 tabulates this growth over the years.

The first element of this increase is the growth in unit production cost per ship. Under the Design-to-Cost discipline, unit production costs are maintained in constant dollars and as engineering changes take place, applicable cost differences are computed in constant dollars so that the DTC goals or targets are maintained and a reasonable comparison can be made.

The Conceptual Report in July 1971 specified a Design-to-Cost goal based on engineering data then available. Early program activities dealt with the process of evaluation trade-offs in operating characteristics, weaponry and major equipment to produce an acceptable capability for a cost at or under the cost goal. When the preliminary design was completed, a new DTC target was fixed. Once the single ship platform was selected and initial characteristics approved, DTC goals

TABLE V.29

GUIDED MISSILE FRIGATE SHIP DATA SHEET PROJECTIONS
(Dollars in Millions)

		FY 71	FY 72	FY 73	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	Unit Cost	Cost to Complete	Total Program Estimate***
1973	Quantity			1		7	11	10								21	50
	RDT&E	.9	11.7	1.5													14.1
	System Cost			191.5	82.0	347.5	531.9	436.8								1127.7	2717.4
	Outfit & PD****																
	TOTAL														54.63		2731.5
1974	Quantity			1		7	11	10	10							11	50
	RDT&E	1.1	11.5	1.5													14.1
	System Cost			202.2	6.8	416.9	609.5	555.4	596.0						64.61	616.9	3003.7
	Outfit & PD						.6	8.0	9.0							203.5	221.1
	TOTAL															820.4	3244.5
1975	Quantity			1		7*	11	10	10	11							50
	RDT&E		12.6	1.5													14.1
	System Cost			202.2		436.5	655.9	614.8	623.7	699.0							3632.1
	Outfit & PD						.3	4.4	1.2	23.3						201.8	231 0
	TOTAL														69.70		**3462.8
1976	Quantity			1		3*	10	11	10	11	10						56
	RDT&E			14.1													14.1
	System Cost			205.6		186.0	955.5	1233.3	1112.0	1312.6	1208.2						6213.2
	Outfit & PD						1.3	5.8	0.4	14.7	69.9					368.8	460.9
	TOTAL														122.0		**6831.5
1977	Quantity			1		3	6	8	8	8	8	8					50
	RDT&E				14.1												14.1
	System Cost				205.6	186.0	802.5	1179.5	1171.6	1272.9	1333.3	1411.4					7562.8
	Outfit & PD						0.9	1.8	6.0	13.8	52.2	61.6				460.8	597.1
	TOTAL														169.5		8475.6
1978	Quantity					4	6	8	9	11	12	12	12				74
	RDT&E					14.0	0.1	1.0	4.2	2.8	1.4	0.2					23.7
	System Cost					391.6	802.5	1179.5	1319.0	1950.1	2222.0	2376.0	2514.0				12754.7
	Outfit & PD						1.0	1.7	10.8	13.8	45.1	71.1	90.2			504.9	738.6
	TOTAL														186.4		13793.4

*Congress reduced due to concern over the MK92 FCS

**3.483 to 6.831 change due to -- .386 for design changes, CIWS and revised GFE; inflation 1.665 & schedule change 535=2,200; .762 for six more ships = 3.348

***Escalation amounts for prior years not included.

**** PD = post delivery

were subsequently indentified each time a major engineering or project change took place. A summary of these changes follows:

TABLE V.30

FFG DESIGN-TO-COST TARGETS
FOR FOLLOW SHIPS
End Cost
(Dollars in Millions)

Milestone	1973 Dollars
Original Goal -- December 1970	50.0
Conceptual Baseline Goal -- July 1971	49.2
Functional Baseline Target -- August 1972	45.7
Updated Target -- October 1973	47.7
Updated Target (DSARC III) -- June 1976	71.3

The difference between an important DTC milestone -- functional baseline -- of $45.7 million and the lead ship baseline target of $71.3 million, a $25.6 million increase, has been explained by project officials as follows:

TABLE V.31

FFG RECONCILIATION OF DTC TARGET
(Dollars in Millions)

Functional Baseline Goal (1973 Constant Dollars)			$45.7 M
Changes	Dollars	Percent	
Engineering	1.8	7	
Estimating (GFE/CFE)	5.9	23	
Characteristics and R/M/A	1.3	5	
Market Factors	8.5	33	
Revised Procurement	2.0	7	
Revised Outlay Rates	3.0	11	
Adjustment for Small Buy	3.1	12	
Total	25.6		
New Design-to-Cost Goal (1973 Constant Dollars)			$71.3 M

By removing the adjustment for small buys, which is not needed if the proposed procurement plan is followed, the new DTC goal would be $68.3 million -- an increase of 37 percent.

Although an increase of 37 percent would appear on the surface to be large, it must be understood that this is an increase from an arbitrary goal which took place during engineering and prototype phases. During this time, many trade-offs and changes were made to maintain costs goals. Project officials have mentioned that without the use of DTC techniques, the average follow ship cost might be considerably higher.

The second major element of cost growth is the increase in the overall buy. The original inventory target was 50 ships. This number was changed several times and now is targeted at 74. The extra 24 ships caused the program to be extended at least two full years. The unescalated cost of these ships is at least $1.6 billion.

The third and largest component of cost growth is escalation. Before the officially approved development estimate, the escalation estimates were averaging approximately 5.8 percent of total program cost. The approved development estimate for escalation was established at $624.1 million. This amount was 19 percent of total program costs as of June 1974.

Escalation increased substantially in the June 1974 "current estimate" and further increased through March 1977 to 57 percent of total program costs as the accompanying table shows.

(7) In Summary, FFG Program Tracking Has Disclosed Problems In Both The Areas Of Cost Estimating And Management Strategies

Although it is very early in the FFG program, findings and conclusions based mainly on lead ship experience are of sufficient importance to warrant comment relative to cost estimating, financial management and project strategies.

With regard to cost estimating and financial management,

- Current (April 1977) end cost estimates project cost growth of 41 percent from original estimates for FFG 7.
- The major contributors to cost growth by category are: basic construction and change orders, hull/mechanical/electrical, ordnance and escalation.
- Using the initial budget estimates and the Bath Iron Works estimate at completion, basic construction cost growth on the lead ship will exceed 70 percent.
    - Labor hours -- budget estimates exceeded by at least 91 percent largely in the cost areas of integration engineering and ship assembly.

TABLE V.32

SUMMARY OF GUIDED MISSILE PATROL FRIGATE PROGRAM ESCALATION CHANGES

(Dollars in Millions)

Total Program	Percent of Program	Dollars	Date	Explanation
3482.8	5.8	202.5	December 1973	1. Ship characteristic changes; 2. New material cost and productivity factors; 3. OSD inflation indices; 4. FY 74 Defense Appropriation Act denial of advanced procurement funding for FY 75 program.
3244.5	19.2	624.1	June 1974	1. Establishment of development estimate baseline for escalation.
5274.6	46.8	2466.8	June 1974	1. 1974 inflationary trend including utilizing later BLS indices and NAVSEA future economic forecast; 2. Previous engineering changes; 3. Additional diesel generator; 4. Revised GFM estimates. Last ship delivery now 4/83.
6831.5	36.1	2466.8 (1)	December 1974	1. Prepare and install Phalanx CIWS beginning with FY 76; 2) Extention of follow ship production due to FY 75 Defense Approriation Act from 7 to 3 ships; 3. Longer material and equipment lead times; 4. Change in procurement strategy; 5. Addition of six ships to FY 80 program. Last ship delivery now 1/85.
6782.2	48.7	3300.5	June 1975	1. Potential cost growth in lead ship cost type contract.
8475.6	53.9	4564.5	December 1975	1. Delete 6 ships added in 12/74 SAR, ; 2. Revised ship quantities; 3. Outfitting and post delivery requirements.
9014.8	53.5	4825.8	June 1976	1. Four ships added to FY 77 program; 2. Refining follow ship outlay rates.
13675.3	56.4	7717.6	December 1976	1. Additional 24 ships added to President's FY 78 budget submit; 2. LAMPS I electronics; 3. Lower escalation requirements for program years FY 75, 76 and 77. Last ship delivery now 2/87.
13837.7	56.8	7858.8	March 1977	1. President's amended FY 78 budget submit transferred two FFG's to FY 82; 2. Revised GFM; 3. Reduced competitive market for follow ships. Last ship delivery now March 1987.

(1) The increase of $831.7 million in this quarter did not appear in escalation total until June 1975.

- Labor dollars -- exceeded by 175 percent.

- Labor rates -- budget estimates exceeded by almost 44 percent.

- Material dollars -- budget estimates exceeded by 27 percent.

- Overhead dollars -- budget estimate exceeded by over 252 percent.

• Numerous change orders (HMRs/FMRs) during basic construction are expected to be responsible for over $18 million in cost growth. A 37 percent increase includes causes such as addition of a fourth diesel generator, a fifth fire pump, addition of longitudinal bulkheads, redesign of fire fighting capability, etc.

• The area of hull, mechanical and electrical has experienced significant cost growth -- a $36 million increase.

  - $23 million of this increase right at the beginning of production was due to additional test and instrumentation at the propulsion system LBTS.

  - The cost for the lead FFG is high due to the charge for the costs (including testing) for both the propulsion and combat systems LBTS's.

• The ordnance category has experienced cost growth of almost $14 million or 36 percent thus far.

  - Major increases are in weapon and sensor hardware:

MK-92 FCS	24%
MK-13 GMLS	17
AN/SPS-49 Radar	94
HARPOON Command and Launch Subsystem	863
SQS-56 Sonar	53

- Reasons for these increases were not defined very well but were due to such things as 1) LBTS equipment; 2) additional spares; 3) low estimates; 4) engineering services; 5) additional GFE; 6) poorly defined initial requirements; and 7) inflation.

- Additional software and testing costs have been responsibile thus far for a large increase in weapon and sensor costs of almost $6 million.

. Denial of R&D funds for the additional testing and modifications to such items as the MK-92 FCS and AN/SQS-56 Sonar contributed to cost growth.

. Estimates for detail design have proven fairly accurate.

- Based solely on budget estimates detail design costs will be $6.4 million under the original budget estimate.

- Cost growth between the contract price and current Bath Iron Works estimate at completion (April 1977) is $20.9 million.

- Costs caused by defective NAVSEC specifications, activities related to the validated drawing concept, changes in ship design, etc., comprise cost growth experienced.

. Escalation has been a major factor of cost growth.

- Impact of escalation on lead ship costs is difficult to determine since escalation is included in each cost category.

- Escalation growth allowances on 74 ship FFG program has increased $7.2 billion since the approved development estimate, a percentage increase of over 1,100.

With regard to project and management strategies,

- Design-to-Cost goals included ship design austerity, use of off-the-shelf items and service tested weapon systems. These intentions were not completely implemented in the final lead ship design and therefore changed the character of the ship.

- The Design-to-Cost dollar goal was optimistic too early and therefore DTC, taken in its strictest interpretation, did not keep design costs close to initial goals. Design-to-Cost goals can be self-defeating if established prior to a firm ship definition.

- The Design-to-Cost dollar goals established, however, cost constraints which exerted pressure to minimize costs and maintain cost consciousness throughout a program, especially during the conceptual design phase.

- The use of land-based test sites promises to be a positive cost control factor.

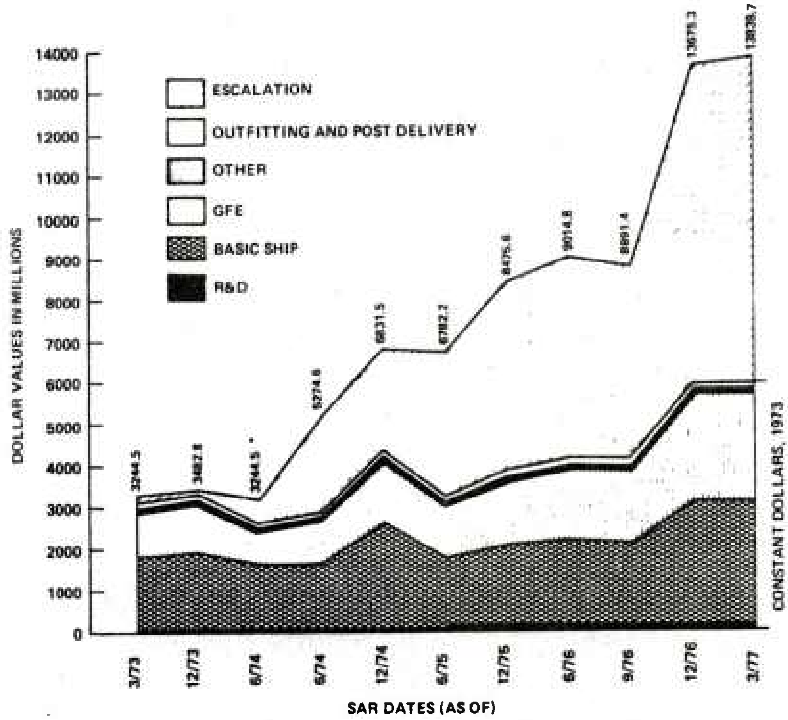
- The use of the validated drawings concept will be proven or disproven as a cost control factor as the construction of the follow ships progress, but currently is a positive project technique.

- The use of the central procurement (standardization) concept may not reflect a positive cost control factor, but will aid in having standardized ships in a class and decrease life cycle costs through the availability of spares and lower maintenance costs.

- The compression of the time interval between lead and follow ship construction tends to lessen the positive cost control aspects of the FFG acquisition strategy.

FIGURE V.11

GUIDED MISSILE PATROL FRIGATE DOLLAR GROWTH OF THE MAJOR PROGRAM CATEGORIES



* OFFICIAL DEVELOPMENT ESTIMATE

SOURCE: FFG SELECTED ACQUISITION REPORTS

7. ESTIMATING FOR GFM IS CARRIED ON WITH LITTLE CONSISTENCY BETWEEN PROJECTS AND PRACTICALLY NO PRIORITY GIVEN TO ITS PERFORMANCE

The cost of Government Furnished Material (GFM) is a significant element of the total cost of a ship. On the major ship classes in current programs, the following percentages apply:

- Hull, Mechanical, Electrical 1 - 3 %
- Electronics 4 - 14%
- Ordnance 4 - 14%

Propulsion equipment is another category of material sometimes handled as GFM which contributes significantly to total ship cost. Overall, for complex nuclear powered ships, GFM can account for up to 45 percent of the total estimate for a ship.

Since GFM often comprises so large a portion of the total ship cost, detailed analyses have been performed on eight different items of GFM.

- AN/SPS-55 Surface Search Radar
- AN/SPS-40 Air Search Radar
- 5" Lightweight Gun, MK-45
- MK-86 Gun Fire Control System
- AN/SQS-53 Sonar
- PHALANX - Close In Weapons System (CIWS)
- AN/UYK-7 Digital Computer
- LM-2500 Gas Turbine Engine

Additionally, certain broad measures of the accuracy for GFM estimates have been reviewed to ensure that problems not disclosed by the detailed review of the eight items listed will be given consideration. Finally, mention is made of the problems of defective and late arriving GFM.

(1) Despite A Lack Of Structure In The AN/SPS-55 Radar Estimating Process, Accurate Estimates Do Result

The AN/SPS-55 radar system is a solid state, surface search and navigation radar capable of detecting targets from as close in as 50 yards and out to 30 miles with good target resolution. The basic system consists of:

- Receiver/Transmitter RT-1124/SPS-55
- Antenna Group OE-172/SPS-55
- Antenna Safety Switch SA-1963/SPS-55
- Radar Set Control C-9447/SPS-55

Other equipments such as displays and repeaters are not a part of the basic SPS-55 system.

- Evolution of the requirement -- The requirement for the AN/SPS radar originated in OPNAV. It was developed to take advantage of evolving technology which included solid state construction and higher frequencies for improved range and reduced weight. The OPNAV/NAVSEA transaction was based on a simple request, rather than through the Specific Operational Requirement (SOR) process.

- Evolution of the design -- The original design was financed by RDT&E engineering development funds since the required equipment was essentially within the state of the art and risk was minimal. OPNAV was able to define the capability required as being generally similar to the capability of the SPS-10 except that the new radar would operate in the X-band rather than the C-band. The development was initiated in 1963 under a performance specification and the original design equipment produced by Raytheon was service approved in 1968. However, there was a considerable time lapse before the equipment was specified for installation on a class of ships. When the decision to use this radar on the DD 963 class was made, the design was reviewed, the transmitter and receiver were combined in one cabinet and a circuit involving suppression of clutter was removed. The design has been stable since.

- Application of the SPS-55 radar -- The SPS-55 surface search and navigation radar is a standard Type I radar system suitable for use on such ship classes as the DD 963, FFG 7, DDG 47, CGN, PGG, PCG, AO and AS.

  The SPS-55 radar is a reliable system. It exceeds the specified mean time between failures (MTBF) of 500 hours.

- Time sequence review of basic equipment costs --

DATE	EVENT
1963	Raytheon selected to develop the SPS-55. The RDT&E contract cost approximately $1.2 million.
1968	Specification was revised as indicated above for procurement as GFE for DD 963 class.
1971	Unable to execute satisfactory sole source agreement with Raytheon. Cardion won competitive multi-year award for 36 sets at $41,200 per set including first article testing and software.
1974	Production set completed technical evaluation satisfactorily.
1976	Cardion awarded sole source contract for 18 sets at $92,000 per set. No development of test gear and software was included in this buy.
1977	Cardion awarded sole source contract for 20 sets at $86,256 per set.

- Estimating history -- Table V.33 contains the record of budget estimates and procurements made for this radar by SEA 01G. Estimates relating to the 1971 procurement could not be found.

