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THESIS

AN ANALYSIS OF THE
COST/SCHEDULE CONTROL SYSTEM
IMPLEMENTED AT
MARE ISLAND NAVAL SHIPYARD

by
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An Analysis of the Cost/Schedule Control System
Implemented at Mare Island Naval Shipyard

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ABSTRACT

This thesis analyzes the Cost/Schedule Control System implemented at Mare Island Naval Shipyard. Each shipyard has the perogative to implement the system as they desire, so each implementation will differ somewhat. The analysis of the underlying problems with Mare Island's system, however, may be applicable to all eight Naval Shipyards. Recommendations for possible actions to improve the Cost/Schedule Control System at Mare Island Naval Shipyard are provided.

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I. INTRODUCTION

A. BACKGROUND

The decade of the 1980s will likely be remembered for the rapid escalation of the national debt and the unsuccessful attempts to harness it. President Reagan's stated strategies for dealing with the national debt focused on policies for stimulating the economy and reducing the size of the government. His desire to reduce the size of the government excluded the Department of Defense, which he determined needed real growth in order to restore the military strength he felt had been lost in prior administrations. In February 1988, for the first time in his tenure and partially as a result of the 1987 Economic Summit between the Legislative and Executive Branches, the President submitted a budget calling for only a 3% increase in defense spending. This increase, which was not expected to cover the cost of inflation, translated into a real loss in defense dollars.

Even with the growth of the defense budget enjoyed in the first half of the decade, the Department of Defense did not escape fiscal scrutiny. Stories of vastly overpriced ashtrays and hammers shocked the public and brought Congressional attention. The focus on fiscal management became sharper and policy statements by the Service Secretaries indicated that military leaders would henceforth be made more directly responsible for the efficient use of public resources entrusted to them.

An annual budget of nearly four and a half billion dollars for ship maintenance and modernization provides a substantial target for cost reduction programming within the Department of the Navy. The Naval Sea Systems Command (NAVSEA) is responsible for the administration of these funds, which are allocated approximately 70 percent to public and 30 percent to private sector shipyards.

Through the early 1980s, the prioritized goal of naval shipyards was 1) on time delivery of 2) quality work at 3) a reasonable cost. Cost awareness held the lowest priority. The advent of increasing budgetary restrictions brought cost consciousness to the forefront and instigated new NAVSEA directives aimed at forcing the shipyards to make cost effectiveness as important or even more important than meeting schedule. Although there have been numerous other initiatives that addressed cost reduction, NAVSEA's requirement that each shipyard implement a Cost and Schedule Control System (C/SCS) is the most prominent shipyard program instituted to date.

B. PURPOSE

The purpose of this research is to define the implementation of a Cost and Schedule Control System (C/SCS) at the Mare Island Naval Shipyard and to evaluate its effectiveness in meeting the objectives stated in its title.

A naval shipyard is a huge and complex activity. Like a giant jigsaw puzzle, it is made up of many irregular pieces, each shaped by internal and external constraints. These pieces must fit together to form a recognizable picture of a productive activity. Any new tool introduced must fit into this puzzle. Therefore, some of the previously existing methods of determining budgeted costs and schedules must be examined and analyzed. Then C/SCS, the new management tool, can be defined and studied.

Specific questions addressed in this research are:

1. What is the current status of the implementation of a Cost and Schedule Control System at Mare Island Naval Shipyard (MINSY)?
2. How does MINSY currently estimate direct labor requirements?
3. Are the data inputs to the system accurate?
4. Are the performance indicators generated valid?
5. Do the generated reports provide useful and timely information to all levels of management?

C. SCOPE

Every naval shipyard is required to have a Cost and Schedule Control System by April 1988, but there is no requirement for uniformity among the yards. In order to maintain a reasonable scope, this research is limited to the implementation efforts at Mare Island Naval Shipyard. This limitation allows for sufficient depth of study needed to provide a meaningful assessment of the system to answer the research questions listed previously. This research was not sponsored by any activity. Travel funds were provided from the very limited pool owned by the Administrative Sciences Curricular Office. Travel to the Shipyard, therefore was limited to four days. Initial research to establish a basic understanding of this most complex organization required the majority of available time. Additionally, management time which we could reasonably expect to monopolize in support of our inquiries was limited since this research was not sponsored by any NAVSEA activity. This limitation is most evident in Chapter VI where we discuss management perceptions of the C/SCS. Interviews with a significant number of line managers would have required considerable manhours of expensive management time, and more time at the Shipyard than the Curricular Office's limited funds would allow. Admittedly, then, this thesis only scratches the surface of a very complicated control system in a most complex organization.

Discussion of specific work items is limited to non-nuclear repair work only so that the research may remain unclassified. There are some major differences in nuclear and non-nuclear work practices, but they are beyond the scope of this research. A background section describing shipyard organization, budgeting and some of the operating constraints is provided to enable the reader to better understand the shipyard environment.

D. RESEARCH TECHNIQUE

The research effort included some background reading but consisted primarily of field interviews with key shipyard personnel and the gathering of reports and other data. There have been several consultant studies of the shipyards and a number of Naval Postgraduate School theses have addressed various aspects of operations at the shipyards. However, none of these studies have directly addressed the Cost and Schedule Control System. The majority of the background readings were instructions, notices and other navy source documents. Both authors visited the shipyard on several occasions and received generous cooperation from those interviewed. Shipyard personnel provided further assistance by commenting on the accuracy of the research as it progressed.

E. OUTLINE OF THE THESIS ORGANIZATION

Chapter II provides a general overview of the workings of a naval shipyard, including its organization and financial structure, some of the unique constraints within which it must operate, and a description of some other recent changes that were implemented in an attempt to increase cost awarenes.

Chapter III describes the Cost and Schedule Control System implemented at the Mare Island Naval Shipyard and discusses the compliance of that system with NAVSEA requirements. Chapter IV continues the discussion with an examination of current shipyard cost estimation procedures which result in the budgeted amounts used in the C/SCS.

Chapter V provides an analysis of the system, addressing the validity of the performance indicators and the usefulness of the reports. Chapter VI reports on management perception and acceptance of the system. Chapter VII summarizes the research with recommendations for improvements to the system and identification of topics for further research.

II. BACKGROUND

A. GENERAL OVERVIEW

The purpose of this chapter is to provide the reader with an introduction to the mission, organization and the financial structure of naval shipyards. It also offers an abbreviated look at some of the initiatives undertaken since 1980 to improve financial management within naval shipyards.

There are currently eight naval shipyards, down from eleven since World War II. The official mission of naval shipyards assigned by the Secretary of the Navy is:

> To provide logistic support for assigned ships and service craft; to perform authorized work in connection with construction, conversion, overhaul, repair, alteration, dry-docking, and outfitting of ships and craft, as assigned; to perform manufacturing, research, and test work, as assigned; and to provide services and material to other activities and units, as directed by competent authority. [Ref. 1]

In the recent past all ship construction was removed from the public sector, leaving as the primary mission of naval shipyards the repair and upgrade of Navy ships and the preservation of a "surge" capability in case of war. [Ref. 2]

NAVSEA has reduced the generality of the shipyards' missions by assigning tasks specifically suited to each yard's capabilities and facilities. For example, Mare Island primarily provides for the repair, overhaul and refueling of nuclear powered submarines.

B. SHIPYARD ORGANIZATION

The majority of this research involves activities performed in the Production and Planning Departments. Figure 1 provides a condensed organizational chart for the Production Department and Figure 2 provides a similar chart for the Planning Department.