TABLE V.33
AN/SPS-55 RADAR

TREND IN BUDGET ESTIMATES AND CONTRACT AWARD PRICES (BASIC HARDWARE ONLY)
(Thousands of Dollars)

Item Description	Est. For	Est. Date	FY Applicable	Amount Estimated	Amount Contract Award
SPS-55			71		41
	DD 963	12/72	73	65	
	DD 963	12/72	74	70	
	DD 963	12/72	75	73	
	DE	06/73	75	74	
	CGN*	06/74	76	89	92
	PCG/ PGG	11/75	76	85	
	CGN*	06/75	77	100	86
	CGN 9/ DDG	11/75	78	105	

* Formerly DLGN

In this Table, the estimates are arranged by Fiscal Year and, then, by date prepared. The trend is reasonable and approximately parallels the growth in material indices over the same period. In the right hand column, contract award amounts are shown opposite estimates applicable to the fiscal year of award. To the extent comparisons can be made, the contract amounts are reasonably comparable to the corresponding estimates. In essence, no estimating problem is evidenced by available data.

• Observations relating to estimating -- In developing the cost history, it was found that records did not exist in any consistent manner until 1972 and that the radar section does not retain cost estimating information. This can be attributed to some extent to the fact that the AN/SPS-55 is a relatively old system and that there were document retention problems resulting from organizational and physical location changes as well as the constant need to dispose of records.

Albeit, there was no evidence of cost data banks or return cost information upon which analogous cost estimates could be derived or cost analyses made. What cost estimate information is available is fragmented throughout SEA 02 (Contracts), NAVSEA 01G historical program year and ship files, and the NAVSEA 01G AN/SPS-55 radar files.

After 1972, NAVSEA 01G records do provide a consistent cost estimate track. As borne out by interviews and documents, these estimates are simply the sum of the previous year's estimate plus additional money for expected cost increases over the next year. None of the estimates indicated specifically the basis for the cost increases other than being the results of general economic trends. Simply stated, for relatively small and inexpensive hardware such as the SPS-55 radar, cost estimating within NAVSEA is not a structured process. Cost estimating in these cases is generally done by contacting a vendor or by reviewing past contract prices and adding inflation factors. Based on the data shown in Table V.33, this method has worked for the SPS-55 radar.

Problems disclosed -- No actual data bank could be found for the SPS-55 radar. Rather, such data as was found was in SEA 01G files and SEA 02 contract files. The data was not organized, but was scattered and was not consistent in format.

The radar section, which must make estimates in support of a number of processes such as budgets and SPDs, does not have trained estimators. Logically, it places most of its emphasis on the technical/engineering phases of the work, but this is at the expense of a formal estimating process and adequate record keeping.

(2) The Lack Of Estimate Documentation On The AN/SPS-40 Radar Makes Any Definitive Appraisal Impossible

The AN/SPS-40 is a long range two-dimensional air search radar which supports early warning detection and tracking for shipboard combat systems.

- Evolution of the requirement -- The requirement for the SPS-40 radar originated as a CNO Operational Requirement in the late 1950's. To date, over 260 of these radars have been purchased, primarily for installation on destroyer and amphibious type ships.

- Evolution of the design -- The original design which went into production in 1959 employed vacuum tube technology. During 1964-1965, improvements to the design were made to provide greater performance. Some of the circuits were changed to solid state. The radar was then designated the AN/SPS-40A. During 1968-1969, the SPS-40A was partially redesigned again to improve capability and reliability. At this time the designation was changed to SPS-40B. The design has remained constant since.

- Estimating history -- The initial cost estimates (planning or development estimates) for an equipment in production since the late 1950's could not be found. The problem was made more difficult by the many organizational changes that have taken place. This particular radar has been managed by two Systems Commands and the personnel involved in both the technical and management aspects have relocated several times. The current project engineer in NAVSEA stated that there is no cost estimate data in his office and the only source of data he knew of was in the AN/SPS-40 contract files in the NAVSEA Contracts Directorate and in the procurement files of SEA 04. The only sources of cost estimates for the AN/SPS-40 were the NAVSEA 01G Ship Program Year files, various NAVSEA 01G ship files, and contract files. The estimates still available are as follows:

TABLE V.34
AN/SPS-40

TREND IN ESTIMATES AND CONTRACT AWARD PRICES
(Thousands of Dollars)

Item Description	Est. For	Est. Date	FY Applicable	Amount Estimated	Amount Contract Award
SPS-40			1959		143
SPS-40	LPD, LPH, FF (DE)	03/63		150	158
	--	--	1965	--	167
	LPD, DE, LSD	10/64	1966	212	
SPS-40A	FF (DE)	04/65	1966	212	
SPS-40B	LCC, LHA	06/67	1969	160	191
	CGN - (DLGN)	06/67	1970	160	
			1973	200/250	
			1974	214/268	
			1975	229/285	
			1976	367/530	455
			1977	659/936	

The estimates shown in the above Table through FY 1970 are believed to be total unit costs including spares, software, etc. However, no records to verify this could be found although it is known that they were made by personnel in NAVSEA and its predecessors. From 1973 and in following years, only hardware and total estimates are shown. The estimates for FY 1973-1975 were made by NAVORD and those for FY 1976-1977 by NAVSEA 01G. Also, the contract prices at time of award for each of the five procurements are shown opposite the estimates for the fiscal years in which the purchases were made.

The estimates tend to progress uniformly from smaller to larger. However, there are model changes which must affect the cost and, of course, there are different rates of inflation. Overall, the estimates are judged to be reasonably good and, as such, do not disclose deficiencies in the estimating process.

The contract prices shown do vary from the estimates, particularly from 1969 on. Since the estimates are not documented in detail, the reasons for the variations are unknown. It is known that there has been growth in three of the contracts which has caused an increase in the variations. This growth is shown in the following Table.

TABLE V.35

SPS-40 CONTRACT PRICES

Contractor	Year	Configuration	Quantity	Unit Price: Award Price	Unit Price: Current End Price
Lockheed	1959	SPS-40	92	$143,606	$143,606
Lockheed	1963	SPS-40	47	$158,086	$187,190
Sperry Marine	1965	SPS-40A	72	$167,000	$192,020
Dynell Electronics	1969	SPS-40B	46	$190,728	$214,760
Dynell Electronics	1976	SPS-40B	7	$455,300	$455,300

The latest, higher contract price appears to be the result of inflationary factors (at least 75 percent between 1969 and 1976) and a sole source, small buy. Also a factor is that certain of these radars are for foreign military sales and have unusual requirements for spares, test instruments and software.

The SQS-40 radar serves as a good example of the problem of comparing total unit cost estimates. There are big differences in the estimates for the items to be purchased in addition to the basic hardware as shown in Table V.36.

Evidence was found to support the contention that the subordinate items are not being consistently handled by different estimators and that, in some cases, items are being overlooked.

TABLE V.36

NAVSEA ESTIMATES FOR THE AN/SPS-40B
(All Figures in 000's of Dollars)

	FY 76 11/12/75	FY 77 12/05/75	Difference in Estimates (FY 77-76)
Hardware	367	659	292
Initial Spares	37	50	13
I&C Spares	37	25	-12
Design Changes	-	66	66
Test Equipment	-	14	14
Project Management	18	-	-18
Contr. Field Eng. Serv.	20	6	-14
Gov. Field Eng. Serv.	30	6	-24
Design Engineering	-	-	-
Technical Data and Doc.	13	5	-8
ILS Management	4	-	-4
Systems Eng. Cost	-	75	75
SQT	-	30	30
QA & RMA	4	-	-4
Total	530	936	406

Also with reference to the above Table, it is to be noted that the estimates were made less than one month apart by the same organization. There is no documentation to explain the large differences.

- Problems disclosed

  - Again, the research and data are poor. For example, no record could be found of the estimate of change in cost attributable to the two significant model changes. Also, estimates directly relating to the contract negotiations could not be found. With the earlier estimates, such documentation as does exist does not reveal whether the estimate covers hardware only or total cost. Without improvement in the documentation consistently good estimating can hardly be expected.

- The data included above indicates that contract prices have exceeded estimates made at the approximate time of contracting by a significant amount (except for the FY 1976 contract). This indicates that responses to SPD's must have been inaccurate and that budget figures must have been low, making the program management task doubly difficult.

- SPS-40 technical personnel showed virtually no interest in the preparation of estimates which could no doubt be attributed to the well-defined baseline of a radar which had been under contract before. Still, the need for more emphasis on the importance of good estimates or for assistance by qualified personnel is indicated.

(3) As With The Previous Equipment, Estimating Performance On The MK-45 Lightweight Gun Seems To Be Of Low Quality But Is Difficult To Make A Judgment About Due To Lack Of Documentation

The 5"/54 Caliber Lightweight Gun (LWG) Mount MK-45 Mod 0 is a fully automatic, lightweight, shielded, single barrel weapon capable of firing 5" projectiles at 20 rounds per minute. It was developed to have the highest possible mission capability, fully automatic operation, all-weather performance, reduced space and manning requirements, low life cycle costs, and maximum safety for crew and ship. Its capabilities extend to defense against air threats, small, fast, highly maneuverable surface targets and provision of extremely accurate gunfire support for ground forces.

- Evolution of the requirement -- The 5"/54 LWG MK-45 is the first completely new major shipboard gun mount designed for the Navy since the 1950's. It was developed by FMC Corporation/Northern Ordnance Division under a contract awarded in April 1964. It was delivered to the Navy for testing in June 1967 and approved for service use by the Chief of Naval Operations in July 1970. Three production contracts have been awarded to Northern Ordnance Inc., and one to General Electric for a total of 96 mounts.

- Application of the 5"/54 LWG MK-45 -- This lightweight gun was designed primarily for use on destroyer type ships, but it also is used on CGNs (DLGNs) and LHAs.

- History of estimates and contracts -- Table V.37 contains a record of selected budget estimates made for this gun. The estimates made in the 1960's were developed by NAVORD while NAVSEA 01G was responsible for the estimates prepared in March 1973 and later. A NAVORD memorandum to OPNAV dated in December 1968 forwarded the estimate dated December 1968 in Table V.37. Certain comments in this memorandum are applicable to nearly all GFM estimates and bear repeating.

  - The price of the gun varies with the quantity procured.

    "As the shipbuilding program changes and the required number of gun mounts is varied, the cost will vary also."

  - "The conflict between the 'program' approach, and the 'budget' approach causes price differences. If the quantities required for the DX program of say 40 ships is priced, the result will certainly be different from that obtained for the LHA ship in a particular FY program as approved by Congress."

- The initial direct buy from Northern Ordnance was necessary for the first contract in order to meet ship delivery schedules. And, "these prices are expected to be somewhat higher than prices that can be obtained after the procurement data package is available and the lead times are compatible."

TABLE V.37

LIGHTWEIGHT 5"/54 GUN MOUNT MK 45, MOD 0

TREND IN BUDGET ESTIMATES - TOTAL UNIT COSTS
(Thousands of Dollars)

Estimate For	Estimate Date	FY Applicable	Amount Estimated
DDG, DE	06/67	-	1,680
CGN(DLGN)	04/68	-	1,936
CGN(DLGN)	12/68	1968	1,974
LHA	12/68	1968	1,740*
DX, DXGN	12/68	1970	1,520
LHA	12/68	1970	1,368*
DXG	12/68	1971	1,490
	01/69	1970	1,522
	01/69	1971-77 (24/yr.)	1,509
	01/69	1971-75 (36/yr.)	1,404
DD 963	03/73	1973	1,630
	03/73	1974	1,685
	03/73	1975	1,744
DDG 47	11/75	1975	3,066
CGN(DLGN 38)	03/75	1976	3,711
DD 963	09/75	1977	3,974
DDG 47	11/75	1978	4,199

* Without Hoist

There have been four separate contracts for the gun as reported in the following Table:

TABLE V.38

CONTRACTS FOR MK-45 LWG

Year of Contract	Contractor	Quantity	Unit Price At Award	Anticipated End Price
1968	Northern Ordnance, Inc.	25	$1,789,000	$2,097,000
1971	General Electric	54	852,000	976,655
1972	Northern Ordnance, Inc.	7	1,300,000	1,300,000
1975	Northern Ordnance, Inc.	14*	1,655,986	1,697,736

* Reduced to ten units after contract award.

The first contract was the result of a sole source buy and Northern Ordnance received a premium price. Further acquisition was opened to competitive bidding, which, along with the large size of the contract (54 systems), resulted in a large unit price reduction between the first and the second contract. However, this lower unit price is misleading since it does not include the cost of lower ammunition,hoists and other items which were contracted for by separate contracts with Northern Ordnance and furnished to GE as Government Furnished Material. This material cost is in the order of $500,000.

The prices decreased markedly when the procurement was opened to competition and, even though the contract prices have grown, the gun mounts are still no more expensive than they were nine years ago.

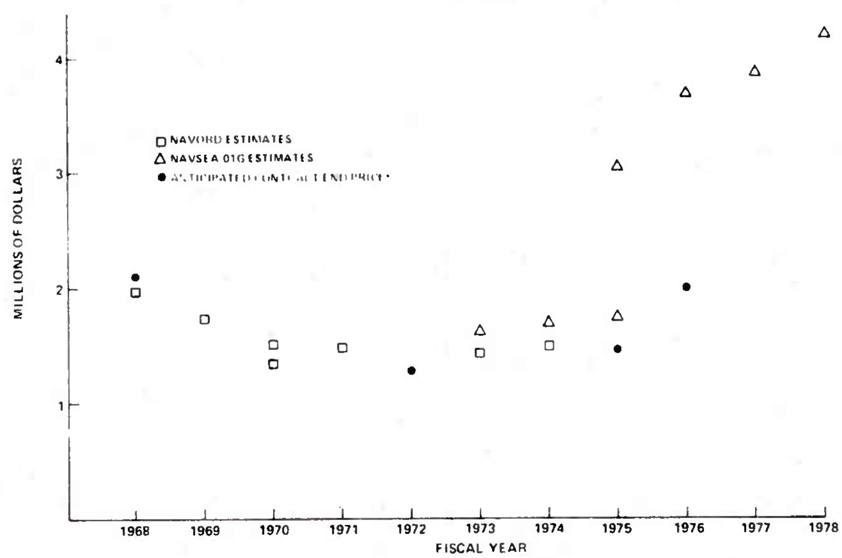
The actual cost decrease is even more impressive than these figures portray as the system has been expanded and increased capability has been added since its initial production. Thus, it appears that the MK-45 has not had excessive cost growth and the Government has been successful in keeping a lid on the cost increases.

In relating estimates (Table V.37) to contract prices (Table V.38), the estimates made by SEA 01G during 1975 stand out dramatically. They are from 50 percent to 100 percent higher than the anticipated end cost of the mounts being procured under the contract awarded in 1976. These increases are attributed by SEA 01G to anticipated inflationary factors and lack of competition as it is anticipated that GE will no longer be interested and 5"/54 LWGs will be procured sole source from Northern Ordnance.

Figure V.12 relates estimates to anticipated end prices per unit. While the data are not exactly comparable (since they apply to different ship types, etc.), they do show reasonable estimating performance until recently. The later SEA 01G estimates appear to be overly generous.

FIGURE V.12

MK 45 LIGHTWEIGHT GUN
ANTICIPATED CONTRACT PRICES vs. ESTIMATES
(TOTAL COST BASIS)



Problems disclosed

- Historical records and documentation covering the estimates are incomplete making the re-construction of estimates difficult to impossible. This factor also contributes to the potential for making inaccurate estimates when estimating responsibility is transferred from one organization to another.

- On these gun mounts as well as other items of GFM, there is evidence that competitive procurement results in lower prices. The estimator must anticipate this, but it is difficult in view of the time lapse between budgeting and contracting.

(4) Cost Growth On The Evolving MK-86 Gun Fire Control System Has Been Moderate But Estimates Are Difficult To Follow

The MK-86 Gun Fire Control System has surface and, in some Mods, air target capability. The system employs radars, a computer and associated control consoles.

- Evolution of the design -- The Specific Operational Requirement (SOR) for a MK-86 Gun Fire Control System (GFCS) was issued in February 1963 and was to control surface to surface gunfire in support of amphibious operations. In February 1964, a contract was let to Lockheed Electronics Company for the design and manufacture of two prototype models. The first system was delivered in May 1966 and accepted by the Naval Ordnance Systems Command. This system was subsequently installed on the U.S.S. BARRY (DD 933) for a concurrent evaluation but, due to technical problems, this evaluation was never completed.

  In November 1966, CNO issued a revision to the SOR covering improvements to further develop the system and also addition of anti-aircraft and missile (continuous wave illumination) capabilities. Lockheed was awarded contracts for this work in July 1967 and by 1969, the MK-86 met performance requirements.

- Application of the MK-86 GFCS -- The MK-86 GFCS Mod 3 controls two guns, primarily on the CGN 36 and DD 963 classes; the Mod 4 controls three guns on the LHA ships; and the Mod 5 controls two guns and provides standard missile guidance for CGN 38 class ships. Still another version, without a dedicated computer, is being considered for AEGIS ships.

- Estimating history -- Estimates have been traced back as far as January 1964 when NAVORD prepared an estimate for the DDG of $1,400,000. Later estimates in 1969 showed a range of $2,250,000 to $2,297,000.

  The first estimates to show hardware plus ancillary costs are for the DD 963 as shown in the following table.

TABLE V.39

NAVORD ESTIMATES FOR THE MK 86 GFCS FOR THE DD 963 (000's of Dollars)

	1/15/70 Estimate	11/30/71 Estimate (Mod 5)	12/10/71 Estimate (Mod 3)
Hardware	3,630	3,800	3,375
Growth	15	-	-
Technical Documentation	192	10	-
Test and Checkout	25	-	80
Sup. Engineering	15	100	-
Field Service Engineering	25	100	61
Travel and Per Diem	25	-	-
I&C Spares	-	50	-
SQT Costs	-	30	-
Initial Spares	-	-	150
Design Engineering Changes	-	-	200
Development Costs	-	-	-
Total	3,977	4,090	3,866

This Table illustrates a problem which was noted for each GFM system examined. Beyond the basic hardware, the items included to reach a total cost estimate vary from estimate to estimate, within and between estimating organizations. This spottiness could be rectified with some care and through use of a comprehensive check off list. More over, when a given item appears in two or more estimates, the estimated amounts are apt to vary widely. Back up information to justify these variations is almost invariably lacking.

Table V.40 contains a number of estimates made by SEA 01G of the basic hardware cost of the MK-86 system. Also, selected estimates made by the project

TABLE V.40

MK 86 GUN FIRE CONTROL SYSTEM
(BASIC HARDWARE ONLY)

TREND IN ESTIMATES
(Millions of Dollars)

Item Description	Est. For	Est. Date	FY Applicable	SEA 01G Estimate	Project Office Estimate
MK 86		1964		1.4	
MK 86 Mod 3	DD 963, LX-1	09/03/75	1977	6.1	3.4 (12/10/71)
	DD 963	09/04/75	1977	3.2	3.4 (10/22/75)
	CSGN	09/12/75	1977	5.1	2.1 (10/22/75)
	DD 963	10/23/75	1977	4.0	
MK 86 Mod 5	DD 963				3.8 (11/30/71)
	CGN 38	04/11/75	1976	5.5	3.0 (01/19/76)
	CGN 38	10/23/75	1978	4.2	3.6 (10/22/75)
	DDG 2-15	10/23/75	1977	4.1	3.5 (10/22/75)
MK 86 (AEGIS)	DDG 47	03/73	1973	1.1	
		03/73	1974	1.2	
		03/73	1975	1.2	
	CGN 41	12/03/73	1976	2.1	
	CGN 38	03/06/75	1976	3.1	
	CSGN	09/23/75	1977	3.3	
	DDG 47	10/23/75	1977	3.4	
	DDG 47, CSGN	10/23/75	1977	3.4	
	DDG 47	11/21/75	1975	2.5	

organization are also shown. With two exceptions, the estimates selected correspond to SEA 01G estimates in terms of ship class and fiscal year applicable. Usually, the estimates are in terms of ship class and fiscal year. Also, the estimates were prepared on approximately the same date. The differences are not inconsequential. The Mod 3 estimates for the CSGN are widely different and the three corresponding sets of estimates for the Mod 5 vary on average by 36 percent.

There have been three production contracts with Lockheed Electronics for the MK-86 GFCS as shown in the Table which follows:

TABLE V.41

PRODUCTION CONTRACTS FOR THE MK-86 GFCS
(Dollars in Millions)

Year	Quantity	Approx. Average Hardware Price*
1970	16	3.0
1973	28	2.6
1975	4	3.3

* Target price at time of contracting

By and large, the contract unit hardware prices more closely approximate the project office estimates than the SEA 01G estimates. Again, the matter of open communication channels arises. The estimates in Table V.40 and the prices in Table V.41 are for the basic hardware only. Thus, there should be comparability but there is no evidence that actual contract prices were introduced into the SEA 01G estimating process.

Problems disclosed

- A lack of adequate communications between the central estimating organization, SEA 01G, and the project office is evidenced by the significant differences in the estimates of unit costs of the basic hardware.

- The lack of consistency in items considered in making the estimate for requirements other than basic hardware is a recurring problem which leads to inaccurate total cost estimates.

(5) Estimates For The AN/SQS-53 Sonar Have Been High But Reasonable And Generally Have Been Able To Foresee Cost Growth That Has Occurred

The AN/SQS-53 Sonar is a modified AN/SQS-26CX, a Sonar which has been installed on many Navy surface ships since the early 1960's. It's purpose is to provide detection, classification, and localization of underwater targets as part of the ASW mission.

- Evolution of the design -- The AN/SQS-26CX Sonar, developed in the early 1960's to interface with the analog Underwater Battery Fire Control System (UBFCS) MK-114, was scheduled for installation on the DD 963 and CGN 38 class ships which are equipped with the digital UBFCS MK-116 and digital Command and Control Systems. In 1967, it was decided that modifying the AN/SQS-26CX Sonar to provide digital outputs was preferable to doing the necessary data conversions in separate converters. The extensive changes to the many cabinets of the AN/SQS-26CX Sonar and the addition of a new cabinet resulted in a change of nomenclature to the AN/SQS-53 and the AN/SQS-53A in September 1971.

- Application of the SQS-53 Sonar -- The AN/SQS-53 Sonar, first defined in 1968, has been installed on DD 963 class ships and the AN/SQS-53A on the CGN 38, 39

40 and 41 (formerly the DLGNs). The CGN 42 and the DDG 47 class ships are also scheduled to have the AN/SQS-53A installed.

Estimating history -- The first AN/SQS-53 sonars were purchased from General Electric Company by Litton Industries for DD 963 class ships. The unit cost of the first nine of these sonars was $3,186,437.

The first SQS-53A sonars procured as GFM were for the CGN 38 and 39. These were modifications of previously designed and constructed SQS-26CX's and were priced as follows:

- Original Unit Cost $1,880,302
- Cost to Modify 1,032,800
- Total Cost 2,913,102

The unit cost estimate made by SEA 06 for the modifications was $983,000. The actual unit price of the modifications was $1,032,800 or within five percent of the cost estimate.

The only procurement of complete SQS-53A systems as GFM has been for the CGN 40 and 41. The SEA 06 unit cost estimates for these systems is shown in the following Table.

TABLE V.42

SQS-53A ESTIMATES AND PRICES
(Dollars in Thousands)

	NAVSEA Estimate	CGN 40 Price	CGN 41 Price
Hardware Engineering Services	3,721 74	2,951 70	- -
Total	3,795	3,024	3,232
Percent Difference		(25)	(17)

Estimating the cost of the well-defined AN/SQS-53A should not have been too difficult. Thus, the over-estimate of 25 percent for the CGN 40 and 17 percent for the CGN 41 could be considered inadequate performance. At the same time, the actual prices are not out of line with those Litton Industries obtained for generally similar systems.

- Prospective procurements of the SQS-53A sonars will be more costly -- If these SQS-53A sonars are eventually installed on the CGN 42 class and the DDG 47's, the costs will be higher as indicated by the following Table which contains estimates prepared by SEA 06 project office for sonar systems.

TABLE V.43

ESTIMATES FOR SQS-53A SONARS FOR CGN 42 AND DDG 47 CLASS SHIPS
(Dollars in Thousands)

	CGN 40 Price	Future Estimate
Hardware	2,951	4,961
Engineering Services	70	166
Total	3,021	5,127

The continuing program for modernization of these sonar systems is a factor in this predicted increase in costs.

- Problems disclosed

  - The cost estimating records for these sonars were more complete than those found for most other items of GFM. Also, copies of contracts and modifications thereto were readily available. At the same, the over estimates for the two complete systems which were purchased as GFM cannot be accounted for except in terms of market factors. The $3.2 million price awarded to Litton for the first nine systems was established just nine months before the Navy contract was signed on February 2, 1973. With the smaller quantity and the later date, the higher Navy estimate would appear to be in order. Thus, this example points to the importance of carefully assessing influences of the market.

- While the technical baseline for the SQS-53A system, including modifications, is well-defined, the substantially higher estimate for the systems for the DDG 47's and CGN 42 is premised on further modernization of the system with accompanying increase in services, documentation and other software. This illustrates the essentiality of keeping the technical baseline up-to-date for estimating as well as other purposes, something that has not been done for all of the GFM items reviewed.

(6) Cost Estimates For the LM-2500 Have Been Consistently Higher Than Actual Costs

The LM-2500 is a single-cycle, two shaft engine consisting of a gas generator, power turbine, fuel control and governing system, associated inlet and exhaust sections, lubrication and scavenging systems, and controls and devices for starting and monitoring operation of the engine. It is available as a gas turbine alone, as a base-mounted unit, or as a completely packaged module.

The engine incorporates a 16-stage compressor; a full annular, dual fuel burning combustor with externally mounted fuel nozzles; a two-stage high pressure gas generator turbine, air cooled, that drives the compressor and accessory drive gearbox; and a six-stage-low speed, low-stress power turbine, with an output speed of 3,600 rpm, which is coupled aerodynamically to the gas generator and is driven by its high energy release exhaust flow.

There are four distinct configuration items: Base/Enclosure Assembly; Gas Turbine Assembly; Gas Turbine Lube Storage and Conditioning Assembly; and a Free Standing Electronic Enclosure Assembly.

- Evolution of the design -- The LM-2500 gas turbine is a marine adaption of the General Electric turbine used in the DC 10 airplane. The first such engine installed in a ship by the Navy was on the GTS ADMIRAL WILLIAM M. CALLAGHAN, a high speed roll-on/roll-off cargo ship built for charter to the Military Sealift Command.

  The advantages sought included weight and space savings; reduction in installation costs; greater ship availability due to reduced down time for maintenance; reduced manning requirements; flexibility in choice of fuels; and rapid ship response.

- Application of the LM-2500 gas turbine -- At present the LM-2500 gas turbine is being installed in

  - SPRUANCE (DD 963) Class Destroyers -- 30 ship program; four gas turbine modules per ship.

- Guided Missile Frigate (FFG) -- 74 ship program; two gas turbine modules per ship.

There are plans to use this gas turbine in additional ship classes; the AEGIS Destroyer and the Sea Control Ship are examples.

- Cost estimating for the LM-2500 gas turbine -- Cost estimates for the LM-2500 marine gas turbine modules for use in new ship construction have been and are being generated by several organizations:

  - NAVSEA 01G
  - SHAPMs for ships utilizing the LM-2500; the Guided Missile Frigate (FFG) Ship Acquisition Office, and, more specifically, PMS 399P4 within that office.
  - SUPSHIP (Supervisor of Shipbuilding) Bath, where Bath Iron Works is acting as agent for the Navy in buying LM-2500 modules under the terms of an option agreement covering the procurement of 60 LM-2500 modules.
  - Naval Ship Engineering Center (NAVSEC), where NAVSEC 6146 provides estimates as called for by SHAPMs, particularly at the beginning of a project.
  - General Electric Company, the vendor for the LM-2500 marine gas turbine modules.

In order to develop an historical track of LM-2500 cost estimates that would be meaningful, only estimates of LM-2500 marine gas turbine modules were considered, and of these, the only ones used were those connected with the Guided Missile Frigate (FFG) program, one of the two principal programs utilizing the LM-2500 engine. The other principal program, the SPRUANCE (DD 963) Class destroyer program, did not have comparable estimates available because the LM-2500 modules were CFE rather than GFE. However, there is some data on the DD 963 gas turbines which provides an initial perspective. In 1970, the unescalated base price for an LM-2500 marine gas turbine module, as provided for in the General Electric/Litton option agreement for 120 modules for the SPRUANCE (DD 963) Class destroyer program was about $1.1 million; the final escalated return cost per module under this agreement, with all deliveries made in the 1972-1976 period, was $1.43 million.

TABLE V.44

LM 2500 GAS TURBINE FOR FFG 7 CLASS

TREND IN ESTIMATES
(Dollars in Millions)

Estimate Date	FY Applicable	Amount Estimated
1970	-	1.3
1971	-	1.1 - 1.5
1972	-	1.8
1973	1973	2.0
	1974	1.8 - 2.1
	1975	2.3
1974	1975	2.8
1975	1976	2.9
1976	1977	3.3
	1978	3.6
1977	1977	3.3
	1978	3.6
	1979	4.6

Several of the estimates in the Table were prepared by PMS 399 for inclusion in SCN budgets. The methodology is summarized in Table V.45.

TABLE V.45

FFG OPTION PRICE ESTIMATES FOR LM 2500
(Dollars in Millions)

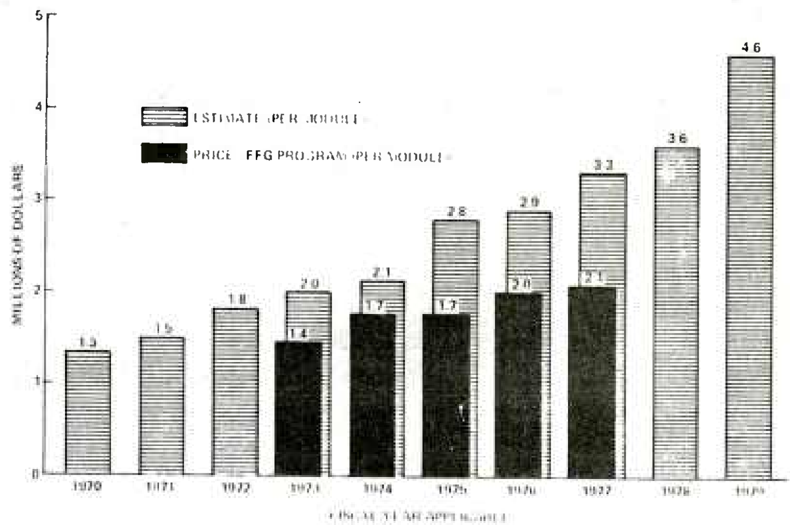
	Estimated Cost Per Ship Set (2 modules)	Estimated Unit Cost (1 module)
FY 1976 Bath Fee	5.71 (Estimate from x 1.03 SUPSHIP, BIW) 5.88	2.94
FY 1977 Inflation FY Inflation FY	5.88 (FY 1976 estimate) x 1.028 x 1.102 6.661	3.33
FY 1978 Inflation FY 1978	6.661 (FY 1977 estimate) x 1.084 7.220	3.61
FY 1979 Inflation FY 1979 Provision for new negotiations with GE	7.220 (FY 1978 estimate) x 1.066 x 1.2 9.236	4.62

Figure V.13 compares certain of the estimates shown in the previous two tables with contract prices. The data are arranged by Fiscal Year to show the trend in both estimate and price.

The estimates depicted on the Figure show the steady growth in cost that is anticipated, a factor of three and one half times the original estimate in nine years.

FIGURE V.13

LM-2500-GROWTH IN ESTIMATES AND PRICES



According to the various organizations making LM-2500 cost estimates, the principal cost drivers of the cost estimates of the LM-2500 modules for the FFG program are:

- Inflation (reflected in escalation as per option agreement for 60 modules)
- Changes in engine
- Smaller ship buy than originally planned
- Expiration of 30 ship set option at end of FY 1978, with consequent necessity of having to provide contingency for added cost for FY 1979 renegotiation.

The price information shown on the Figure represents General Electric's billings based on deliveries. Thus, the time relationships are only approximate. Also, the price increases arise from the conditions established in the basic Bath/General Electric contract. The price to be agreed upon in the follow-on contract is, of course, unknown at this time. As Table V.45 indicates, a contingency of 20 percent has been added. The need for this size contingency is not obvious from the Figure which indicates that estimates have been overly generous to date.

- Problem areas

  - Data banks -- None. Estimates must be obtained from files of the various organizations.

  - Return cost and bid data -- Very scarce or non-existent in the files of the various Navy organizations making estimates.

  - Escalation and inflation predictions -- Inflation factors are used in developing estimates, but little, if any, use is made of the escalation formula contained in the General Electric/ Bath Iron Works option agreement covering the procurement of 60 LM-2500 modules.

  - Review procedures -- NAVSEA 01G and the SHAPMs coordinate their estimates, but the methodology used by all the Navy organizations involved in LM-2500 cost estimating is not standardized.

(7) The Close In Weapons System (PHALANX - CIWS) Is A Weapon Developed By A Cost-Conscious Group Over Its Pre-Procurement Phases

The PHALANX-CIWS is an automatic, self-contained unit consisting of a search and track radar, digitalized fire control system, and a 20 millimeter M1A1 gun which fires depleted uranium projectiles.

The system is mounted in a single, above deck structure requiring a minimum of interface with other shipboard systems.

- Evolution of the requirement -- The CIWS is a fast reaction system designed specifically to fulfill the "last ditch defense" concept against all low-flying, high speed antiship missiles. The CIWS system is designed for a quick and inexpensive installation on virtually all types of surface ships and requires only ship's power and coolant water for operation.

- Evolution of the design

  - In 1966, the Chief of Naval Operations asked for proposals from industry for a lightweight gun system which could defend ships from attacks by antiship cruise missiles. In 1968, General Dynamics submitted a proposal for the CIWS and began concept formulation and feasibility tests.

  - Between 1969 and late 1973, the plan was to develop, in quick succession, prototypical and operational suitability models with heavy reliance on simulation and increasingly stringent phased testing of some nine or ten early units.

  - During 1973, Defense Department policy took on the form of "fly-before-buy" and this concept required a considerable change in the method of producing and testing the early CIWS units. Emphasis was placed on comprehensive testing on only a few prototype units. This new approach caused a complete re-appraisal of projected costs. The result was a tripling of expected end cost of R&D.

- Since late 1973, the second phase has been in effect with rather steady progress to target cost despite testing and funding difficulties.

Table V.46 depicts the schedule for the 12 milestones which were planned to successfully complete the program. The reason for program delays beginning at Event Five -- Complete At-Sea Test of Prototype #1 -- are set forth in the footnotes.

- Despite the delays and testing problems, the CIWS appears to be operating at or over design requirements. As a result, production (R&D plus procurement) of 437 units, 434 of which are to be produced between FY 1978 and FY 1983 is now planned. 321 of the units are identified in the WPN appropriation for back-fit on operating ships; 113 are for new ships in the SCN appropriation; the remaining three are the RDT&E units.

- <u>Cost estimating history</u> -- Unlike other weapons systems being studied, the CIWS project has no procurement history. Although procurement was originally planned for an earlier period, first production runs are now planned for June 1979.

  Due to the character of the project, a study of cost estimating performance primarily relates to the ability of project and contractor personnel to correctly estimate the end cost of the R&D process. Beyond that, one can trace the evolution of a procurement price and its use for both project and budget purposes.

  Table V.47 shows the key milestones of cost growth in this project through March 31, 1977.