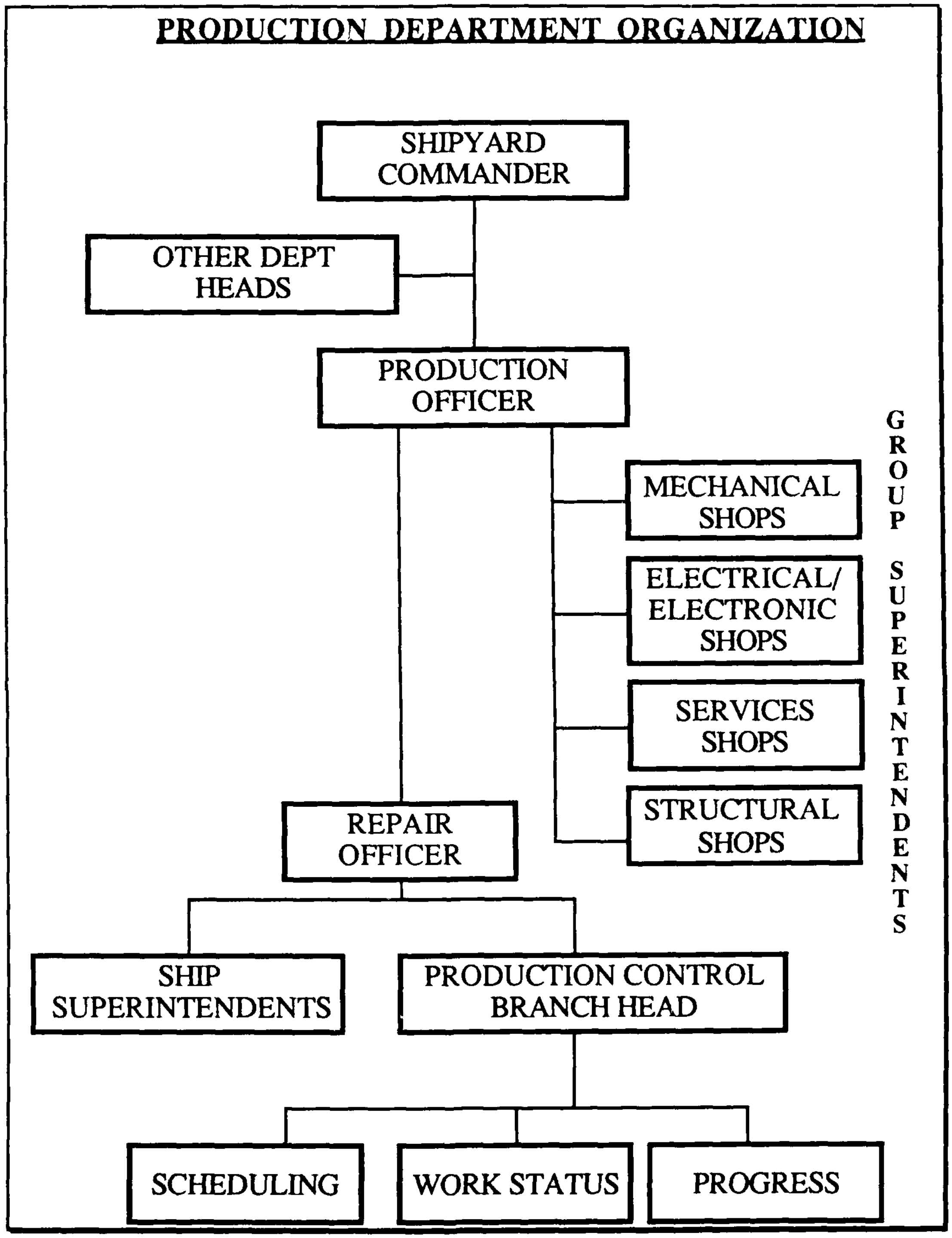

Figure 1. Production Department Organization

The Production Officer reports to the Shipyard Commander on all productive activity. His primary assistant, the Repair Officer, provides the overall direction on total work accomplishment. The Group Superintendents also report to the Production Officer. Each Group Superintendent is responsible for a number of shops which make up a major trade or work area. For instance, the Mechanical Group consists of the Inside and Outside Machine Shops as well as several other related shops.

At least two Ship Superintendents are assigned to each ship to direct productive work specific to that hull. The Ship Superintendents report to the Repair Officer. The Production Control Branch Head, also reporting to the Repair Officer, is responsible for workload, work force and schedule management. The responsibility for designing and implementing the C/SCS was assigned to the Production Control Branch.

Figure 2 displays the key divisions of the Planning Department and provides an indication of how large this department is. The planners and estimators provide the initial estimate of mandays needed to accomplish a particular work package. The process is very complex and cannot be adequately described in a few paragraphs. A full description of the cost estimation process is provided in Chapter IV.