TABLE V.46

CIWS PROGRAM EVENTS

Event	Planned	Actual	Delay	
			Mos.	Reasons
1. Award contract and start Engineering Development	December 1970	December 1970	0	
2. Complete fabrication of Engineering Development Model (pre-prototype)	May 1972	May 1972	0	
3. Complete testing of pre-prototype	September 1972	September 1972	0	
4. Complete testing of Prototype #1 and #2	December	December	0	
5. Complete At-Sea Test of Prototype #1	November 1973	March 1974	4	(1)
6. Complete RMA proofing of Prototype #2	December 1973	NA	4	(2)
7. Award contract for Operational Suitability Model (OSM) program	November 1973	June 1974	7	(3)
8. Deliver OSM #1	November 1974	November 1976	24	(4)
9. Commence At-Sea Test of OSM #1	February 1975	May 1977	27	(4)
10. Complete At-Sea Test of OSM #1	July 1975	July 1977	24	(4)
11. Award Production Contract	July 1975	October 1977	27	(5)
12. First Production Run	January 1977	June 1979	30	(6)

Reasons for Delay

(1) Extended land-based testing and bad weather.

(2) Decided to use Prototype #2 as testing model for life of program.

(3) Reprogramming action acted on by Congress seven months after contract ready to execute. Further delay after Congress reduced Operational Suitability Model (OSM) buy from six to option for one. Option for one exercised 1 March 1976.

(4) These events are a function of the Congressional holding action. The option for one OSM was exercised in March 1975 with actual delivery in November 1976 (8 months). Testing of the OSM was correspondingly delayed. Although program delays are approximately two years at this point, once the one OSM was authorized for completion, the contractor cut four months off the original planned time for award and delivery of the OSM and two months off the originally planned time for at-sea testing. RDT&E budget cuts by Congress also contribute to the general slowdown in progress.

(5) Last three months delays due to preparation for DSARC III, expected in September 1977.

(6) At DSARC III approval, full scale production will occur; the estimated 27 month lag is necessary for set up of production facilities.

TABLE V.47

CIWS COST GROWTH SUMMARY

	1/73	6/73	12/73	6/74	12/74	12/75	3/77 Current
R&D(1)	42.2	53.0	123.1	123.4	119.6	127.7	126.4
Procurement (1)	526.3	490.5	517.1	579.6	716.9	806.2	943.6
Program Estimate(1)	568.5	543.5	640.2	703.0	836.5	933.9	1070.0
Units	360	370	367	367	364	362	437
Average Unit (1) Cost	1.54	1.47	1.74	1.92	2.30	2.58	2.45

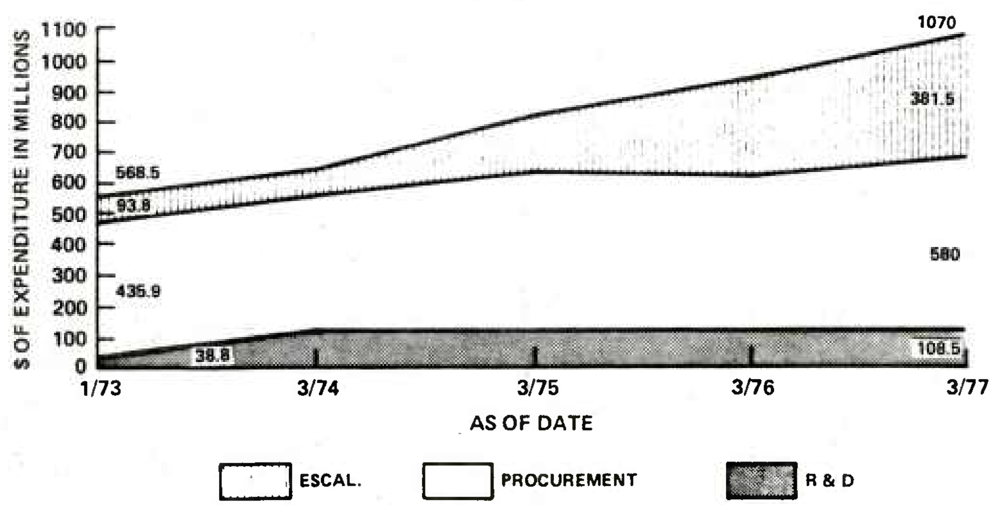
(1) Figures in Millions of Dollars

The Decision Coordination Paper (DCP) for CIWS which reflected the first development philosophy shows an end cost estimate for R&D of $42.2 million. During the change in approach, this was raised $10 million and finally, once a new "fly-before-buy" direction was developed, a cost of $123 million was estimated. This latter amount has increased to only $126.4 million in over three years. Thus, very little variance from target has been experienced in the R&D area.

Figure V.14 shows a breakdown of the overall cost

FIGURE V.14

DOLLAR GROWTH OF MAJOR CATEGORIES CIWS



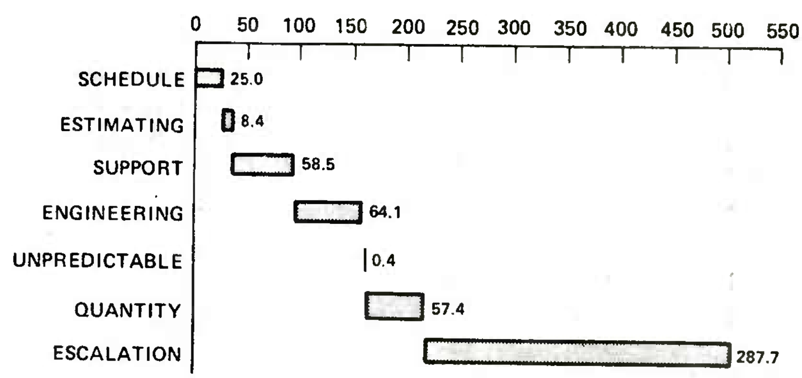
SOURCE:
CIWS SELECTED
ACQUISITION REPORTS

growth from $568.5 to $1070.0 million. The amounts for R&D and procurement shown on the Figures are in constant FY 1972 dollars.

Figure V.15 summarizes the overall cost growth by contributing factors. The program has not been without its engineering, reliability and funding problems which have caused about 13 percent of the cost growth. The largest portions of growth, however, appear due to quantity changes and escalation growth as shown in the Figure below.

FIGURE V.15

SUMMARY OF CIWS COST GROWTH BY CONTRIBUTING FACTORS ($ IN MILLIONS)



SOURCE:
CIWS SELECTED
ACQUISITION REPORTS

• <u>R&D and procurement cost estimating performance</u> -- The CIWS project group is small, well-managed and result-oriented. Cost related decisions are made after careful review of information provided by several sources.

- General Dynamics, the CIWS contractor, has an extensive estimating and cost control section under the direction of the assistant controller. Two estimates are made in this division, totally independent of each other. The first estimate is an engineering estimate based on actual data utilizing the first prototype as the baseline. The second independent estimate is a parametric estimate developed by utilizing the DEC Computer Cost Prediction Model (PRICE).

- A completely independent contractor, Tecolte Research, Inc., prepares an independent parametric estimate based on contractor return cost data. Tecolte has a small staff of people educated in engineering, mathematics, physics and economics which provide research, analysis, engineering and consulting services to government and private agencies. Their cost analysis/estimating experience is between 10 and 15 years.

  In the case of the CIWS, Tecolte prepares a parametric estimate based on cost estimating relationships. The data used is obtained through Contractor Cost Data Reports, Cost Information Reports and data solicited from contractors by Tecolte themselves.

- When these estimates are received by the CIWS project office, the management staff reviews and compares them. CIWS project management maintains tight rein over changes in cost estimates by monitoring and questioning all significant variations.

- Further, special contract clauses, not part of DOD INST. 7000.2 outline returned costs required by the project office. The reports are based on existing contractor MIS output which are also relevant to CIWS management activities. Typical reports include:

  Actual costs against bid estimates showing cost-to-complete on a monthly basis;

  Performance data based on Work Breakdown Structure and Functional organization;

Man-power loading by WBS and functional organization;

Material cost by major cost element;

Milestone schedule and progress.

From the above it can be seen that serious attention has been given to cost estimating and cost control by the CIWS project office. All that can reasonably be expected is being done in terms fof utilizing timely information and support by the contractor and independent cost estimators. Still, there has been a 57 percent increase in the expected unit cost of a CIWS. This clearly illustrates the very significant impact of influences above and beyond the control of NAVSEA. However, there are problems with respect to estimates of the cost to install the CIWS aboard ship which should be within NAVSEA control.

- Supporting equipment services and software cost estimates for CIWS vary widely -- Two appropriations are applicable for CIWS equipment budgeting.

  - WPN appropriation for back-fitting CIWS during overhauls on ships in the fleet. (Installation funds separate.)

  - SCN appropriation for CIWS equipment and installation on ships being constructed.

The estimates prepared for these appropriations reflect add-ons for costs necessary to install, test and prove the weapon on a ship. These vary, of course, on whether the ship is under construction or in service.

The present practice of NAVSEA 01G in estimating for the SCN budget is shown in Table V.48. It is significant to note the basic hardware cost of the CIWS ($2,600,000) compared with the costs after the addition of other supporting and installation charges ($5,646,000). The difference between the two figures is over $3 million for the FY 1977 lead system. Of this total, $61,000 applies to the CIWS gun itself.

Almost $640 thousand applies to engineering support charges. In addition, there are substantial installation charges included in each ship estimate. The CIWS project office and SEA 01G disagree on costs for engineering support and installation. Costs will vary between ships, i.e., a carrier will be higher than a destroyer, but based on actual costs during research and development, the NAVSEA 01G estimates are thought by the project office to be high. There is little disagreement between NAVSEA 01G and the CIWS project office over the CIWS hardware estimates.

TABLE V.48

NAVSEA 01G COST ESTIMATES -- CIWS
(All Ships)
($ in Thousands)

	Lead System FY 77 Estimate	Lead System FY 78 Estimate	Follow System FY 77 Estimate	Follow System FY 78 Estimate
Equipment Cost				
Hardware	2,600	2,615	2,600	2,615
Remote Control Indicators	85	-	85	-
Peculiar Support Eng.	130	-	130	-
Production Support	127	-	127	-
GFE - gun	61	60	61	60
Ordalts	30	-	30	-
Shipping Fixtures	12	13	12	13
Project Management	12	13	12	13
I&C Spares	150	268	150	268
Design Eng. Changes	601	268	601	268
Test Equipment	73	79	73	79
Initial Spares/Support	480	536	480	536
Tech. Data, Doc., OD's	58	50	23	9
ILS Management	49	14	49	14
QA and RMA	84	11	84	11
	4,552	3,927	4,517	3,886
Growth 10%	455	393	452	389
	5,007	4,320	4,969	4,275
Engineering Support Costs	639	647	289	305
Total Estimate:				
Equipment/Support Costs	5,646	4,967	5,258	4,580

The SEA 01G generalized format is based on weapons systems requiring extensive engineering and integration, complicated installation and extensive testing. Due to lack of data and staff, little ability exists to examine weapon systems on an individual basis to determine individualized supporting and installation charges required. The CIWS, which is the product of extensive R&D effort, Operational Suitability Models and is a stand-alone and easily installed system, should not require the level of supporting expenditures called for by the generalized format.

The estimates for WPN units for ships in service also have add-on charges, but not to the extent of SCN figures. The WPN figure for FY 1977 is estimated at $3.2 million, or approximately $2.6 million for basic hardware and $600 thousand for support expenditures other than installation.

- Problem areas

  - The amount and quality of data utilized by the project office is well-thoughtout and useful in decision-making activities. The good performance of the project office in adhering to budgeted costs of R&D and procurement can be attributed to the emphasis given to the cost estimating function. However, there was growth from external factors and this points to the need to develop the information flow and analysis techniques necessary to better anticipate the impact of these factors.

  - The use of a generalized system for estimating the cost of supporting items can result in significant misestimates which could be rectified if the practice were to attempt to review such costs for new major systems in detail in conjunction with the project office.

(8) <u>Cost Growth Is Not A Problem In The AN/UYK-7 Procurement And Estimating Performance Is Relatively Good</u>

The AN/UYK-7 is a general purpose, stored-program, solid state, binary computer designed for real time applications. For weapon systems, the computer performs the data processing and computations needed for target tracking, generation of gun, torpedo and missile orders, and for providing display data to fire control systems and tactical data system operators. It is installed in cabinets or bays in various combinations of the following units: Central Processing Unit (CPU), Memory Units (single or double density), Input/Output Controller, Power Supply Unit, Dummy Unit, I/O Adapter (4, 8, 12 or 16 channels), Maintenance Console Unit, and Remote Operating Console Unit.

- <u>Evolution of the requirement</u> -- In order to avoid problems associated with the proliferation of Navy computers, the Chief of Naval Operations directed the development of a general purpose digital computer upon which the Navy could standardize for shipboard applications in the 1970's. The AN/UYK-7 Computer was developed in response to this direction and represents an improved version of the CP-901 used by NAVAIR. The computer's modular construction makes it readily adaptable to a wide range of shipboard applications including those of both specialized and general natures and it can be installed on all type ships

- <u>Procurement experience</u> -- The initial cost estim approximately $524,000 for the AN/UYK-7 t furnished for the Advance Ship Missile Sys

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which is now AEGIS) was generated by the Computer Systems Section of NAVSEC. Due to their previous computer procurement experience and the standard nature of the components involved, the above initial cost was based on a well-defined baseline. This no doubt contributed to the fact that the actual cost of the ASMS computer (approximately $534,000) was within $10,000 of the NAVSEC estimate.

Since the above initial contract, there have been approximately twelve Navy sole source firm fixed price contracts with Sperry Rand. Approximately 348 AN/UYK Computers have been procured by the Navy which is the sole procuring agent of the Department of Defense for this system.

By definition, a standard AN/UYK-7 computer consisted of a central processing unit, an input-output controller, three memory units, an input-output adapter, and a power supply. However, the computer system is capable of fast, easily facilitated expansion through the addition of modules. For example, by the addition of memory units, the memory capacity of the computer can be extended; also, memory units have double density capability. The limits of system expansion are determined by the amount of inter-module communication required and the addressing capability of each module. This flexibility has resulted in many configurations, all "tailor made" to fit a specific application.

This flexibility factor has several implications. First, to review contract costs it is necessary to price out a standard computer. SEA 045 recently made a comparison of the basic cost of an equivalent 1 bay single density computer during the period from 1972 to 1977 with the following results.

Contract N00024-	Basic Cost Per Equivalent Standard Computer
72-C-1327	$304K
72-C-1256	247K
73-C-1327	228K
74-D-1193	223K
75-D-7165	225K
76-D-7195	231K
77-D-7121	279K

The above costs have remained stable; which is certainly amazing in view of the inflation experienced by so many of the Navy programs. This stability has contributed to the accuracy of the estimates for these computers made by SEA 04.

For the SCN Budget the flow of estimates is as follows. SEA 04, SCN Support Section, will provide AN/UYK-7 Computer cost estimates to SEA 01G for ships listed in the Program Objectives Memorandum (POM). The estimate is based on the most recent bid proposals from the manufacturers, Univac-Sperry Rand, and will include the current inflation factor being used by the contractor. It should be noted that because the Navy is the sole procuring agent for all AN/UYK-7's, the availability of current prices and bids appears to be of significant value in the estimating process and is used to the exclusion of a parametric or engineering method.

The flexibility in the configuration of the UYK-7 computer for different applications does result in widely varying dollar amounts being reported in different budget forms for different ship classes. Examples have been found where a difference in the number of bays or the density resulting from changed specifications have been overlooked. This points to the need to keep configuration information with the estimates.

The magnitude of the dollar differences that may arise is illustrated by the following data taken from FY 1975 budget back-up forms itemizing UYK-7 computer estimates.

- FFG 7........$ 437,000
- SSN 688...... 596,000
- CGN 38...... 1,587,000

The preceding data strongly indicates that cost estimating has not been a problem due to the stability of the production contracts from year to year and that cost overruns have not been experienced when procuring AN/UYK-7 Computers. The comparatively large amount of computers procured over an approximate seven to eight year period and UNIVAC producing the maximum number of computers which can be built in their facility has provided production stability with resulting monetary savings for the Navy. On a ship by ship basis there has been some problem with estimates since the estimates have not always stayed abreast of specification changes.

• <u>Problems disclosed</u>

- The AN/UYK-7 computer has an excellent cost history which provides a sound basis for good estimating. At the same time, this case highlights the need to know the precise configuration when estimating. This requires record keeping which was not in evidence in the central estimating organization.

- Furthermore, this case highlights the need for the estimating organizations to maintain close communications with the technical organization. Any change, contemplated or accepted, in a ship system (e.g., weapons, command and control) can impact the computer configuration. The same holds true for nearly all systems except for those which are truly stand alone.

(9) <u>Estimates For Government Furnished Material May Be Deficient At The Item Level, Ship Level Or In Anticipation Of Problems At Time Of Delivery</u>

Although the eight GFM items studied in detail were developed and managed by different organizations and were in different stages of development and production, there were several common findings applicable to the majority.

- Basic hardware estimates as related to contract prices were not precise and were frequently misestimated in the order of 20 percent.
- A consistent approach to estimating items other than basic hardware (e.g., spares, manuals, services) appears to be almost totally lacking.
- Estimates generally originated with contractors or past contract prices.
- In the technical organizations, estimating usually received little emphasis.
- Procedures for estimating, maintenance of data banks including return costs and compilation of configuration data to support estimates are almost entirely lacking.
- Communications between the central estimating organization and the many GFM estimators are not adequate.
- Analysis of market factors related to GFM procurement is inadequate, particularly for competitive procurements.

Chapter VII contains several recommendations designed to correct the problems identified by these findings. There are, however, two areas of action that deserve particular notice. First, a universally adapted system for detailing, recording and maintaining estimating data is needed. Second, much greater interplay on a personal level between members of the central estimating staff and the GFM estimators in the technical organizations is needed to improve the flow of market, production and technical knowledge essential to good estimating.

- All GFM items must be considered in a total ship cost estimate -- Accurate estimates of the cost of a ship must include good estimates of the entire GFM suite. For a repeat design where no significant change in characteristics is planned and where the individual items are off-the-shelf or within the state of the art, estimating should be relatively simple. However, with a new design where equipment selection is in a state of flux and some equipment is in a development stage, estimating is difficult. These conditions are reflected in the GFM estimates for the three ships tracked in depth.

  As shown in the following table, there are changes in the estimates for the three ships which are beyond the amounts that might be expected. The reasons are discussed in the sections covering tracking of the three ships. The point to be noted here is that no matter what the status of the ship, significant variations in predicted actual costs versus original estimates do arise. Again, there must be constant communication and constant updating of configuration, test site and similar data if estimates prepared for the budget are to stand up. If configuration or plans are changed significantly after the budget submission, and the changes are not anticipated, differences as shown in the table are bound to arise.

TABLE V.49

GFM ESTIMATES
($ Thousands)

GFM Category	Estimate	AOR 7	SSN 678	FFG 7
HM&E	Original Current % change	1,605 2,190 36	3,602 3,904 8	6,790 43,243 537
Electronics	Original Current % change	860 985 14	6,922 6,611 4	8,800 10,250 16
Ordnance	Original Current % change	4,546 5,000 10	2,882 2,211 23	38,000 51,572 36

- The handling and care of material is a factor in estimating -- There have been a number of studies and reports on the problems caused by receipt of GFM either too early, too late or in defective condition. Therefore, this area was not examined in depth in this study. It is, however, an area which should be given attention by the estimating organization since the amounts of money involved can be large as shown by the following:

  - The MK-74 Guided Missile Fire Control System experienced defects causing 960 discrepancy reports on the CGN 36 and 558 discrepancy reports on the CGN 37, at a total cost to repair/replace (including material) of $1,095,095 and $418,387 respectively.

  - Unsatisfactory anchors (4) for use on the CGN 36 and 37 were reported by SupShip-Newport News on 23 May 1973. Subsequently, three other unsatisfactory anchors for use on the CGN 38 were received and reported in February 1976.

The values shown in the following tabulation represent a summary of discrepancy reports and estimated cost to correct for selected ships as of January 1975.

TABLE V.50

DISCREPANCY REPORT PROBLEMS ON SELECTED SHIPS

	Number of Discrepancy Reports	Estimated Cost to Correct
SSN 686	752	$ 599,691
CVAN 68	2,321	1,081,548
CGN 36	3,015	1,638,514
CGN 37	2,123	1,175,706

* * * * * *

Summarizing, there are areas for improvement in the development of cost estimates for Government Furnished Material. Much of this improvement can be accomplished by actions within the realm of NAVSEA by carrying out the recommendations in Chapter VII.

8. A NUMBER OF IMPORTANT ESTIMATING AND COST MANAGEMENT ISSUES HAVE SURFACED DURING THE DETAILED ANALYSIS OF SHIPS AND GFM ITEMS

In the Interim Report of this project, 39 potential cost drivers were identified and defined. As the analyses of ships, weapons and other GFM items were performed, efforts were made to keep these cost drivers in mind. The categories or areas of potential growth dealt with were as follows:

- Programming/Budgeting Factors
- Technical Definition
- Estimating
- Personnel
- Scheduling
- Contracting
- Construction
- Government Programs and Requirements

Problems exist in most of these areas.

(1) <u>The Size Of Cost Growth In Ships Correlated Roughly With The Number Of Cost Drivers Present</u>

As each ship was studied, the occurrence of these potential cost drivers was noted. Figure V.16 shows their occurrence on each ship project. If the cost driver was present, it is so indicated by an X; if the cost driver was a serious problem, it is noted by a 2X.

No percentage or finer weighting can be applied to the table, but it can be suggested that

- The greater the number of these items present, the greater the difficulty for the estimator.

- The number of cost drivers present correlate roughly with the magnitude of the overruns:

  - SSN 678 -- 20 percent growth, 4 cost dri
  - FFG 7 -- 41 percent growth, 17 cost d
  - AOR 7 -- 52 percent growth, 18 cc

Touching briefly on the reason for choosir

FIGURE V.16

INFLUENCE OF COST DRIVERS

COST DRIVER	PRESENCE OF COST DRIVERS SSN 678	FFG 7	AOR 7
Programming/Budgeting			
constraints on estimates		X	2X
unanticipated escalation		X	2X
reduced program			
program uncertainties		X	X
additional stock units			
Technical Definition			
insufficient definition		X	2X
system upgraded	2X	2X	
additional systems	X	X	X
additional specifications	2X	X	X
incorrect plans			X
late changes under contract	X	X	X
Estimating			
poor estimates			X
inadequate time to estimate			X
changed market conditions		2X	X
different overhead burden		X	
less efficient shipyard			
low productivity		X	
fewer shipyards			
retention of shipbuilding base		X	
Personnel			
management instability			
too few estimators			
estimating responsibilities diffused			2X
Scheduling			
schedules event delays		X	X
poor scheduling		X	X
late GFE/GFI			X
late CFE/CFI		X	2X
Contracting			
poor form of contract			
Construction			
technical difficulties		X	
shipbuilder's backlog			
low productivity		X	X
work stoppages			X
mismanagement			
inadequate facilities			
labor shortage			
Government Programs			
management layering			
excessive management			
excessive inspections			
social programs			
delay in government actions			
TOTALS	4	17	18

items as cost drivers, the following is submitted.

- Constraints on estimates
  - Pressure existed in the FFG program to maintain estimates at or below DTC goals.
  - Budget decisions constrained estimates during AOR 7 budgeting.
- Unanticipated escalation
  - Important at the very beginning of the FFG program, but estimates soon took high escalation into account.
  - AOR 7 escalation was used up prior to delivery and additional funds requested -- never really had a handle on escalation estimates.
- Program uncertainties
  - Uncertainties about ordnance and sensors, operational testing, cost effectiveness -- all have caused cost growth in the FFG program.
  - Uncertainties relating to characteristics (modified repeat versus new class), acceptable budget cost, completeness of prior ship drawings -- all caused growth in the AOR 7.
- Insufficient definition
  - Certain GFM characteristics were not decided upon until late in development and caused bad end cost estimates. (FFG 7)
  - Drawing and specifications of prior ships in the class were not kept up-to-date. (AOR 7)
- System upgraded
  - The SSN 678 was the first ship in the SSN 637 class to have the re-engineered hull.

- New, more capable GFM were added to FFG 7, i.e., FCS, sonar, gun, etc.

- Additional systems

  - In the SSN 678 -- AIGS III S&W, Satellite navigation, new launch console and a number of others.

  - In the FFG -- LAMPS III, CIWS, extra generator, TACTLASS, etc.

  - In the AOR 7 -- helo hangers, NATO SEA-SPARROW, improved habitability, pollution abatement and increased frozen food and ammunition capacity.

- Additional specifications

  - On all ships, additional systems and/or modified systems caused additional specifications and costs throughout the building period.

- Incorrect plans

  - As has been mentioned, the AOR 1 through 6 plans had not been kept up-to-date.

- Late changes under contract

  - HMRs were common for all three ships.

  - Plans changes for SSN 678 amounted to $9 million, for the FFG 7 about $20 million and a much smaller figure for the AOR 7.

- Inadequate time to estimate

  - AOR 7 estimates often were made under a short deadline.

- Changed market conditions

  - The FFG program office listed nine companies capable of building the ship, only two were interested; effect was to add $8 million to the cost of an average follow ship.

  - Stable economic and market conditions existed for the SSN 678, quite the opposite for the AOR 7 and FFG 7.

- Different overhead burden

  - Overhead for the shipyards building the FFGs was greater than estimated due to lack of other repair and commercial work.

- Low productivity

  - The FFG 7 and the AOR 7 can be said to have suffered from lowered productivity to a serious extent. This was due to lack of prior complex Navy construction, layoffs for lack of work, etc.

(2) <u>Serious Estimating Errors Are Being Made For New -- And As Often Follow -- Ship Designs</u>

Throughout this section, estimators have missed key elements of ship estimates.

- Man-hour estimates are almost all low by large margins. Although this may be due to productivity losses, it is usually a result of estimating from dated information. Generally, bid data or similar ship data is used. No feeling for current conditions is exhibited.

  It must also be noted that shipyards have not been much better.

- Material costs and the changing market place for key items of ship equipment were not reacted to quickly.

- Overhead cost growth was not reflected in estimates.

- Market place factors -- seller's market in 1974, smaller number of Navy shipyards demanding higher profit margins, etc. -- were not included in cost predictions.

Two fundamental problems seem important with regard to these misestimated elements:

- The planning, programming and budgeting system requires estimates so far in advance and it is so difficult to adjust estimates that the estimates become outdated quickly and do not reflect current situations.

- The estimating process must be improved significantly if it is to produce reasonable estimates in the current environment.

(3) <u>The GFM Case Histories Provide Additional Information Regarding Estimating And Cost Growth</u>

Cost estimating for GFM is, except for several recent cases studied, so varied as to not allow the chart approach to cost drivers used with the ship studies. In general, estimates are quotes from vendors with installation mark-ups added, or contract prices escalated forward but seldom is there a concerted effort to maintain control over unit costs of shipboard equipment.

Some general conclusions can be made about many GFM systems:

- There is no uniform method of estimating for GFM.
- Few data banks are maintained so that a review of past costs can be performed by Navy management or others.
- From information that can be collected, wide, unexplained variances exist in estimates made for ships. These variances have no consistency by year or by similar ships.
- Although in many systems solid technical baselines exist, estimating and cost control personnel are not required to take advantage of this situation to improve estimating performance.
- Installation add-ons seem to have no particular relationship; except in a few cases no return costs are required or utilized.
- Although weapons and sensors are being estimated for SCN appropriations, many have R&D quality baselines making it difficult, if not impossible to estimate for the weapon or sensor to which they are applied. All GFM gets the same handling.

All these points apply to a number of GFM items -- irrespective of cost. The more expensive items (over $4 million) are handled similarly to cheaper items (less than $1 million).

Some GFM procurements studied stand out as well managed, and cost conscious efforts.

- The procurement of the LM-2500, although estimates are relatively high, shows normal cost patterns, and adequate data would seem to be available.

- The CIWS project exhibits particular cost consciousness and much effort is placed in preparing accurate projections and managing to a cost target.

Recent steps taken by NAVSEA 01G provide some prospect for improvement, but much more should be done to estimate and control the procurement of GFM which amounts (over the last eight years) to $7.015 billion.

VI NAVY COST ESTIMATING IN A NEW PERSPECTIVE

VI NAVY COST ESTIMATING IN A NEW PERSPECTIVE

It has been noted that over the last two decades, there were periods of relative stability in the economic environment, the shipbuilding industry and in Navy programs themselves. During the 1970's, however, that stability has been replaced by a period during which many problems came to a head all at the same time.

- Productivity in shipbuilding was lowered severely as a result of demand instability, social legislation, lessening worker job interest, and the effects of changing ownership of the shipyards.
- Severe inflation which offected labor and material costs.
- Market place adjustments where the number of companies building Naval and large commercial ships became fewer in number, thereby tending to increase profit demands and bid prices -- and generally complicating the relationship between owners and builders.
- New engineering complexities of ships which caused schedule delays, re-engineering and more difficult ship integration and outfitting.
- Increased importance of cost management due to decreasing budgets for shipbuilding which required more accurate estimating and new emphasis on project cost control.

The estimator, during periods of instability and confusing relationships, becomes a key element in the management process. The professional expertise of the estimator in making reasonable predictions about the future becomes much more important to successful programs than in stable times when less estimating skill and judgment is required.

It is the responsibility of the professional estimator to keep abreast of economic conditions and be aware of trends which influence his predictions. It is also the responsibility of the estimator to develop the estimating capability appropriate to the difficulties of the task. Evidence would appear that NAVSEA has not yet prepared itself to develop this improved capability.

It has also been mentioned that the aberrations of the 1970's are unusual and perhaps this is the first time in recent history when so many problems "hit" Navy shipbuilding programs all at once.

Even in more normal times, however, cost estimating and management has been a problem. Table VI.1 illustrates that in the early post World War II period cost growth was even then a concern to the Navy and Congress. During this period, new technologies such as nuclear propulsion, guided missiles and extensive use of electronics were being developed for shipboard use. It would seem that since then, the complexity of construction has caused continual problems related to cost estimating.

TABLE VI.1

COSTS OF 1952 - 1960 SHIPBUILDING PROGRAMS
(Dollars in Millions)

Program Year	Original Estimate	1961 Budget or End Cost Estimate	End Cost vs. Original Difference	Percent Growth
1952	1,786.5	1,921.3	134.8	7.5
1953	644.5	694.1	49.6	7.7
1954	547.6	529.8	(17.8)	(3.3)
1955	824.8	888.9	64.1	7.8
1956	1,253.8	1,476.7	222.9	17.8
1957	1,357.9	2,177.6	819.7	60.4
1958	1,351.2	1,752.6	401.4	29.7
1959	1,738.3	2,050.5	312.2	18.0
1960	593.4	670.0	76.6	12.9
Total SCN	10,098.0	12,161.5	2,063.5	20.4

SOURCE: BUSHIPS Comptroller Division Report -- The End Cost of Shipbuilding Budgeting, dated 15 January 1960

This would seem to indicate that a general improvement in the Navy's capability to predict program costs has been needed for a long time. The current problems have exaggerated a more general condition.

A professional group which could handle the complexities of Navy estimating would require, as a mimimum, the following characteristics:

- Strong management which could rationalize a cost estimating methodology that would have the greatest opportunity of meeting modern estimating problems and around which an efficient organization could be built.

- An organization with enough "reach" so that close affiliation could be built up between the estimators and project personnel, between estimators and industry components, and between estimators and the ship and weapon engineering community.

- The availability of modern systems and procedures which would allow the storage and retrieval of large amounts of engineering, economic and industrial data; the models or systems that would allow quick response to estimating tasks and would allow learning from past errors and successes.

- Enough influence and authority to require proper product definition and to enforce the strict classification of estimates as indicators of risk and confidence.

- An overall impact and importance to NAVSEA top management that would make the estimating process vital in the management of shipbuilding.

- Sufficient resources in staff and funding to carry out assigned responsibilities.

This places a new importance on the estimating process and provides a new perspective or context in which to consider improvements in Navy estimating.

This general approach differs somewhat from the approach taken by a number of studies undertaken in the past and is also different, at least in degree, from criticism by various sources leveled at the Navy over the last few years.

1. SOME TWENTY STUDIES PERFORMED OVER THE LAST FORTY YEARS HAVE MADE REFERENCE TO ESTIMATING PERFORMANCE

A total of 20 significant studies have been examined and synthesized during this project. The earliest study examined was performed in 1939; the latest was dated 1977. Most of the studies cover the past ten years during which period the most serious cost aberrations and overruns have taken place. Table VI.2 lists the studies reviewed to assess the impact of past recommendations and their specific applicability to cost estimating.

All these acquisition studies and reports relate directly or indirectly to estimating. A commonality in particular phases of the estimating process runs through each study, even though greater emphasis may be placed on organization, management and other aspects of acquisition . Many of the recommendations and suggestions have been implemented, while others for various reasons have either not been implemented or only implemented in part.

The majority of studies have been undertaken by various components of the Department of Defense, its consultants and the General Accounting Office (GAO). A great perception of the overall problem is evident although only limited exploration of the basic cost estimating process has been undertaken. Many cost drivers have been identified and a few of the reports recognize the unpredictable pitfalls facing estimators which can only be reduced by an adequate estimating base.

TABLE VI.2

CHRONOLOGICAL LIST OF ACQUISITION STUDIES

Date	Title	Source
09/21/39	Cost of Naval Ships	Bureau of S and A to SECNAV
12/01/67	New Construction Cost of Major Warships	Chief, Naval Operations (Holloway)
01/30/69	An Evaluation of the Effectiveness of the Ship Procurement Study	NAVSHIPS Procurement Review Group (Sanders-Scanlon)
02/10/69	Study of Economic Factors Applicable to Shipbuilding	Center for Naval Analyses
04/10/69	Survey of Government and Industry Cost Estimating and Cost Control	Booz-Allen
04/69	SCN Pricing and Control Sutdy	Chief, Naval Material
07/01/70	Blue Ribbon Defense Panel	President and Secretary of Defense
09/05/70	Review of Estimating Techniques within Department of Defense	ASPR Pricing Subcommittee
09/21/70	Organizational Problems in SCN Procurement Systems	Center for Naval Analyses
06/10/71	Command Inspection of Naval Ship Systems Command Headquarters	CNM
07/72	Shipbuilding and Conversion Improvement Program (SCIP)	CNO
07/17/72	Acquisition of Major Weapon Systems -- Department of Defense	GAO
07/24/72	Theory and Practice of Cost Estimating for Major Acquisitions in Department of Defense	GAO
12/72	Report of the Commission on Government Procurement	Industry - Government (Public Law 91-129)
03/73	Study of Cost Escalation	Department of Defense
10/22/74	Discussion of Navy Shipbuilding Industry Business Relationships	Shipbuilders Council of America
01/75	Report of the Navy-Marine Corp Acquisition Review Committee (NMARC)	SECNAV
04/11/75	Financial Management Planning Group Inflation Study	ASN
09/30/75	Report of the Acquisition Advisory Group to Deputy Secretary of Defense	Deputy Secretary of Defense
01/18/77	Financial Status of Major Acquisitions as of June 30, 1976 (covering all major, fully or partially Government funded programs)	GAO

A few of the studies have been developed with the participation of industry. The Commission on Government Procurement Report (1972), Blue Ribbon Defense Panel Report (1970) and the Navy and Marine Corps Acquisition Review Committee Report (1975) are examples. The Commission on Government Procurement covers government-wide acquisition programs. Its basic emphasis is on the entire process including research and development, major systems, commercial products, engineering services, Federal grant programs, liabilities, patents and administration. The report states the following with regard to estimating:

> "Because of the repeated pattern of major cost increases in system acquisitions, many people have concluded that there is need for better cost estimating and better risk analysis. However, improved estimating techniques can bring only relatively small improvements. About 15 percent of cost growth in major programs during the 1960's can be attributed to the inherent imprecision of present cost estimating procedures. Better cost control will come only if fundamental changes are made in the way systems are refined and chosen early in the acquisition process; these steps largely determine ultimate cost and performance."