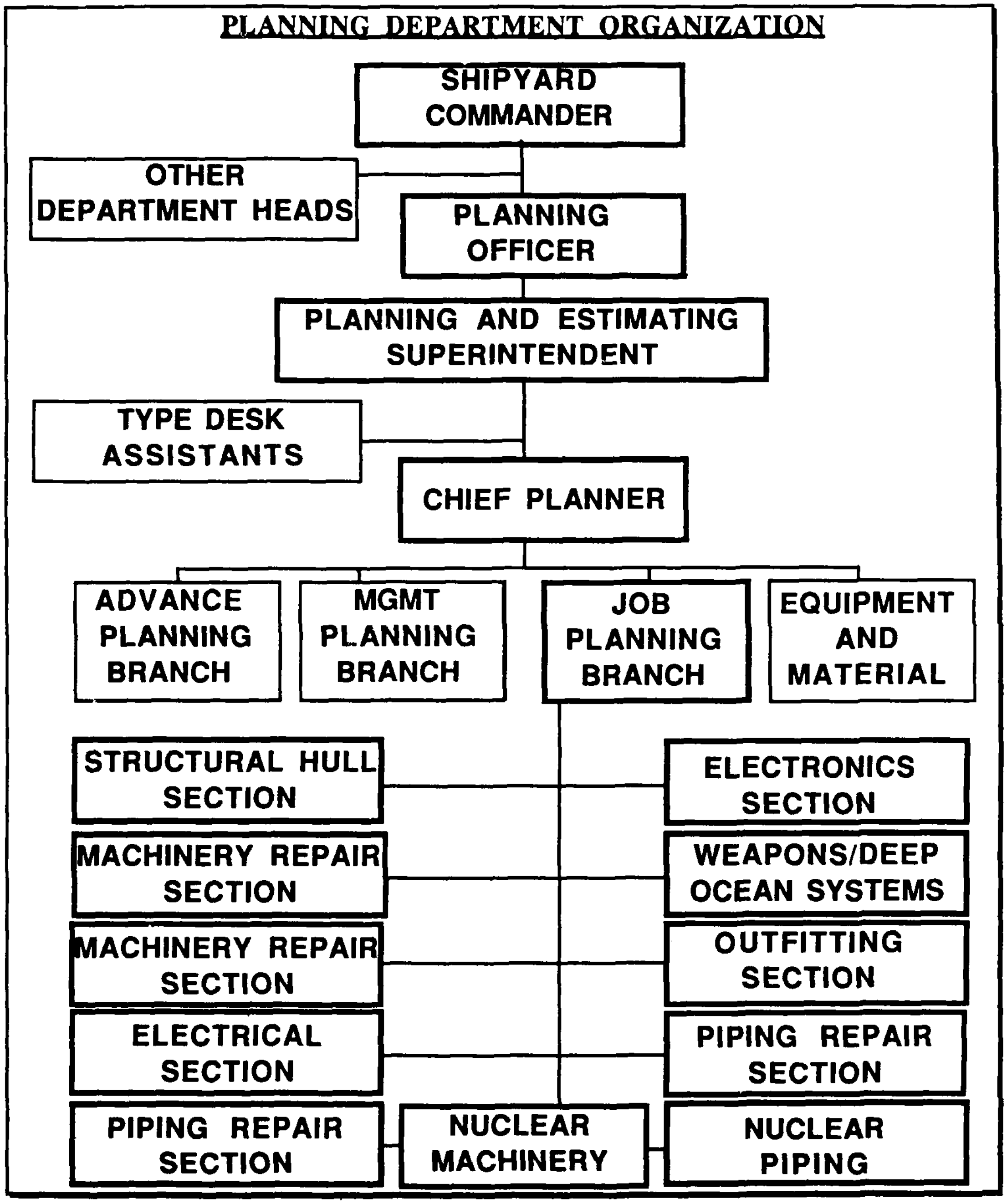

Figure 2. Planning Department Organization

C. THE NAVY INDUSTRIAL FUND

Naval shipyards' operating funds come primarily from the Navy Industrial Fund (NIF). The NIF was established by Congress to provide a more "businesslike" approach to industrial activities and to bypass the need for annual appropriation of funds. The NIF was provided with a corpus, or revolving fund, of working capital which supports the activity. The fund is used to finance operations until payment has been received from the customer. The financial goal of every NIF activity is to break even, to have revenues equal costs.

The NIF was intended to provide better management as the result of three primary features. First, there must be a contractual relationship between the customer and the activity so that the customer can budget for expenditures and the activity can define the task, accurately estimate the cost, and properly schedule work force and material requirements. Secondly, NIF requires a cost accounting approach which relates cost to specific jobs. And finally, the NIF provides flexibility by being freed from the Congressional appropriation cycle.

The cost flow cycle of the NIF is demonstrated in Figure 3. As demonstrated, all costs of production, direct and indirect, as well as general and administrative expenses are financed by the NIF. The NIF activity bills the customer for the work and the revenue is used to replenish the fund.

Though the NIF itself is exempt from Congressional appropriation, the preparation, approval and execution of a shipyard budget is similar to that of any other defense activity.

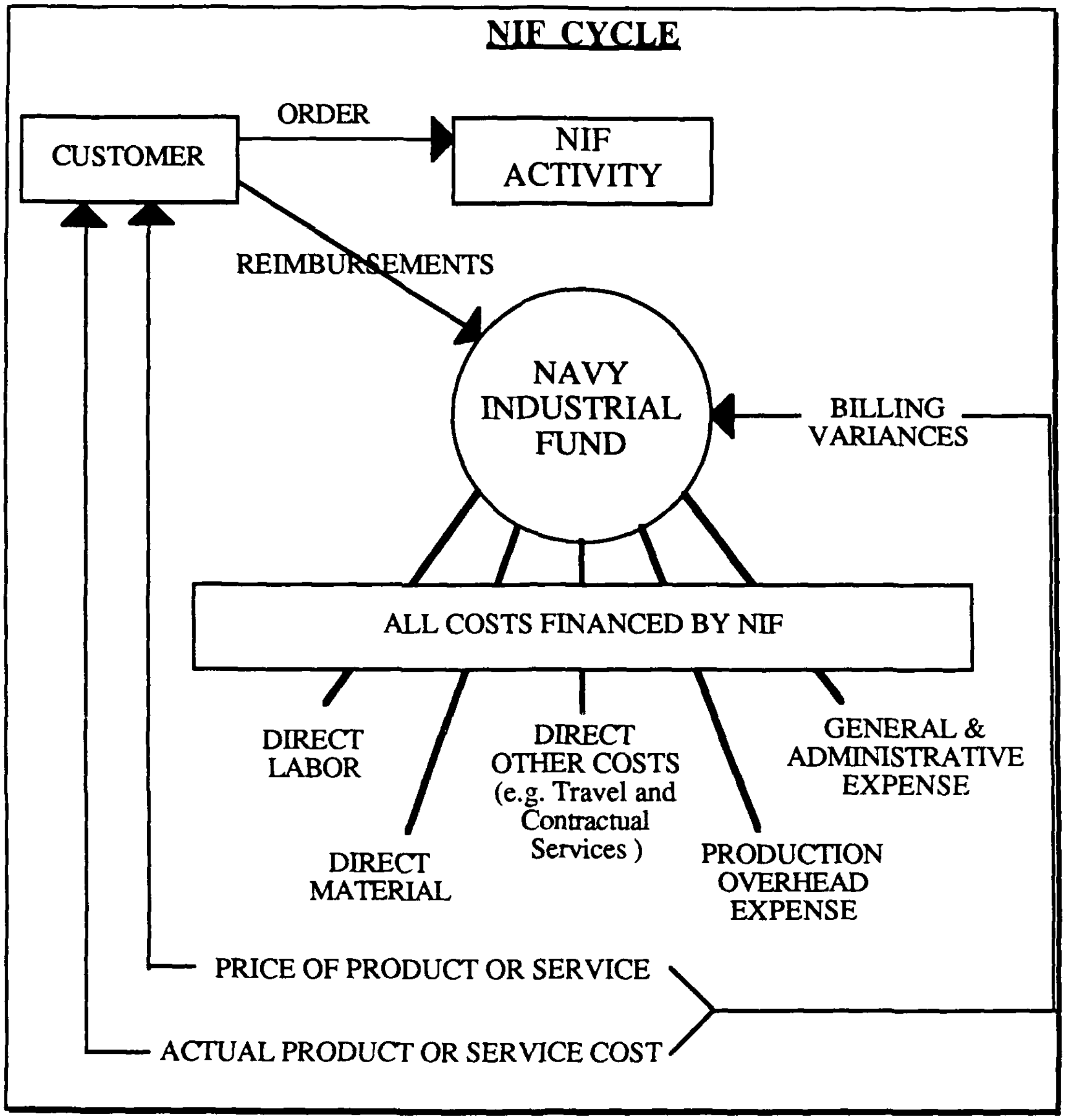

Figure 3. NIF Cycle

D. SHIPYARD BUDGETING

The shipyard prepares an Annual Financial Management Budget (AFMB) based on budget guidance from NAVSEA. The AFMB is developed by matching customer needs and resources to shipyard capacity, capability and costs. Planned workload is translated into various accounting classifications such as direct or indirect labor. Dollar values are assigned to each account in accordance with guidelines established by the Comptroller of the Navy (NAVCOMPT) and NAVSEA.

The AFMB is reviewed by NAVSEA and, after negotiated adjustments, combined with AFMB's of the other shipyards into a single NAVSEA shipyard activity group budget. This budget is submitted to NAVCOMPT which holds hearings and marks the budget. Reclamas are made by NAVSEA. On completion of that level of review, NAVCOMPT provides the consolidated Department of the Navy (DON) budget to the Secretary of Defense and to the Office of Management and Budget. It is finally submitted as part of the Presidential Budget to Congress. Therefore, the approved budget may be significantly different from the one originally submitted by the shipyard.

E. UNIQUE SHIPYARD CONSTRAINTS

Naval Shipyards, like other large industrial organizations, operate under a number of constraints. Common constraints include limited physical and capital resources. Other constraints are formed by laws, regulations and direction from higher authority. Naval Shipyards differ from commercial activities in that they are required to budget billing rates at least two years in advance and they are often limited in their ability to accept or decline specific work packages.