The Blue Ribbon Defense Panel Report is heavily oriented in DOD organization, but it has a few pertinent findings on cost estimating and contracting, the highlights of which are:

- The accuracy of cost estimates for acquisition programs has been widely overrated. It should be axiomatic that one cannot place a price on any program containing unknowns.

- Contractor eagerness to sell long-term acquisition programs influences low-side cost estimates.

- Contracting policies and procedures have a tendency to support the level of proposed cost estimates.

- Competitive pressures of concept formulation/contract definition have led to over-optimistic cost estimates for acquisition and not permitted a hard look at inherent pricing uncertainties. Parametric cost estimating techniques offer the potential for improved planning of cost factors.

- The lack of cost data base information for prior programs limits the accuracy of cost predictions for current ones.

- Original cost estimates should be considered only as baselines and should be revised and updated across the system or equipment life cycle.

The Navy and Marine Corps Acquisition Review Committee Report (1975) is the most complete of those recently undertaken. There were a total of 254 recommendations made, of which 29 had some direct or indirect application to the estimating process. The Report states:

> "Existing Navy cost estimating staffs are professional, competent and produce better estimates than they are generally given credit for. However, they are under-staffed in relation to their workload and are frequently required to develop estimates to a very tight schedule on the basis of very limited data. To ensure the integrity, completeness, and currency of cost estimates, it is necessary that the cost estimating groups in the Naval Sea Systems Command be given adequate manpower and improved information and that the cost data be given to the NSARC."

As a result of reviewing these studies, a total of 14 estimating factors were selected as being common to all. The commonality of the various acquisition recommendations and areas of greatest concern to those involved in developing the many findings are best demonstrated through a matrix of the studies as shown in Table VI.3. The Table identifies aspects of the estimating process that were of greatest concern to those involved in developing the many acquisition study findings. For example, there was considerable agreement on the need for a clear "Technical Definition" of the system to be estimated. Heavy emphasis was also placed on the need for a complete data bank, as well as the economics of shipbuilding which are very basic tools in the estimating process.

Many of the findings in the past studies, for example Bureau of Supplies and Accounts "Cost of Naval Ships" study completed in 1939, are essentially valid today. While some of the recommendations in each study have been implemented, particularly those which can be accomplished at the operating level, many recommendations requiring significant changes in the acquisition process at higher management levels are more difficult.

Each of the 14 estimating factors listed in Table VI.3 have been analyzed and discussed in terms of the past study recommendations in Appendix B of this report. Each analysis includes a brief definition of an estimating factor, a discussion of its importance and its application in the current

TABLE VI.3

SUMMARY OF MAJOR ACQUISITION STUDY RECOMMENDATIONS RELATED DIRECTLY OR INDIRECTLY TO THE ESTIMATING PROCESS

Major Acquisition Study Title / Source Of Study	Date of Study	Estimating Considerations													
		Technical Definition	Data Banks	Staff Resources	Staff Training	Reserves	Economics of Shipbuilding	Documentation	Review and Authentication	Realistic Construction Schd.	Related Costing Functions	Centralized Estimating	Classification of Estimates	Budgeting Process	Cost Management Control
Cost of Naval Ships (Bureau Sand A to SECNAV)	09-21-39	X	X				X								X
New Construction Cost of Major Warship (Chief, Naval Operations - Holloway)	12-01-67	X	X	X		X				X	X	X		X	X
Evaluation of the Effectiveness of Ship Procurement Study (NAVSHPS Procurement Review Group - Scanlon)	01-30-69	X	X			X	X			X				X	X
Study of Economic Factors Applicable to Shipbuilding (Center of Naval Analysis)	02-10-69	X	X	X			X								
Survey of Government and Industry Estimating and Cost Control (Booz - Allen)	04-10-69	X	X	X					X						
SCN Pricing and Control Study (Chief, Naval Material)	04-69	X	X	X			X			X			X	X	
Blue Ribbon Defense Panel (President and Secretary of Defense)	07-31-70		X	X	X		X						X	X	
Review of Estimating Techniques Within DOD (ASPR Pricing Subcommittee)	09-05-70	X	X			X	X		X				X		X
Organizational Problems in SCN Procurement Systems (Center for Naval Analysis)	09-21-70		X												
Command Inspection of Naval Ship Systems Command Headquarters (Chief, Naval Material)	05-10-71				X	X						X	X		X
Shipbuilding and Conversion Improvement Program (SCID) (Chief, Naval Operations)	07-72	X				X	X								
Acquisition of Major Weapon Systems - DOD (GAO)	07-17-72	X	X				X	X	X						
Theory and Practice of Cost Estimating For Major Acquisitions in DOD (GAO)	07-24-72		X				X	X	X						
Report of the Commission on Government Procurement (Industry - Govt. Public Law 91-129)	12-72	X								X					
Study of Cost Escalation (DOD)	03-73	X	X				X			X					
Discussion of Navy Shipbuilding Industry Business Relationships (Shipbuilders Council of America)	10-22-74	X	X				X								
Report of the Navy-Marine Corp Acquisition Review Committee (NMARC) (SECNAV)	01-75	X	X	X		X	X	X	X	X	X	X	X	X	X
Financial Inflation Management Planning Group Study (ASN)	04-11-75		X			X								X	X
Report of the Acquisition Advisory Group to Secretary of Defense (Deputy Secretary of Defense)	09-30-75					X	X	X						X	X
Financial Status of Major Acquisitions as of June 30, 1976 (GAO)	01-18-77		X			X			X					X	
IMA RECOMMENDATION CATEGORIES	10-77	X	Ⓧ	X	X	X	X	X	Ⓧ	X	X	X	X	Ⓧ	X

NOTE: (1) Those marked Ⓧ are of special significance in the estimating process estimating procedure. Finally, conclusions are offered indicating to what degree the present NAVSEA estimating practices follow the more important study recommendations and what improvements, if any, are believed necessary. Highlights of the conclusions are as follows:

- Technical Definition -- A sufficient definition of the system or ship should be required.
- Data Bank -- A continuing system of updating and upgrading estimating data banks should be developed.
- Staff Resources -- Additional staffing with experienced personnel is required to meet the many estimating, budgeting and analysis requirements.
- Staff Training -- A training program exists which should be supplemented with additional on-site field assignments for which sufficient funds should be provided.
- Reserves -- With unpredictable cost trends continuing, sufficient margins and reserves should be provided. This is especially true where less than class "C" estimates are provided.
- Economics of Industry-- Acquisition of current industry economic information including that from shipyards, SupShips and Navy auditors should be accelerated.
- Documentation -- This is currently required in NAVSEA but it is not always being accomplished and the importance of developing and maintaining these records to cover each phase of the ship system and GFM estimating process cannot be over-emphasized.
- Review and Authentication -- Higher level reviews of budget estimates are lacking and should be established.

- Realistic Construction Schedules -- Due to the importance of developing realistic construction award and completion schedules, improvements in predicting correct schedules are required. Failing this, greater funding margins should be provided for contingencies.

- Related Costing Functions -- Compliance with existing directives is not being met due to time and staff limitations. This condition may be improved by assignment of selective cost related functions to other groups or by staff increases within NAVSEA 01G.

- Centralized Estimating -- This responsibility within NAVSEA and the delegation of NAVSEA 01G as the focal point for all estimates has been complied with.

- Classification of Estimates -- An estimate classification system has been established since 1969 and is in use, but needs a more stringent criteria for budget quality estimates.

- Budgeting Process -- Despite the complications and politics common to acquisition programs, the budgeting process must reflect professional estimates within which the programs may be successfully completed with a minimum risk of claims or budget overruns.

- Cost Control Management -- There is no continuing flow of program cost information into NAVSEA 01G. It is developed on an ad hoc basis when necessary for preparing certain estimates.

As has been shown, several reports recognize the vagaries of the estimating process, and further indicate that estimating is often not the direct cause of overruns. The GAO Report of January 18, 1977 on Financial Status of Major Acquisitions as of June 30, 1976 (covering all major fully or partially Government funded programs) indicates that only six percent of the $150.9 billion overrun of 201 civil and defense acquisition programs (with total original value of $249.6 billion) is attributed to estimating. The balance is due to quantity changes, engineering, support, schedules, economic changes, and sundry such as environmental costs.

A study group in the Office of the Assistant Secretary of the Navy (Installation and Logistics) has been established and, with the assistance of a private contractor, is currently addressing all problems brought forth by the U. S. shipbuilding industry. The purpose of the study is to improve Navy-industry management practices and business relationships, with the goal of avoiding future claims.

The initial phase will document the various views and problems of the industry as already indicated through the many past studies relating to Navy acquisition problems. The study group will also review and document the views of the Navy on what has been done, is being done and could be accomplished to improve the general business environment. After completion of the preliminary findings, a series of meetings are planned with industry in an attempt to resolve many of the controversial issues.

This is an indication of the general desire to improve the situation and arrive at a stronger position with regard to predicting program costs and controlling cost growth. Nothing in these 20 some reports conflicts with this report's conclusion that the estimating process requires a re-thinking -- a new perspective. One thing that does come through is that a patchwork approach to improving the cost management process will not solve the problem. A few recommendations here and there, a new study, more people, etc., will not suffice; a plan of action is required which is a generalized attack on the problem.

2. CRITICISM OF NAVY SHIPBUILDING HAS BEEN DIRECTED AT AN ALLEGED DETERIORATING CAPABILITY TO CONSTRUCT SHIPS REQUIRED FOR THE NATIONAL DEFENSE

The focal point of the current criticism is the annual Congressional review of the budget. At this forum, Navy, OSD, industry and Congressional points of view are presented -- usually with lively debate on all sides.

The Congress believes that

- The Navy cannot derive a long range building program that corresponds to a well-thoughtout defense strategy.
- The absence of this strategy causes short term instability with all sorts of fallout such as incomplete engineering of ships placed in the budget, faulty estimates, overruns, etc.
- The Navy has lost its ability to manage complicated programs and management should be improved from top levels down to SupShips.

- The Navy does not take seriously its responsibility to estimate realistically and work to control costs through strict project discipline.

Other government and industry organizations, the President, OSD and the industry have voiced similar criticisms which vary in degree but not substance. Some of the most frequently voiced are:

- Combatant surface ships were being included in the Navy budget with incomplete plans, specifications and analysis.
- Slippages due in part to unrealistic delivery dates.
- Lengthy change order approval process.
- Unrefined cost estimates are submitted as budget class estimates.
- Instability in yearly shipbuilding programs impedes shipyard modernization.
- Navy decision-making process is too complex and lengthy.
- Adversarial relationships are prevalent mainly in nuclear areas, but also in conventional yards.

Table VI.4 summarizes the criticism examined which shows a high degree of similarity.

TABLE VI.4

SUMMARY OF RECENT CRITICISM OF NAVY SHIPBUILDING

CRITICISM	CRITICS			
	Congress	Executive	Shipbuilder	In House
Low budget estimate/Under funding	X	X	X	X
Unrealistic delivery estimates	X	X		
Program Instability	X	X	X	X
Unrealistic shipbuilder productivity estimates	X	X		
Excessive government changes	X	X	X	
Inadequate technical definition	X	X	X	
Faulty specifications	X	X	X	
Late and faulty GFM/GFI	X	X	X	X
Excessive Gov't. mgm't. requirements	X	X	X	X
Late specification changes	X		X	X
Excessive management turnover	X	X	X	
Excessive management layering	X	X	X	X
Excessive claims	X	X	X	X
Inflexible contracting methods		X	X	X

3. THE SOLUTION TO THE COST ESTIMATING AND COST MANAGEMENT PROBLEM DOES NOT INVOLVE NAVSEA ALONE

This study has concentrated on NAVSEA and its capabilities in the estimating area. Recommendations will be made in this study which are believed to provide the basis for a complete overhaul of the estimating process, not just a "band-aid" or "finger in the dike". It is believed that a rethinking of the process and implementation of a specific plan of action will provide an increased capability which will provide a higher level of estimating performance and ability to contribute more successfully in the management of ship and weapons acquisition within NAVSEA.

This increased capability and performance, however, must also be accompanied by improvements outside of NAVSEA. A lack of planning and budgeting discipline, lack of and changing technical definition, all can cause even improved estimates to be unreliable.

VII RECOMMENDED COURSE OF ACTION

VII RECOMMENDED COURSE OF ACTION

Each preceding chapter in this report has pointed to problems which have, over the years, been a deterrent to quality estimating performance. Over 50 specific problems have been addressed and substantiated in a number of different contexts. Some of these are of more serious consequence than others, but all should, in some way, be recognized and solutions developed.

These may not be the only problems, of course, but since they are contributors to cost growth and bear on estimating, solutions should bring about improvements. This chapter will summarize these problems and suggest steps which can be taken to bring about higher quality performance in the future.

1. THE NAVSEA COST ESTIMATING ORGANIZATION MUST BE CAPABLE OF DEALING WITH A WIDE RANGE OF COMPLEX PROBLEMS AND PRODUCING RELIABLE ESTIMATES

An estimating group is expected to deal with a variety of current and potential problems which may have an impact on predictions about the future. Further, it is in the nature of things that these problems will, in some form or another, remain and be continuing elements in the estimating equation. The key point here is that a credible estimating organization must have capability appropriate to the numbers and complexities of the problems, and that it rationalize the entire estimating process so that it can cope with the environment in which it exists. To accomplish its objective, an estimating organization must produce reliable results regardless of the situation and remain adaptable to changing environments.

(1) Many Of The Problem Areas Identified In This Study Are Outside The Direct Control Of The NAVSEA Estimating Division

NAVSEA estimators should be equipped to recognize, understand and adjust for problems of three general types which are outside their immediate sphere of control: Industrial and Economic Problems, Administrative and Political Problems and finally, Engineering and Construction Problems.

- Economic and industrial problems were discussed primarily in Chapter II and can be summarized as follows.

  - Subsequent to World War II, an increasing number of technologies have evolved which have had a revolutionary affect on naval shipbuilding.

  - Naval shipbuilding, as with some highly technological commercial ships, has become a highly complex engineering and construction activity.

  - Material and labor inflation has grown phenomenally and unpredictably at times over the past decade.

- The real cost to industry of social legislation is being felt in a number of ways but chiefly in increased overhead costs and reduced productivity.

- Contributing also to increased overhead cost and lowered productivity is a changed work ethic which appears to be subtle, but pervasive.

- A change in management objectives related to the shipbuilding industry and considerable management turnover have been brought about by conglomerate ownership of the shipyards.

- A reduction in the number of shipyards capable and/or interested in building complex naval ships.

- Shortages of skilled labor and a high turnover in labor at all levels have also been a cause of lowered productivity.

- Employee fringe benefit costs have been increasing at almost double the rate of direct labor earnings.

Most or all of these problems have contributed to a reduction in shipbuilding productivity, unforeseen material and labor increases, rising overhead cost and a general uncertainty as to how these factors relate to cost estimating and control.

• Administrative and political problems were mentioned as part of Chapters III and V.

- There is evidence that the planning process could be improved to provide less year-to-year changes in the five year shipbuilding program and thereby provide a more stable environment to accomplish necessary engineering activities for desired ship programs.

- More stable program planning and the resultant increased time available for engineering would allow estimate build-ups over longer periods of time based on fundamentals -- not generalities.

- The planning, programming and budgeting process in which estimates are made often requires that estimates be prepared in short periods of time which do not allow thoughtful consideration of issues.

- The planning, programming and budgeting process which requires estimates to be prepared 27 months in advance obviously does not foster precision estimates in a fast-paced economic environment.

- Administrative delays cause award dates to be different than those planned in the budget submission thereby causing apparent cost growth.

- The budgeting system requires that estimates remain accurate over a long period of time-- sometimes five to ten years -- with little allowance for margins reflecting the uncertainty inherent in such estimates.

- Although estimates are coded to reflect the degree of risk associated with the prediction, users on all levels often dismiss its significance or override its purpose.

- Once an estimate is submitted for a particular ship or program, a greatly modified ship from the point of view of characteristics is often built which, although advantageous in terms of military capability, precludes the accuracy of a previous estimate.

- The budgeting process from NAVSEA on up to Congress is frequently a political process -- both literally and figuratively -- in which funds are withheld, allocated and re-allocated with what appears to be little regard for the rationale behind the original program estimates. This process also results in changing the number of ships and therefore the cost and also in pushing programs into different building periods thus changing the escalation characteristics of the estimates.

- The policy with regard to inflation-related estimate elements is often treated as a political tool rather than a realistic measure of expectations.

All of the problems in this general area lead to cost growth in one way or another and this occurs whether the original estimates are good or bad.

- Engineering and construction problems are mentioned in various sections of the report.

  - Rapidly advancing technology introduces uncertainty into the estimating process due to the complexity of engineering and greater numbers of stumbling blocks.

  - The planning of the acquisition and engineering process by program sponsors and other operations-oriented managers has often resulted in insufficient time being allowed to accomplish fundamental engineering or system documentation. Further, a general absence of development standardization is apparent.

  - Engineering changes are a way of life due to emphasis on characteristics changes to achieve increased military performance but prediction of end cost under these circumstances becomes extremely difficult.

  - The Navy does not seem motivated to manage to the budget figure during engineering and construction phases.

- Schedules and commitments which start out displaying "healthy" optimism often result in construction delays causing substantial cost growth.

- Each program office is allowed the freedom to work relatively independently, thereby causing a lack of standard procedure.

These kind of problems create communication breakdowns and a set of circumstances which provide weak fundamentals on which to base predictions.

Earlier comments in this report have suggested that two fundamental situations must be recognized:

- First, about one-half of total program cost growth can be associated with economic and industrial factors which are outside the control of government departments.

- Second, the remaining portion of total program cost growth can be associated with problems within the control of the Navy or other government departments. These have been represented under the Administrative/Political and Engineering /Construction captions above.

The point here is that cost growth will occur despite any improvements in NAVSEA estimating unless specific action to eliminate or reduce the affect of these problems takes place.