The stabilized manday rate is a product of the AFMB. The Defense Department requirement for rate stabilization was intended to permit customers to plan for funding a specific level of work without having to worry about cost escalation. Activities develop a basic stabilized manday rate which includes a direct labor rate adjusted for anticipated inflation and overtime usage, and an overhead rate which includes indirect labor and all other overhead expenses. This basic rate is adjusted by NAVSEA and DOD factors which are designed, in part, to provide payback for capital equipment used and to develop a fund for acquiring future capital assets. The resulting stabilized manday rate is usually approved at least two years prior to the fiscal year in which it will be applied. Once a rate is in effect for a ship, it remains in effect until the repair period ends, even if more than one fiscal year is involved. After approval, shipyards cannot change rates without Defense Department approval, which is rarely attempted. The requirement for rate stabilization is a significant constraint on the shipyard commander's ability to control the profitability and finances of his activity.

The workload used in developing the AFMB is based on customer needs identified by the Chief of Naval Operations, NAVSEA and the Type Commanders. This workload forecast is also used to determine work force size and mix of skills. Changes in fleet operational commitments, unplanned damage repairs, changes in the size or mix (nuclear versus non-nuclear) of work packages and many other emergent factors routinely impact the amount and type of work that is actually undertaken in a given fiscal year. Thus, in addition to having little control over the rates he may charge, the Shipyard Commander is severely limited in his ability to control the amount and type of work his activity will receive.

The shipyard receives an Overhaul Work Package (OWP) for each ship approximately one and a half to two years prior to the commencement of an overhaul. Actual cost estimation for the particular project begins at this point. Chapter IV discusses this process in detail. Actual work schedules associated with the overhaul are also developed at this point. The schedules incorporate plans for the most efficient use of the available resources. Detailing the scheduling of work is beyond the scope of this research. However, it should be noted that changes in work scope, such as those discussed in the paragraph above, are common. The impact of these changes on regularly scheduled work often drastically influences subsequent activity. The additional unscheduled work usually delays work already in progress.

However, the shipyard is often compelled to finish the scheduled work as planned because of the operational commitments of the ship. Applying additional labor and increasing the use of overtime to meet schedule adds to the cost of the overhaul.

F. FISCAL INITIATIVES

NAVSEA recognized the political and economic factors discussed in Chapter I. In its Naval Shipyard Corporate Business and Strategy Plan (NSCBSP), NAVSEA indicated that cost must become as important as schedule in the shipyards' accomplishment of their mission.

> ...Although substantial increases in defense spending were incurred, recent concern with the national deficit will most likely continue to make defense money difficult to obtain. ...There will be more and more governmental attention paid to the affordability of the Navy. Increased efficiency will be demanded. The...reduction in Navy shipyard maintenance money in FY-87, and the recent analysis of shipyard NIF (Navy Industrial Fund) management are the beginning of a move toward cost consciousness, as opposed to accomplishing overhauls in the shortest time possible. [Ref. 3]

There have been numerous initiatives undertaken to improve financial management and cost control in the shipyards. The Navy contracted with the firm of Coopers and Lybrand to perform a complete management study of it's Navy Industrial Fund Activities. Within NAVSEA, some new programs were directed prior to the Coopers and Lybrand study, but most changes occurred after the release of the study.

Many of the recent directives issued by NAVSEA are discussed in the Headquarters Business Plan for Naval Shipyard Operation Improvement (attachment 2 to the NAVSEA NSCBSP). These directives apply to all eight shipyards but in many cases specific guidance is not provided, making implementation an individual effort rather than uniform shipyard wide. A few of the most visible changes are discussed below. Any implementation efforts mentioned are those of Mare Island Naval Shipyard (MINSY) unless otherwise indicated.

In November 1985, the Commander of NAVSEA issued a letter stating that the role of the Comptroller at naval shipyards should be enhanced. The Coopers and Lybrand study had indicated that the comptroller was merely serving in a transaction and recording function. The Commander stated his conviction that the Comptroller should be providing financial analyses, projections and advice to the shipyard Commanders to guide them into appropriate channels of inquiry and to aid in management decisions. He directed the institution of a functional training course for instructing comptrollers and other key financial personnel in the unique aspects of shipyard comptrollership. He also discussed the creation of a cost analysis section within the comptroller department and the establishment of an additional military billet at the Lieutenant Commander/Commander level. The officer would serve as assistant section leader to a senior civilian who would provide continuity. This section would provide cost and budgeting analysis, and its military billet would serve as a training ground for future shipyard comptrollers.

MINSY established the Cost Analysis Section in February 1986. It is currently staffed with four cost analysts at the GM-12 level and headed by a senior cost analyst at the GM-13 level. The incumbents average over 15 years service in the shipyard and have planning, scheduling, estimating and production control in their backgrounds. According to the current shipyard comptroller, he plans to keep this section "hungry" and productive by limiting individual tenure to under three years with replacements continually coming in from the field. MINSY has also received the additional military billet. The incumbent is a Lieutenant who is a recent graduate of the Naval Postgraduate School with a degree in Financial Management.

In an effort to force cost reduction, the Secretary of the Navy implemented the Efficiency Improvement Program, which cut 500 million dollars from the FY-87 program without reducing the amount of work to be accomplished. NAVSEA apportioned the cut to the individual shipyards. MINSY's portion of the cut was $57.2 million. The cut essentially resulted in lower manday billing rates for all availabilities started in 1987, and equated to a 17% reduction from previously approved rates. The lower rates were continued in 1988.

The most dominant and visible change directed by NAVSEA was the requirement to establish a Cost and Schedule Control System. The theory and application of that system at MINSY is the subject of the next chapter.

III. COST SCHEDULE CONTROL SYSTEM

A. NAVSEA GUIDANCE ON C/SCS

In December 1984, NAVSEA issued NAVSEAINST 7000.13. The instruction directed all naval shipyards to implement a Cost Schedule Control System. The C/SCS idea was not a new one. The Department of Defense had required such a system of all private contractors in its instruction 7000.2 of June 1977. NAVSEA's primary goal in requiring C/SCS was to direct the shipyards to develop a system which would provide accurate cost and schedule information so that line management could use that information to improve cost control. Schedule adherence had been a top priority for the past few years, often at the expense of cost control. Therefore, though the system was for cost and schedule control, cost was the primary concern. NAVSEA set December 1985 as the date for full implementation of C/SCS at all shipyards.

The instruction defined ten basic criteria or principles which shipyards must meet for their C/SCS to be approved. The principles focused on data collection, work breakdown structure, performance measurements and means of resolving deviations from planned performance. The system required collection of actual cost and schedule data at the work task element level. Total projects were to be broken down into small elements for ease in management. Actual cost and schedule performance must be compared with planned cost and progress at the lowest level, with deviations resolved by the responsible line manager. The information obtained at the lowest level must aggregate to the total project. The third section of this chapter will describe the criteria in greater detail and discuss Mare Island's compliance in implementation.

Under the cost and schedule control system the line manager holds ultimate responsibility for portions of the project under his supervision. He is held accountable for proper charging of costs as well as for execution of the cost and schedule plans. NAVSEA noted the importance of line management involvement in the budgeting process and in the development of the work breakdown structure.

Although principal requirements were laid down, there was no specific guidance on the formulation of the system. Shipyards were directed to use existing cost control and scheduling systems and expand them to meet the new requirements. Because these existing systems varied among the shipyards, each was allowed to develop C/SCS to accommodate its current methods.