(2) NAVSEA Planning Must Be Based On The Assumption That These Problems Will Continue To Exist

There are a number of improvements that NAVSEA can make which will be noted later in this chapter. The improvements suggested are based on a recognition that the aforementioned problems will continue to exist and be the environment in which the estimating process must function.

The economic and industrial problems will remain a challenge to accurate estimates in the future. In this area also, crystal balls are usually cloudy. Respected economists, for example, are difficult to pin down on long range trends. It takes unusual estimating capability to be continually on target in this area.

The political nature of programming and budgeting and the interaction of the Navy with OSD, OMB and Congress will, in the same sense, continue as before. This is not a "given" in the same sense as the economic and industrial problems, but national attitudes, the pressures of redistributing and managing national resources, and the nature of large organizations themselves would make a dramatic change in NAVSEA's favor seem rather remote.

Similarly, Navy management problems are a response to a complex set of situations and constraints that are deep-seated and not capable of rapid change. The alleged problems of cost growth and less than efficient management are the effects of a large set of problems which may or may not be solved.

Whatever capability is established must work within the constaints set up by these problems.

(3) Over The Years (And Currently) The Cost Estimating Capability Of NAVSEA Generally Has Not Been Equal To The Problems Confronted

In judging the performance of NAVSEA, the most important criterian against which performance must be evaluated is the general reliability of the product over a period of time. In periods when problems are small in scale, the NAVSEA estimating group may have sufficient capability to produce reliable estimates whereas in periods when problems are of serious magnitude, significant capability to produce the same result is required.

The limiting factor is, of course, the attitude of Navy management toward cost prediction and cost management functions and the allocation of resources when appropriate to maintain proper estimating capability. Ideas have been suggested over the years to improve the estimating process and some of these have been implemented -- especially in the cost analysis area. The inability, however, to support similar improvements in the cost estimating area have caused a situation where less than reliable performance often occurs.

A few examples that were pointed out in this study are:

- A persistent problem in predicting "basic construction"-- the price of a ship construction contract.
- A general lack of consistency in predicting the installed cost of Government Furnished Material.
- Difficulty in adequately forecasting market trends in a relatively small yet complex industry.
- Lack of fundamental estimating skills such as prediction of manhours, labor rates, material costs, overhead, building periods, etc.

These examples are symptomatic of a general lack of appropriate capability given the large scale of problems faced and the increasing importance of the NAVSEA estimator to the entire Navy program.

(4) <u>The Remainder Of The Problems Identified In This Report Relate Directly To The Current Capability Of The NAVSEA Estimating Group</u>

A group of problems have been pointed out in several sections of the report that relate to the estimating organization, methodology and procedures of NAVSEA.

- There are about 50 organizations contriubting to cost estimating with no unifying methodology or standards controlling their separate products.

- Estimating staff has not grown in numbers, expertise and experience in proportion to the growth of economic, industrial, engineering and administrative problems. There are also critical gaps in experience levels, i.e., shipyard experience.

- Estimating is being done in a highly aggregated format regardless of the stage of engineering development or other program information available.

- There are no predictable tendencies to GFM overruns or underruns and little documentation exists which indicates concern about this problem.

- Little evidence has been uncovered of an effort to utilize data processing systems to manage the large amounts of information to which estimating professionals must refer.

- Efforts have been lacking to collect and utilize information from project offices, field installations, contractors or other industry groups which would assure that all necessary facts were being uncovered and trends were being recognized.

- No evidence exists that return costs of ships under construction or from complete ships has been utilized to improve estimates being prepared or to perform post mortum analyses to improve overall capability.

- Generalized cost estimating relationships are sometimes used when the facts of individual situations would produce better results.

- The definition of what budget quality estimates should represent is unclear and presently is not based on sufficiently high standards.

- Due to current problems and staffing deficiencies, estimating management has not been able to supply adequate direction -- both from a methodological point of view and in day-to-day operations.

- No data banks exist which deal with economic and industrial conditions in the industries constructing government furnished material. Escalation errors are a result of this gap in information.

- Presently, special cost related studies (e.g., life cycle costing, should cost, design-to-cost goals, etc.) are relegated to a secondary priority.

- Building periods are often miscalculated thereby causing a fundamental estimating assumption to be incorrect.

These are problems which are apparent in reviewing the case histories, the detailed analysis of FY 1975 and FY 1976 estimate preparation, the organizational study done within NAVSEA and finally, by comparison to the good points of other estimating organizations researched.

*   *   *   *   *

In light of these findings it would appear desireable for NAVSEA to take steps to correct those problems within its control. This would greatly improve its ability to cope with the other sets of problems mentioned which are not under its control. As well documented and reliable estimating performance evolves over future months and years, the responsibility for implementation to that budget becomes clearer and can be shared by a larger number of participants in the process. Once NAVSEA has improved its own capability, the "ball is in the other court", so to speak, and the responsibility for actions related to the budget becomes the responsibility of others.

2. <u>THE PROBLEMS CHARACTERIZING THE CURRENT COST ESTIMATING SITUATION CAN BE SOLVED AND FINANCED WITHIN REASONABLE RESOURCE CONSTRAINTS</u>

Over the course of this study recommendations regarding estimating improvements have been developed and will be discussed in this section. The recommendations address the fundamentals of estimating and cost analysis and can become a framework for considerable improvement in estimating performance. The suggestions are based on two premises:

- Resources should be invested in staff and other systems after a thorough examination of an overall estimating procedure.
- Once the procedure is formalized, it should be documented, staff employed and systems developed which will complement and be supportive of the improved procedures.

In this way, an estimating and analysis organization can be developed which is appropriate to the problems at hand and which will make the best use of resources invested.

An estimating group is similar to other organizations in that it has a set of objectives which support the basic objectives of the organization of which it is a part. In some cases, the performance of these objectives is accomplished in a rather casual manner, in others in a more disciplined manner. In an estimating division such as NAVSEA 01G, the latter approach is the more desirable due to the nature and criticality of the product. It is necessary, therefore, that plans for improvement follow a rationale which will assure that proper results will be forthcoming.

The first recommendations address the problems of cost estimating in NAVSEA directly. Later in this chapter, suggestions are provided for organizations outside of NAVSEA since many of these organizations directly impact on the results of estimating. The plan of action, then, starts with substantive improvement of estimating within NAVSEA and ends with ideas NAVSEA can provide other groups to share in estimate improvement.

RECOMMENDATION 1: A General Strengthening Of The Cost Estimating Process Is Necessary

The problems identified in the previous section with regard to cost estimating are serious and require appropriate remedies. The general strengthening of estimating capability should include the following improvements.

- The organization's ability to seek out and understand important information bearing on estimate preparation should be improved.

  - This involves the periodic, short-term assignment of NAVSEA personnel to project offices, field installations, contractors, etc., to collect background data from "where the action is".

- It involves the tasking of field or project personnel for specific estimate-related tasks in support of particular estimating problems.

- It involves the proper use of bid data, returned costs for ships being built and completed, and other information that might be supplied by the Navy Audit Service, DCAA, Contract Office, etc. Proper information is so vital to estimating performance that it should be made available with little or no restriction.

• A system should be designed which would allow estimates to be prepared in more detail which would provide consistency and standardization.

- This would include the conceptualization of a Work Breakdown System on several levels that would be applicable for all ships and items of government furnished material.

- It would include proper hardware to store large amounts of data, process the data and provide appropriate response times for current estimating demands.

- It would provide estimate documentation and back-up support in an organized and retrievable manner.

Such a system would provide not only the processing capability but a discipline which is necessary in technically-oriented organizations.

• A staffing plan should be developed which would provide an experience level and numbers of personnel appropriate to current demands.

- This would include a set of professional standards appropriate to shipbuilding expertise, economic and industrial research, information processing, operations research and other professional skills as necessary.

- It would include a training program for new employees and continued education for established employees.

RECOMMENDATION 2: The Cost Estimating Staff Should Be Closely Associated With The Ship Production Staff, And Should Be Given Greater Organizational Prominence

A critical assumption made in estimate preparation is the period during which the ship is to be built. An erroneous assumption, as has been shown, can greatly influence an estimate. It is also apparent that research done in support of ship production activities keeps staff in touch with shipyard workloads and the character of the market place. This kind of information is a must for estimate preparation and analysis of industrial factors. In view of these benefits it would serve the best interest of both groups to be managed with a single organizational head.

It is recommended that this consolidation of the estimating and scheduling organization be undertaken without delay. The consolidated group should be placed organizationally such that communications with key acquisition personnel is facilitated and independent judgment is assured.

RECOMMENDATION 3: A Procedure Should Be Instituted That Requires Periodic Auditing And "Post Mortem" Reviews Of Estimates

An independent review of selected estimates is a healthy management technique. This review should be done within NAVSEA and to some extent within the cost estimating organization itself. This kind of review corrects honest mistakes, occasional sloppiness and produces corrective action over the long term to improve performance. It would include as a minimum:

- A periodic, surprise audit of selected estimates by either top level NAVSEA personnel or contractors hired for such a task.
- A scheduled analysis of important ship and GFM estimates should be performed by the cost estimating organization itself. The lessons learned should be worked into the ongoing estimating group training program.
- These analyses should include research as to the accuracy of estimate classification, economic indices, building periods, productivity, overhead and other industrial trends, etc.

These audits and post mortems would assure NAVSEA that estimates were reasonable and that procedures were in effect which would foster long term improvement.

Independent estimates or audits outside of NAVSEA such as estimates for DSARC reviews by OP 96 should remain and perhaps be strengthened. Since the information base for these independent estimates comes from NAVSEA, however, their contribution to consistently reliable estimates is minimal -- especially if NAVSEA takes the steps mentioned.

RECOMMENDATION 4: A Substantial Continuing Effort Should Be Made To Keep Abreast Of The Impact Of Changes In Shipyard Productivity, Overhead Costs And Other Important Estimating Elements

This study has shown that rapid changes in shipyard productivity have taken place that have not been predicted by either Navy or shipyard estimators. The result has been poor estimates and unpredicted cost growth. The special study on productivity prepared for this report shows that very little has been done by either the Navy or the shipbuilding industry to quantify the effect of factors that determine productivity.

The review of estimating performance has demonstrated the difficulty in estimating other key elements such as overhead costs, material and labor inflation; New information collected (per Recommendations 1 and 3) should be utilized to systematically analyze and keep current on these subjects. These analyses should include but not be limited to quantifying the effect of social legislation, the changing work ethic, ownership and management changes, series production, etc.

RECOMMENDATION 5: The Concept Of Estimate Classification Should Be Redefined And A Supporting System Of Estimate Preparation Established

Currently, estimates are prepared in a highly aggregated manner whether engineering and project information exists in detail or not. A better approach would be for estimates to parallel (in detail and precision)engineering and project information that evolves during the acquisition process. Assuming proper estimating and processing tools, it would be possible to have a cost model of each ship, weapon, sensor or other item of GFM. The model would develop gradually from a generalized base to a more detailed, accurate model based on returned costs during the production phase. The product of any model could be combined, it is assumed, with other ship or GFM models to build up a total ship estimate.

The system of estimate classification, then, should be structured to keep pace with the degree of definition present in the model at any particular time. The overall degree of definition for a ship would be the result of adding up and weighting the various risk estimates for major ship-related elements -- weapons, industrial factors, etc. Estimate precision, a well-reasoned estimate rationale and back-up information would be introduced in this way. Several important situations would follow naturally.

- A budget estimate would be redefined to include a degree of detail and documentation that would include:

  - Completion of preliminary design or its equivalent in terms of acquisition system standards.

  - Weight estimates in three digit breakdown for each system.

  - Complete equipment list and values for items with values exceeding $10,000 or $25,000, depending on total ship cost.

  - Signed Top Level Requirement by CNO.

  - An industry capacity analysis to set realistic contract award and delivery dates.

- Regardless of the purpose for which an estimate is prepared, it should identify in a formal manner the origin of the request, time and other constraints related to preparation.

- Risk weighting should account for such other items as program complexity, construction time, time between estimate and award, etc.

- The currently defined "X" classification should be utilized each and every time an estimate is modified by non-estimating personnel.

RECOMMENDATION 6: A Standard System For Preparing, Maintaining, Retaining And Transmitting Configuration And Estimating Data For Government Furnished Material Should Be Instituted

Because of the number and diversity of organizations handling GFM, procedures should be developed to assure the consistency and standardization of configuration and estimating data provided to the NAVSEA estimating group and others requiring estimates. Beyond this general objective, the procedures should

- Encourage close communication between personnel responsible for different aspects of estimating, thus facilitating the exchange of information on market conditions, potential suppliers, pertinent changes in interfacing systems and other factors essential to sound estimating.
- Support development of a responsive data bank containing both estimating and return cost data.
- Provide a consistent approach to estimating items other than basic hardware (e.g., spares, manuals, services).
- Provide for a progression of more detailed work breakdown information as the system proceeds through development.
- Provide a means of ensuring that all items in a ship's GFM suite are considered.
- Provide for compatibility of the GFM estimates with other ship system data maintained by NAVSEA, thus making the preparation of parametric or engineering estimates a more organized activity.

- Provide for indices to be maintained by the Cost Analysis group with specific applicability to industries producing weapons, sensors, propulsion systems, etc., so that applied escalation rates are more appropriate.

- Provide technical personnel with collateral responsibility for preparing estimates with the support and assistance of personnel from the central estimating staff.

RECOMMENDATION 7: Senior Cost Estimating Staff Should Be More Involved In The Contract Negotiation Process

One of the important concepts behind these recommendations is that estimating personnel must operate "where the action is". The information base from which estimators work must be current and comprehensive.

In line with this concept, on the one hand, and also because contracting officials can benefit from the expertise of experienced estimators, it is recommended that estimators participate in a senior advisory role to contracting officers.

Generally, an independent government estimate is prepared by NAVSEA for the guidance of the contracting officer. A natural continuation of this process would be for the estimator to confront, with the contracting officer, shipyard negotiators and advise as to differences or conflicts which may develop. The last logical step relates to the review of shipyard bids and the reconciliation of positions.

The estimators, when working with the contracting officer in this manner, gain experience and awareness and improve both the estimating and negotiating process.

*   *   *   *   *

There are only two points in the above recommendations that have investment implications of any significance.

- A one-time investment will be required to define, document, program and implement the estimating system to be utilized.
- Added staff will be required to carry out the system.

Outside of these reasonable investments, all other recommendations require primarily a rethinking of estimating concepts, more efficient utilization of current resources and establishment of procedures and standards to improve the process.

3. DESPITE CONSIDERABLE ESTIMATING IMPROVEMENT WITHIN NAVSEA, ACTIONS OF OTHER ORGANIZATIONS CAN PRECLUDE CONSISTENTLY RELIABLE ESTIMATES

The report has thus far covered four different categories of problems. In the fourth category were those directly related to NAVSEA cost estimating and, in the preceding section, solutions to those problems have been recommended. It has also been mentioned that problems in the other three categories will in all likelihood remain to influence future estimates for better or worse. Even though the charter of this study limits it to the activities of NAVSEA, it is felt to be important that NAVSEA have a list of recommendations for other organizations in the government which, if recognized and implemented, would contribute to long term estimate reliability.

RECOMMENDATION 8: Planning At All Levels Should Be Redirected To Provide A Firm Engineering And Estimating Base

The cycles of the planning, programming and budgeting process extend over a significantly long period of time in the case of naval procurement. With respect to a program such as the FFG, for example, the planning and budgeting window is over ten years in length. The system requires budget estimates two years in advance of appropriation and works on the notion that these estimates can remain accurate over five to ten year periods.

In the best environments, this is a most difficult task. When less than optimum conditions arise, reliability cannot be expected. Certain changes would improve the estimating and resource allocation environment.

- A consistent vision of naval shipbuilding requirements over a five to ten year period would permit less changing of yearly programs and make the funding of engineering development an investment providing higher returns in terms of reliable estimates, firmer ship configurations, more predictable project schedules, etc.

- The exercise of a higher level of discipline with respect to changes -- changing requirements, changing characteristics and, in general, unnecessary complication of the allocation process -- should be sought.

- A recognition that the construction of naval combatants is one of the most complex engineering and industrial processes performed in the country. The prevailing attitude that changes must be a way of life and are absolutely necessary endangers commitments made to Congress as to how much naval defense will cost the country.

RECOMMENDATION 9: Acquisition Programs Should Not Be Included In Budgets Until They Pass DSARC II Or Its Equivalent

A great deal of controversy exists due to the fact that less than budget quality estimates are sent to Congress for authorization and appropriation. Too often, in the view of many, ill-defined ship programs are presented for Congressional action with resultant cost growth after a higher level of definition is achieved and a higher, but more accurate estimate is developed.

To eliminate this situation, it is suggested that programs to be included in a budget must have passed the DSARC II acquisition system milestone. Several advantages are associated with this idea.

- The preliminary design engineering level will have been reached.
- All Defense Department acquisition managers will be familiar with development progress and potential problems.
- A reasonable estimate can be made at this stage.

RECOMMENDATION 10: A Continued Emphasis Should Be Placed On The Accountability Of Program And Planning Management To Operate Within Established Budgets

In the strictest sense, a budget submission is a plan not a commitment. It does become a commitment, however, when the budget plan becomes an appropriation from which funds will be apportioned and allocated. Too often, the "plan" definition is used as an escape clause.

- Planning, program and project management assignments are not always scheduled with strict accountability for management actions in mind. They are often too short and allow decisions to be made by personnel who do not have to live with the results. It is a difficult phenomenon to document in any detail, but many officials interviewed believe this to be the case.
- The budgets appropriated are often not taken as seriously as they should be; Engineering and characteristics changes, schedule changes, administrative delay, etc., seem to have a higher priority than meeting budget commitments.

Accountability for cost overruns should be considered as important as other competing and sometimes conflicting policies which foster short assignments and allow a high rate of ship and project changes.