The brief instruction started motion toward developing C/SCS at the shipyards, but NAVSEA found it necessary to expand its guidance and make some changes in the general philosophy about the program. The December 1985 target for implementation proved to be unattainable. Through a series of letters, NAVSEA lengthened the time for implementation and reduced the scope of work to be covered by C/SCS. Shipyards were now directed to implement C/SCS on all CNO scheduled availabilities performed within the confines of the shipyard, beginning with those starting after April 1, 1988. Also, the primary focus of the system was changed from total costs to only direct labor costs. The ten basic criteria were expanded and additional ones, concerning cost and schedule projections and internal reporting and graphics, were added.

B. IMPLEMENTATION AT MARE ISLAND NAVAL SHIPYARD

The Shipyard Commander tasked the Production Control Branch with the responsibility of choosing and implementing an appropriate system. NAVSEA had directed the Naval Sea Systems Command Automated Data Systems Activity

(SEAADSA) to develop a C/SCS software package for installation in the shipyard's existing Management Information System (MIS). Additionally, several commercial software packages were available.

1. Selection of Software

Mare Island chose to implement the Artemis C/SCS for several reasons. (Artemis is the brand name of a software package sold by Metier Corporation.) First, the shipyard's mainframe computer which housed the MIS was already near capacity without the addition of another major system. More importantly, the decision makers believed the Artemis system best fulfilled the shipyard's requirements. They felt Artemis provided the best turnaround time for reporting and the flexibility to produce a variety of reports and graphics. They also believed that the system could be expanded to cover indirect labor and material costs in the future. In addition, the shipyard was already using Artemis software for scheduling all regular overhauls so existing scheduling data would be compatible.

This choice resulted in one major weakness of the system. Artemis scheduling and C/SCS information are gathered, calculated and stored on a Hewlett Packard minicomputer that does not interface with the shipyard's Honeywell mainframe computer. Timecard data, which is the basis for actual expenditures used in C/SCS, is collected through the Honeywell based MIS. Thus, this information is transferred from the mainframe to the Hewlett Packard by means of magnetic tape. There have been difficulties in making this transfer with occasional losses of data resulting. Retrieving the lost data to make a second transfer to the minicomputer is so time consuming that the timeliness of the reports is severely impacted.

2. Mare Island Added Objectives

In addition to meeting the NAVSEA requirements, MINSY listed two other objectives for its C/SCS system. First, the reports were to be most valuable to the waterfront managers. Secondly, the system should provide information to help all management improve cost and schedule performance, making the shipyard more efficient and competitive. The internal reports, which will be discussed later in this chapter, were designed with these goals in mind.

Although this thesis focuses on the value of the current C/SCS to internal shipyard management, the fulfillment of corporate direction cannot be ignored. Indeed, many of the basic objectives required by NAVSEA facilitate the stated goals of the shipyard. Studying Mare Island's actions to comply with those objectives provides the clearest understanding of the current status of its C/SCS.

C. COMPLIANCE WITH NAVSEA CRITERIA

This section provides details of the current status of Mare Island's implementation of C/SCS in terms of the NAVSEA required criteria. The discussion is not all inclusive, but does present the most important developments to date.

A brief explanation of the managerial and work hierachy follows. This information is provided to define some terms that will be used in the remainder of this section.

The managerial and work hierarchies are also called the organizational and work breakdown structures. Table I below identifies the work levels from the largest (ship) to the smallest (line item) element and shows the responsible manager for each level.

TABLE I. Work and Organizational Breakdown

Work Level	Responsible Manager
Ship	Senior Ship Superintendent
Key Event	Project Management Team
Milestone	General Foreman
Key Operations (key ops)	Key Shop Foreman
Line Items	Foreman

A normal ship overhaul consists of approximately 65 key events, 250 milestones and 6000 - 8000 key operations (key ops). The Project Management Team is headed by the senior ship superintendent (usually non-nuclear) and consists of the nuclear ship superintendent, nuclear and non-nuclear test engineers, combat systems engineers and a type desk representative.

1. NAVSEA Criteria for C/SCS

Table II below lists the NAVSEA criteria for approval of a shipyard's C/SCS. Many of the criteria are related and the discussion of Mare Island's implementation is based on those relationships.

TABLE II. C/SCS Validation Criteria for Naval Shipyards

1. Accurate Charging of Direct Labor
2. Physical Progress Assessment
3. Hierarchical Work Breakdown Structure
4. Hierarchical Financial Breakdown Structure
5. Line Management Acceptance of the Work Breakdown Structure
6. Line Management Acceptance of Budgets
7. Cost Performance Data Collection
8. Schedule Performance Data Collection
9. Performance Measurement Baselines
10. Resolution of Performance Variances
11. Cost and Schedule Projections
12. Internal Reports
13. Graphics
14. Training
15. Directives

a. Direct Labor Charges

The first and seventh criteria, accurate charging of direct labor and cost performance data collection, deal with direct labor cost charging. The requirements are for accurate charging at or below the key op level. Cost charging data is collected on the timecard and approved by the foreman. The individual worker's labor is charged to a specific job order (line item) and identified with the appropriate key op.

The shipyard has also established a procedure for charging excess labor. If the foreman has more workers than he needs for jobs in progress, he is required to send the excess to Work Center 29 where their labor is charged to Work Center 29 overhead. The labor pool in Work Center 29 is used for plant and property maintenance work normally accomplished by the Public Works

Department. Because shop foremen are held accountable for exceeding the budgeted overhead for their shop, they had often, in the past, charged excess labor as direct labor cost to jobs in progress rather than to overhead. Work Center 29 was designed to eliminate the charging of excess labor as direct labor without impacting on the individual shop's overhead.

NAVSEA requires the shipyard to perform a statistical sampling of direct labor charges to determine accuracy. The shipyard established an Internal Review organization to perform this function and its findings are reported quarterly to NAVSEA as directed. The findings are also reported to the Production Officer for follow up and disciplinary action as necessary.

b. Physical Progress

The second and eighth criteria are physical progress assessment and schedule performance data collection. Again, the requirements are for accuracy and for collection at or below the key op level. The foreman uses the timecard to indicate, in ten percent increments, the percentage completion of the job by line item. Foremen have been instructed on how to determine the percentage of completion. For jobs under three weeks or 500 hours duration, the foreman may make an honest estimate. For larger key ops, the foreman is expected to break the job into 10% increments and then determine percent completion of the job based on the increments completed. Mare Island has charged the Progress Branch with performing independent assessment of progress to insure accuracy. The findings are reported to the Production Officer.

The foreman also notes any deviation from standard by using a letter code that defines why work was delayed. For instance, the letter code tells whether a delay was caused by a material problem, a technical problem or a delay while waiting an assist trade. Such identification provides an analytical tool for later study of actual performance against budgeted performance.

c. *Work Breakdown*

Two criteria, three and five, require a hierarchical work breakdown structure (WBS) that is accepted by line management. The first requires that work be broken down to the line item level with successive aggregation to the key op, the milestone, the key event and the total project in a manner consistent with standing NAVSEA instructions on the subject. The shipyard was already in compliance with those instructions. However, the Advance Planning division of the Planning Department is now in the process of developing a Phase Oriented Key Operation Numbering system (POKON) that is intended to better support C/SCS.

The second requires line management acceptance of the work breakdown structure. Mare Island established a Industrial Planning Group to afford interaction between the Planning and Production Departments in determining the WBS. That group has since been disestablished so that there is not a formal method for line management involvement in determining work breakdown.

d. *Financial and Budget*

Criterion four calls for a financial breakdown structure and criterion six requires line management involvement in the budgeting process. Mare Island was exempted from the first requirement of aggregating key op budgets to total project budget because it conflicted with another required NAVSEA budgetary procedure. Currently, Mare Island has no formal procedure for including line management in the process for determining the budgeted number of mandays for a given job.

e. *Performance Measurements*

Three related criteria, nine, ten and eleven require performance measurement baselines (budgeted costs) from which cost and schedule variances can be calculated, resolution of the performance variances, and revision of cost and schedule projections, respectively. The criterion for performance measurement baselines specifically requires the use of budgeted cost for work scheduled (BCWS), budgeted cost for work performed (BCWP) and actual cost for work performed (ACWP) to determine variances according to the equations below.

$$\text{Schedule variance} = BCWP - BCWS$$

$$\text{Cost variance} = BCWP - ACWP$$

It should be noted that the shipyard in general, and specifically in the development of these indicators and equations, uses cost and mandays as synonymous terms. The cost indicators can be expressed in dollar amounts by multiplying mandays by the stabilized manday rate. Mare Island uses the following performance indicators for cost and schedule:

Cost Indicators

$$\text{Earned Value Index (EVI)} = \frac{\text{Budget Mandays} \times \text{\% Complete}}{\text{Actual Hours Expended}}$$

$$\text{\% of Budget Estimated at Completion (Percent Budget at Completion)} = \frac{100}{EVI}$$

$$\text{Estimated Actual Mandays at Completion [also called Budget at Completion (BAC)]} = \frac{\text{Budget}}{EVI}$$

Schedule Indicators

$$\text{\% Completed Each Day} = \frac{\text{\% Complete}}{\text{Today - Start Date}}$$

$$\text{Estimated Time to Complete} = \frac{100}{\text{\% Completion Each Day}}$$

(1) Cost Indicators. The EVI is described as representing revenue earned for expenses incurred to date. The shipyard line managers are taught that an EVI of less than one indicates that less than a dollar is earned for every dollar spent. The percent budget at completion represents a projected percentage of the budgeted costs (mandays x stabilized rate) that can be expected if past work performance is maintained. For example, if a ship's total EVI is .85, only 51 minutes of work is being accomplished for every hour spent. It's percent budget at completion of 1.18 indicates that at the current level of efficiency, the final mandays used and final cost will be 18% higher than budgeted. Line managers could multiply the BAC by the stabilized manday rate to determine estimated actual cost to complete, but the manday projections are more meaningful to them.

(2) Schedule Indicators. The schedule indicators assume the past rate of completion will continue. Presently these indicators are only used for finding schedule variances at the milestone level. Mare Island does not use BCWS to calculate total schedule variance. They assume the budgeted schedule for remaining work can still be met. The new projected end date is determined by adding the remaining budgeted time to the estimated time to complete for the milestone under consideration.

(3) Variances. Actions taken by Mare Island to resolve cost variances include the assignment of a Cost Analyst to each project under C/SCS and biweekly meetings with all senior management to discuss the variances. Schedule variances have not yet been studied for resolution. C/SCS data has not been used to review or revise projected schedules or predicted end cost.

f. Training

Criterion fourteen requires the shipyards to provide effective training to all levels of management. Mare Island contracted with ANADAC, INC. to produce training material and to train shipyard personnel as instructors. Formal training has been institutionalized for all first and second line supervisors and nearly 1200 managers have been trained. Some middle and senior civilian and military supervisors have been briefed on C/SCS but training material specifically oriented to their needs has not been developed.

g. Other Validation Criteria

The remaining criteria deal with instructions, internal reports and graphics. Mare Island issued its instruction 7000.3 Cost and Schedule Control, Direct Labor in February 1988. There have been other instructions and policy statements issued to clarify or expand on the information in the primary instruction.

Mare Island currently produces reports formatted in organizational breakdown structure and in work breakdown structure. These reports will be discussed in detail below. Currently, the only graphics being produced are those providing EVI and key op closure information.

D. C/SCS INTERNAL REPORTS

This section identifies reports developed from C/SCS information that are currently being issued and provides a brief explanation of the intended use of each. The reports are identified by alpha-numeric code (CS 0xx) and title, and are updated weekly. Table III below summarizes the reports by number, user and the level of organization or work.

TABLE III. C/SCS Reports

Report #	Management Level	Organizational or Work Level
CS 002	Ship Superintendent Progressman	Whole Ship Milestone
CS 003	Shipyard Commander Project Manager	Whole Ship Key Event
CS 004	Production Officer Group Superintendents	Shops
CS 005	Milestone Manager Key Shop Foreman	Milestone Line Item
CS 007/8	Line Foreman	Line Item
CS 014	Shop Superintendents	Work Centers
CS 015	Group Superintendents ProductionOfficer Repair Officer	Groups

CS 002 Budget Report by Milestone. This report is intended for use by the Ship Superintendent and Progressman. It provides information on the ship's overall status including ship EVI, BAC, and Percent Budget at Completion. The report provides the same performance information on the milestones of the project and

identifies the key shop responsible for each. It also lists scheduled, projected and actual start dates for each milestone.

CS 003 Budget Report by Key Event. Developed for use by the Shipyard Commander, Project Manager and the Senior Ship Superintendent, this report provides the same information as CS 002, but for key events instead of milestones.

CS 004 Budget Report by Shop. Used by the Production Officer and the Group Superintendents, this report shows budgeted and expended mandays, percent budget expended and percentage completion by shop. This information is used to develop the EVI, BAC and percent budget at completion, which are provided for each shop.

CS 005 Budget Report by Milestone. This report repeats the data given in CS 002. However, it also provides the same information about the individual line items associated with each milestone. Additionally, an estimated time to completion variance and estimated completion date are provided for each milestone. The date each milestone is closed to further labor charges is also listed. After that date, labor charged to the closed milestone will be flagged by the MIS computer. The foreman may correct the charge by inserting the proper job order number. If the foreman fails to correct the charge within a specified period of time, the labor is automatically charged to his shop's overhead by the computer. This report was designed for use by the Milestone Manager (General Foreman) and the Key Shop Foreman.

CS 007 (non-nuclear) and CS 008 (nuclear) Supervisors' Desk Top C/SCS Worksheet. These reports are intended to provide working information for the line foreman. The worksheet contains data and performance measures for each job (by line item) scheduled to start in the next three weeks and for any job that has hours expended against it. The information provided is meant to facilitate the foreman's scheduling of workers and reviewing progress of the job. There is space provided for the foreman to fill in his estimate of percentage completion of each job on a daily basis, giving him an easy reference for filling in the time cards later. The report also notes the date that each line item was recognized as complete, indicating that no further charges can be made against it.

CS 014 Budget Report by Work Center. The Shop Superintendents use this report. It contains EVI, BAC and estimated budget at completion for each work center within a shop.

CS 015 Budget Report by Group. This report provides the same information as CS 014 but for each group of shops. This is used by the Group Superintendents and the Production and Repair officers.

Other Reports. New reports are being created as users become more comfortable with the system. Now that they understand the types of information that can be provided to them, managers are requesting reports in specific formats for their personal use. Reports are only distributed to those people who request them. The current method of distribution requires the user to pick up the reports from a specified location or make some other arrangement for their delivery.