4. IN SUMMARY, THE RECOMMENDATIONS OFFERED ARE PRACTICAL AND PROVIDE THE OPPORTUNITY FOR SUBSTANTIAL IMPROVEMENT OF ESTIMATING CAPABILITY

Recommendations outlined in this chapter are made on the assumption that some new and some re-defined functions would be created within the NAVSEA estimating group. A grand design or specific organization is not suggested at this time. That kind of decision can only be made after a specific approach is approved by management.

Certain overriding concepts do evolve from the recommendations offered and these functions are outlined in the accompanying Figure VII.1.

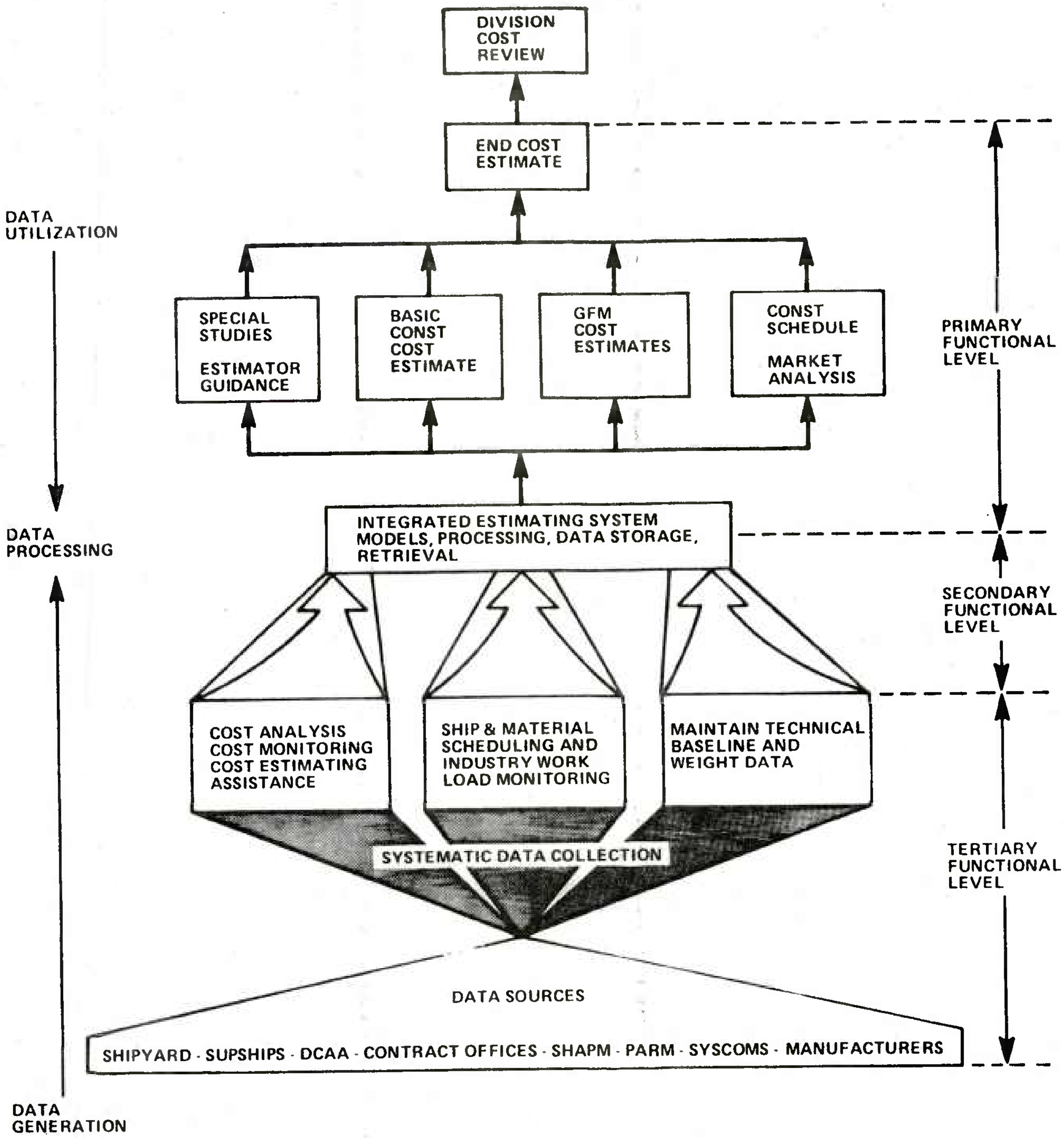
- The Division would be organized for the performance of five primary estimate-related functions:

  - Basic ship estimating
  - GFM estimating
  - Ship scheduling
  - Analysis and special studies
  - End cost estimating

  As a matter of policy, each group would contribute necessary estimate elements with their associated risk classifications.

FIGURE VII.1

SHIP COST ESTIMATING FUNCTIONAL PROCESS



The assembly of the total ship estimate, although performed by a senior staff member, would reflect a consensus of all contributors to the estimate as to its dollar amounts and associated risk.

- The secondary level of functions is a mix of staff, models, computers, data and procedures which would be the operational heart of the estimating process.

- A tertiary level of functions relates to the activities of cost and estimating specialists. The responsibilities of these staff members would be to assist project offices in preparing estimates for any number of purposes, collect important engineering and project information that bears on estimating and in general, be experts on particular ship systems, GFM systems, industrial elements, etc.

  The estimating staff would also be charged with making necessary field trips to naval or contractor facilities in their efforts to collect the most up-to-date, pertinent information available and to assist in contract negotiations.

  The nature of the relationship of this staff to NAVSEA cost estimating vis-a-vis project offices can vary but it would seem obvious that the closer the relationship of these individuals to project office staff, the better the mutual benefits.

Again, this is not offered as a grand design but rather as functions which are implied by the recommendations. The methodology finally derived can be based on these kinds of functions and staff eventually employed could fit into the patterns suggested.

* * * * *

The following charts summarize the recommendations offered, indicate the payback to resource ratio and relate them to the problems needing solution.

RECOMMENDATION 1 (NAVSEA Controllable)	PAYBACK POTENTIAL	RESOURCES REQUIRED	PROBLEMS ADDRESSED DIRECTLY	PROBLEMS ADDRESSED INDIRECTLY
<u>A general strengthening of the cost estimating process is necessary</u>. • The organizations ability to seek out and understand important estimating information should be improved. • A system should be designed which would allow estimates to be prepared in more detail. • A staffing plan should be developed which would provide experience level and numbers of personnel appropriate to current demands. • Management should be strengthened to provide more day-to-day guidance and assure the implementation of the new methodology.	High	Reasonable	• There are about 50 organizations contributing to cost estimating with no unifying methodology or standards controlling their separate products. • Estimating staff has not grown in expertise and experience in proportion to the growth of economic, industrial, engineering and administrative problems. There are also critical gaps in experience levels, i.e., shipyard experience. • Estimating is being done in an aggregated format regardless of the stage of engineering development or other program information available. • Little evidence has been uncovered of an effort to utilize data processing systems to manage the large amounts of information to which estimating professionals must refer. • Efforts have been lacking to collect and utilize information from project offices, field installations, contractors or other industry groups which would assure that all necessary facts were being uncovered and trends were being recognized. • Due to current problems and staffing deficiencies, estimating management is handicapped in providing adequate direction --both from a methodological point of view and in day-to-day operations.	• Naval shipbuilding, as with some highly technological commercial ships, has become a highly complex engineering and construction activity. • The planning, programming and budgeting process which requires estimates to be prepared 27 months in advance obviously does not foster precision estimates in a fast-paced economic environment. • The budgeting system requires that estimates remain accurate over a long period of time -- sometimes five to ten years -- with little allowance for margins reflecting the uncertainty inherent in such estimates.

RECOMMENDATION 2 (NAVSEA Controllable)	PAYBACK POTENTIAL	RESOURCES REQUIRED	PROBLEMS ADDRESSED DIRECTLY	PROBLEMS ADDRESSED INDIRECTLY
The Cost Estimating Staff should be closely associated with the Ship Production Staff and should be given greater organizational prominence. • Provide for improvement of building period assumptions. • Produce more accurate market analyses. • Improve communications. • To insure independence of judgment.	High	Low	• Building periods are often miscalculated with the inevitable result of bad estimates. • The cost estimating function within NAVSEA should be afforded greater command recognition and responsibility.	• Schedules and commitments which start out displaying "healthy" optomism from a planning point of view often result in delays causing substantial cost growth.

RECOMMENDATION 3 (NAVSEA Controllable)	PAYBACK POTENTIAL	RESOURCES REQUIRED	PROBLEMS ADDRESSED DIRECTLY	PROBLEMS ADDRESSED INDIRECTLY
A procedure should be instituted that requires periodic auditing and post mortem reviews of estimates. • Periodic unscheduled audits. • Scheduled post mortem analyses of past estimates, the results of which are included in training programs. • Special research of risk classifications, industrial indices, building periods, etc.	High	Low	• A persistent problem in predicting "basic construction " -- the price of a ship construction contract. • The difficulty to adequately foresee market trends in a relatively small but complex industry. • Lack of fundamental estimating skills such as prediction of manhours, labor rates, overhead, building periods, etc. • No evidence exists that return costs of ships abuilding or from completed ships has been utilized to improve estimates being prepared or to perform post-mortem analyses to improve overall capability. • Once an estimate is submitted for a particular ship or program, a different ship from the point of view of characteristics is often built which, although advantageous in terms of military capability, precludes an accurate estimate. • Engineering changes are a way of life due to characteristics changes to achieve increased capability. • A general lack of consistency in predicting the installed cost of Government Furnished Material.	• The planning, programming and budgeting process in which estimates are made often requires estimates over short intervals which do not allow thoughtful consideration of issues. • Once an estimate is submitted for a particular ship or program, a different ship from the point of view of characteristics is often built which, although advantageous in terms of military capability, precludes an accurate estimate. • The budgeting process from NAVSEA on up to Congress is a political process -- both literally and figuratively -- in which funds are withheld, allocated and re-allocated with little regard for the rational behind the original program estimates. This process also results in pushing programs into different building periods thus changing the escalation characteristics of the estimates. • Engineering changes are a way of life due to characteristics changes to achieve increased capability. • Navy managers do not seem to be motivated to manage to the budget figure during engineering and construction phases. • The budgeting system requires that estimates remain accurate over a long period of time -- sometimes five to ten years -- with little allowance for margins reflecting the uncertainty inherent in such estimates.

RECOMMENDATION 4 (NAVSEA Controllable)	PAYBACK POTENTIAL	RESOURCES REQUIRED	PROBLEMS ADDRESSED DIRECTLY	PROBLEMS ADDRESSED INDIRECTLY
A Substantial Continuing Effort Should Be Made To Keep Abreast Of The Impact Of Changes In Shipyard Productivity Overhead And Other Important Estimating Elements Determine The Causes For Changes In Shipyard Productivity. . Dedicate resources to review and analyze in-depth instances where the manhours to construct the same ship increase substantially. . The analysis should include, but not be limited to quantifuing the effect of - Social Legilation - Labor Build Up - Work Ethic - Management - Training - Series Production etc.	High	Medium	. Recent changes in labor productivity warrants a special effort on the part of the Navy to identify and quantify factors causing productivity change and to reflect these in the estimating procedure. . The SEA 01G staff has had very little shipyard experience. . Assist in early detection of changes in productivity. . The real cost to industry of social legislation is being felt in a number of ways but chiefly in increased overhead and reduced productivity. . Contributing also to increased overhead and lowered productivity is a changed work ethic.	. The lack of program stability characterized by change of ship types and numbers places a heavy demand on the estimating staff to produce good estimates in a constricted time frame and often with poorly defined ships. . An evaluation of market factors on cost at time of budget preparation is extremely deficient but most important and warrants a greater degree of analysis and recognition than now being given.

RECOMMENDATION 5 (NAVSEA Controllable)	PAYBACK POTENTIAL	RESOURCES REQUIRED	PROBLEMS ADDRESSED DIRECTLY	PROBLEMS ADDRESSED INDIRECTLY
The concept of estimate classification should be redefined and a supporting system of estimate preparation established. • Estimate classification should interpret risk as a function of engineering definition. • Risk classification should be the product of weighting a number of estimates risks -- separate ship systems, GFM, industrial factors. • Budget estimate should be more detailed	Medium	Low	• The treatment of inflation-related estimate elements is often a political tool rather than a realistic measure and should change risk assessments associated with estimates. • The definition of what budget quality estimates should represent is unclear and presently is not based on sufficiently high standards.	• A more stable program and a firmer engineering base would allow estimate build-ups over longer periods of time based on fundamentals -- not only parametrics. • Although estimates are coded to reflect the degree of risk associated with the prediction, users on all levels often dismiss its significance or override its purpose.

RECOMMENDATION 6 (NAVSEA controllable)	PAYBACK POTENTIAL	RESOURCES REQUIRED	PROBLEMS ADDRESSED DIRECTLY	PROBLEMS ADDRESSED INDIRECTLY
A standard system of preparing, maintaining, retaining and transmitting configuration and estimating data for GFM items should be instituted. • Support development of a responsive data bank containing both estimating and return cost data. • Provide a consistent approach to estimating items other than basic hardware (e.g., spares, manuals, services). • Provide for a progression of more detailed work breakdown information as the system proceeds through development. • Provide a means of ensuring that all items in a ship's GFM suite are considered. • Provide for indices maintained by the Cost Analysis group with specific applicability to industries producing weapons sensors, propulsion systems, etc. • Provide technical personnel with support and assistance of personnel from the central estimating staff. • Provide for compatibility of the GFM estimates with other ship system data.	Medium	Low	• A general lack of consistency in predicting the installed cost of Government Furnished Material. • There are no predictable tendencies to GFM overruns or underruns and little documentation exists which indicates concern about this problem. • NAVSEA has allocated very limited resources to the task of estimating the cost of GFM.	• The direction and utilization of the engineering process by program sponsors and other Navy managers has often resulted in fragmented engineering documentation and a general absense of development standardization. • Each program office is allowed the freedom to work relatively independently, thereby resulting in a lack of standard procedure.

RECOMMENDATION 7 (NAVSEA Controllable)	PAYBACK POTENTIAL	RESOURCES REQUIRED	PROBLEMS ADDRESSED DIRECTLY	PROBLEMS ADDRESSED INDIRECTLY
Senior Cost Estimating Staff Members Should Be More Involved In Contract Negotiation Process . Increase estimators working contract with industry. . Contracting Officer and SHAPM will receive benefit of cost estimating experts during negotiations.	Medium	Low	. Increase estimators awarness of shipbuilding industry problems by bringing the estimator in close contact with shipyard estimators and negotiators. . Expose estimator to more complete shipyard estimate back-up data	. Increase organizational prominence of the cost estimating staff . Facilitate the procurement of all shipyard bid or proposal back-up data that the Navy is entitled too. . SEA 01G has formulated a training plan that has not been fully implemented because of lack of time and funding. The plan, however, is intermittent, lacks emphasis on field experience and is not performance oriented.

RECOMMENDATION 8 (Controllable Outside NAVSEA)	PAYBACK POTENTIAL	RESOURCES REQUIRED	PROBLEMS ADDRESSED DIRECTLY	PROBLEMS ADDRESSED INDIRECTLY
Planning at all levels should be redirected to provide a firm engineering and estimating base. . Consistant, multiyear vision to lessen year to year program changes. . Excercise of discipline with regard to changes. . Understanding that constant change and reliable resource estimates are incompatible.	High	Low	. The study has found evidence that the planning process could be improved to provide less year-to-year changes in the shipbuilding program and thereby provide a more stable environment to accomplish necessary engineering activities for desired ship programs. . A more stable program and a firmer engineering base would allow estimate build-ups over longer periods of time based on fundamentals -- not only parametrics.	. The planning, programming and budgeting process in which estimates are made often requires estimates over short intervals which do not allow thoughtful consideration of issues. . The planning, programming and budgeting process which requires estimates to be prepared 27 months in advance obviously does not foster precision estimates in a fast-paced economic environment. . The budgeting process from NAVSEA on up to Congress is a political process -- both literally and figuratively -- in which funds are withheld, allocated and re-allocated with little regard for the rationale behind the original program estimates. This process also results in pushing programs into different building periods thus changing the escalation characteristics of the estimates. . The direction and utilization of the engineering process by program sponsors and other Navy managers has often resulted in fragmented engineering documentation and a general absense of development standardization.

RECOMMENDATION 9 (Controllable Outside NAVSEA)	PAYBACK POTENTIAL	RESOURCES REQUIRED	PROBLEMS ADDRESSED DIRECTLY	PROBLEMS ADDRESSED INDIRECTLY
Acquisition programs should not be included in budget until they pass DSARC II or its equivalent. • Eliminate lower than C class estimates in budgets. • Engineering definition would be sufficient for appropriation purposes. • Program maturity would be sufficient to predict building periods, number of yards, etc.	High	Low	• The planning, programming and budgeting process in which estimates are made often requires estimates over short intervals which do not allow thoughtful consideration of issues. • The budgeting system requires that estimates remain accurate over a long period of time -- sometimes five to ten years -- with little allowance for margins reflecting the uncertainty inherent in such estimates.	• The planning, programming and budgeting process which requires estimates to be prepared 27 months in advance obviously does not foster precision estimates in a fast-paced economic environment.

RECOMMENDATION 10 (Controllable Outside NAVSEA)	PAYBACK POTENTIAL	RESOURCES REQUIRED	PROBLEMS ADDRESSED DIRECTLY	PROBLEMS ADDRESSED INDIRECTLY
A continued emphasis should be placed on the accountability of planning and program management to established budget dollars. • Length of assignments should be increased...Persons making decisions should live with them. • Budget amounts not "managed to" and sometimes not taken as serious targets or ceilings.	High	Low	• The Navy does not seem motivated to manage to the budget figure during engineering and construction phases. • Schedules and commitments which start out displaying "healthy" optomism often result in delays causing substantial cost growth. • Once an estimate is submitted for a particular ship or program, a different ship from the point of view of characteristics is often built which, although advantageous in terms of military capability, precludes an accurate estimate.	