In summary, Mare Island has made a diligent effort to implement a C/SCS that conforms to NAVSEA requirements. The emphasis apparently has been aimed at producing reports and training managers in their use. However, the validity of some of the information presented in these reports seems questionable. Chapter IV discusses the problems associated with the budgeted amounts used in the reports and Chapter V will analyze the shortcomings of the resulting performance indicators.

IV. THE COST ESTIMATING PROCESS

The process by which Naval Shipyards estimate costs for future repair work is not standardized, but the basic steps are similar. The following description of the process at MINSY is similar to the process at any of the eight Naval Shipyards.

A. COST ESTIMATING AND BUDGETING

The cost estimation procedure is very complex. A line diagram of the process would bear more resemblance to a maze than an organization chart. Coopers and Lybrand discuss this maze in some detail in their report (Ref. 4). The complexity and potential problems in accurate cost estimating presented by the current process are beyond the scope of this research and are not essential to a discussion of the C/SCS. Therefore, a simplified form containing all the major steps will be presented.

CONCEPT OF STANDARDS

A theme which runs throughout the discussion of cost control is standards. The cost estimating process at MINSY is based on the application of a quantity standard. The quantity is manhours. The origin of quantity standards dates back to the industrial revolution when industrial engineers attempted to quantify standard amounts of physical inputs necessary to manufacture specified products. In the early 1900's the concept of standards evolved to include price standards. Eventually cost standards, that is a quantity standard times a price standard for a certain output, were also developed. These standards were all developed in the manufacturing environment where there is a physical unit of production (output) to be measured. The transportation of manufacturing standards to a non-manufacturing environment like a shipyard is difficult. The difficulty arises most notably from the lack of a physical unit of production by which output can be measured. The ensuing discussion of cost estimating must be considered in light of the inherent difficulty of applying manufacturing standards to the repair industry, in this case MINSY.

Before a meaningful discussion of the cost estimating process can be undertaken there are some unique terms and constraints which must be addressed.

CLASS ESTIMATING STANDARDS

In the early 1980s, NAVSEA introduced the Class Estimating Standards (CES) in an attempt to standardize and limit costs at the Naval Shipyards. The CES pertains only to 637 Class submarines. These standards addressed manday estimates at the Ship's Work Line Item (SWLIN) level for repair work only. SHIPALTS were not included in the CES. (SHIPALTs are specialized work packages for specific equipment or systems which are designed to improve operational performance. They are not intended to achieve repairs as is the case with "repair work.")

With representatives from each Shipyard in attendance, NAVSEA reviewed all the SWLINs in a normal overhaul for a 637 class submarine. For each SWLIN, the Shipyard representatives were required to identify their respective manday estimates. These estimates were compared and NAVSEA selected one of these manday estimates as the Class Estimating Standard for that SWLIN. At the conclusion of this conference, NAVSEA collated the new standards and promulgated the Class Estimating Standard for the 637 class submarines. Each Shipyard involved in overhauling these ships received a copy and reviewed it for achievability. This review provided an oppo: .nity to conduct a more thorough analysis of the Shipyard's ability to meet the standard than was available during the standardization conference.

In those instances where an individual Shipyard's planners/management felt a standard was unattainable, a revised manday estimate was submitted to NAVSEA for approval. All variations from the NAVSEA CES were controlled in this manner. Thus, each shipyard is likely to have a variant of the CES. For example, the NAVSEA CES for a particular SWLIN might have been based upon a resource available in one or more Shipyards, but not available to all. (One Shipyard may have a newer lathe which requires fewer direct labor hours per unit of output, or an automatic vent cleaner which requires only one operator vice an entire cleaning crew.) For those Shipyards which did not have access tc this resource, a proportionately larger standard would be appropriate.

Annual reviews of the CES are conducted by NAVSEA with corresponding changes made as necessary. The total CES (aggregate of all SWLIN standards in the baseline) provides the manday ceiling within which the Shipyard must complete standard overhaul work.

The development of the CES does not fit into a classic description of task and cost standardization for reasons discussed earlier. However, it provides a starting point. Once the standard has been set, updates can be made as often as management deems necessary. What is important is the establishment of a "standard". From this foundation increasingly improved standards can be derived. Currently, there is insufficient data relative to the standards used to provide any meaningful trend information. As this data becomes available, a future analysis of the standards chosen may be a worthwhile study.

BASELINE OVERHAUL

The baseline overhaul is one in which work actually accomplished is exactly as described in the Overhaul Work Package. The Overhaul Work Package is the document which describes by SWLIN the work which a ship's Type Commander wishes to have accomplished during the overhaul. This baseline is a nominal overhaul and actually rarely occurs.

There are two reasons why the actual overhaul differs from the nominal. First, the baseline overhaul includes only repair work. There are numerous Ship Alterations (SHIPALTs) which are accomplished during an actual overhaul. These SHIPALTs account for approximately 25% of the mandays expended in an overhaul. Second, approximately 30% of the OWP requires repair work that is not specifically described. For example, "restore the fresh water system and test for proper operation" does not enumerate the number of valves which should be overhauled or replaced. Depending on the condition of the system being repaired, the actual work required to "restore" the system can vary significantly. One significant factor which causes varying equipment conditions is the operating environment of the ship, i.e. warm water, arctic, etc. Because of security restrictions regarding the operations of submarines, no such data has been available to the shipyards for analysis. Therefore, there will normally be "growth" or "new work" in any overhaul. This "growth" and "new work" may be the result of the ship differences just discussed or equipment condition as described below.

GROWTH

This is an increase in the amount of work required to complete an equipment repair. Growth is normally experienced in repairs where the condition of the equipment is unknown prior to opening it for inspection. The CES is based on a theoretical standard amount of work to repair, however, actual equipment condition is usually worse than the theoretical standard. Growth work must be accomplished to complete the equipment repair. The cost of growth work must be estimated in the cost of completing the overhaul.

NEW WORK

This is additional work discovered during an equipment repair which is not directly related to the repair job. It may or may not be required to complete the specific equipment repair, but usually does affect overall system restoration. If the customer desires the work to be accomplished then he must pay for it. As the cost of New Work is borne by the customer, it is not estimated in the cost of completing the overhaul.

STANDARDS FOR PLANNING SHIP OVERHAULS

Individual planners are required to identify the standards which they have applied in their key op manhour estimates. There are four standards which are used:

U Standard - A NAVSEA universal standard. It may have been a particular Shipyard's E Standard (see below) or one that NAVSEA developed internally.

E Standard - An engineered standard which has been developed at MINSY.

A Standard - A planner's own estimate based on personal experience.

O Standard - A standard in name only. It is used only when none of the above standards apply. It is the planner's best estimate based on personal experience in related work.

The above standards are listed in order of their precedence. On average, 65% of the estimates are based on "E" or "U" standards, 25% on "A" standards, and 10% on "O" standards.

Note that these standards are applied at the key op level. The CES described earlier pertains to SWLIN level work. The manhours estimated for the key ops cannot exceed the CES for the SWLINs to which they aggregate. For example, if a

SWLIN is authorized 1000 manhours by the CES and is comprised of 100 key ops, the total manhours estimated for those key ops cannot exceed 1000. In order to meet that 1000 manhour ceiling, individual key op estimates must be adjusted so that their sum does not exceed 1000.

Having identified the relevant terms a discussion of the cost estimating process is now possible.

B. THE MANDAY ESTIMATING PROCESS

Ship overhauls are planned three to five years from the projected start date in accordance with the Navy's ship overhaul plan maintained by NAVSEA. The initial figures employed for planning purposes are very general and are used for workload planning rather than cost estimation. The actual cost estimation process begins with the receipt of the Overhaul Work Package (OWP). This OWP is initiated by the Type Commander and lists all work (repair and SHIPALTs) required to be performed during the overhaul. It is presented in an approved Work Breakdown Structure (WBS).

The OWP is first reviewed by the Planning and Estimating Section (P&E). The planners estimate manhour requirements for each SWLIN, by line item, in the OWP. The total estimate cannot exceed the Class Estimating Standard for that SWLIN. These estimates are then aggregated to the total repair estimate. This is the **"P & E Initial Estimate"** in Figure 4.

It is important to recognize that this total repair estimate is an aggregate of mandays required to accomplish each individual line item in the OWP. The estimate reflects the standards for individual SWLINs. It does not account for actual mandays which will be affected by scheduling, delays, workman expertise, growth, etc. Thus, it is only the aggregate of all SWLIN estimates, a benchmark planning figure, which must be adjusted by management to reflect the Shipyard's standards for planned execution of the work package. This factoring is accomplished at two levels.

1. **Level One Factoring.**

First, the **"P & E Initial Estimate"** is reviewed by the P&E Officer and the Type Desk Assistant. The P&E Officer accelerates the original estimate by factors provided by NAVSEA. These factors incorporate Navy-wide historical growth into the estimate. This revised figure is called the **"Should Cost Analysis Record" (SCAR)**. It is NAVSEA's standard for accomplishment of the overhaul. Simultaneously, the Type Desk Assistant accelerates the original P&E estimate by two factors. First, a historical MINSY performance factor will be applied. This figure accounts for all inefficiencies in the execution of the repair package, avoidable and unavoidable, which have historically affected MINSY. The work progress branch collects this performance data. Second, a growth factor reflecting historical growth in repairs experienced at MINSY is applied. This data is maintained by the Type Desk Assistant. The resulting estimate is called a **"Predicted End Cost" (PEC)**. The PEC represents the Shipyard's standard for accomplishment of the overhaul. It cannot exceed the ceiling established in the Class Estimating Standards.

2. **Level Two Factoring.**

Thus far, there has been no allowance for performance variation among shops. The above variations from estimates have been due to historical growth and outside factors. In order to more accurately predict what an overhaul will cost, a performance factor must be applied. These performance factors are maintained by work center. Application of the performance factors, however, is not an automatic process. A performance factor cannot be applied if the resultant budgeted mandays (SCAR x Performance Factor) exceeds the PEC. Therefore, performance factors are limited to keep budgeted mandays within the PEC. These are the "**Shop Level Performance Factors**" referred to in Figure 4.

The final step in the cost estimation process is the assignment of the **Shipyard Commander's Management Reserve**. If the total budgeted mandays is less than the number of mandays used to compute the PEC, and the difference represents an acceptable management reserve, then no adjustment to the performance factors assigned at Level Two is necessary. If the overall budgeted mandays (SCAR x Performance Factor) equals the PEC and the Shipyard Commander wishes to retain a management reserve then performance factors will be adjusted as necessary to reduce budgeted mandays to a level which will support the Shipyard Commander's desired management reserve. This final PEC then becomes the shipyard's "**Final Overhaul Budget**" (in mandays).

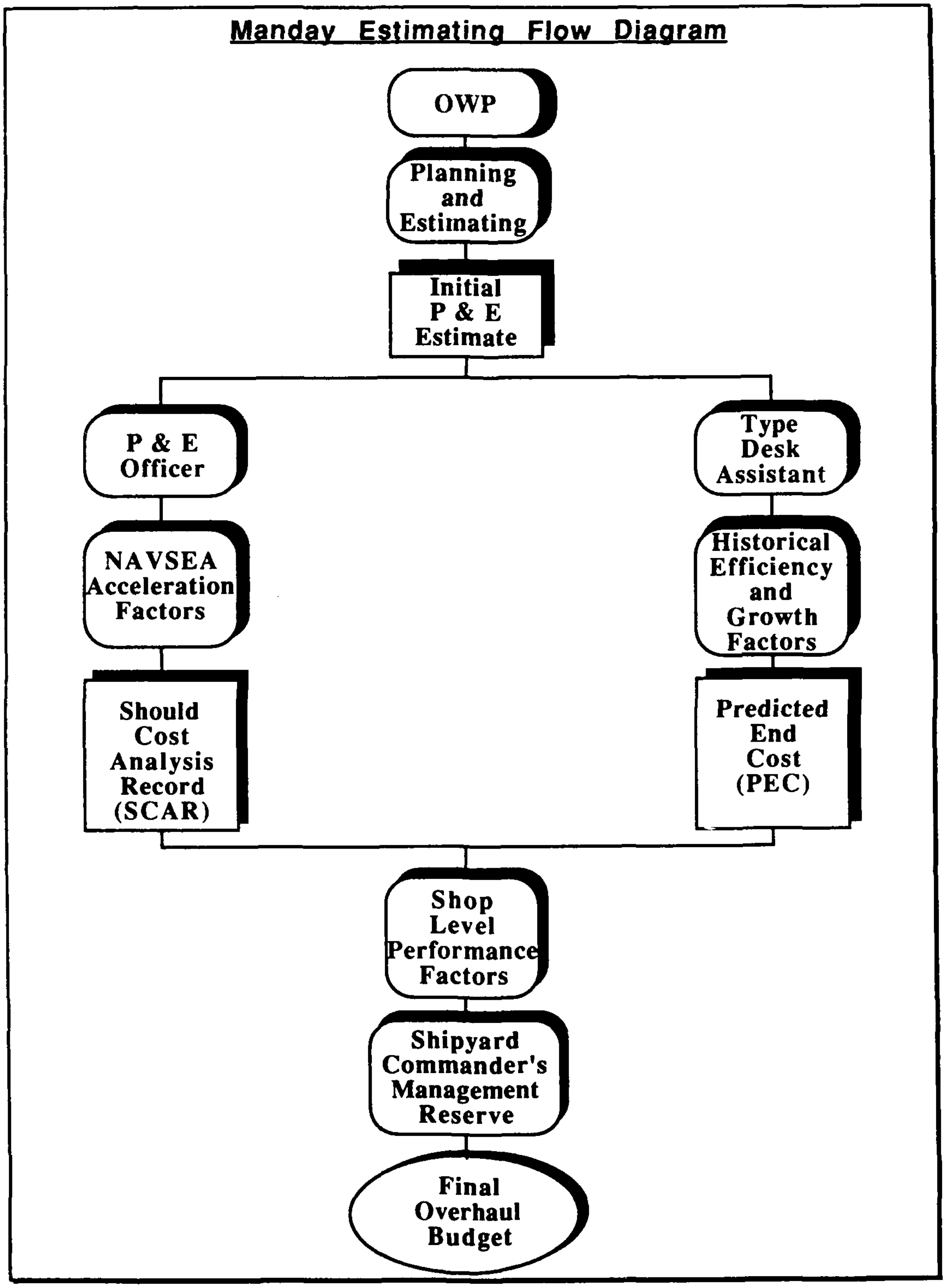

Figure 4. Manday Estimating Flow Diagram

V. ANALYSIS OF THE C/SCS SYSTEM

This chapter will provide an analysis of the C/SCS system from the perspective of its accomplishment of its developers' goals. Recommendations to improve or correct problems noted in this chapter are contained in Chapter VII.

A. MINSY CONCEPT OF THE C/SCS

In its desk guide on the system, MINSY has stated four purposes for the C/SCS :

- to provide cost and schedule performance indicators on key ops and line items currently being worked on
- to allow the foremen and general foremen to take informed corrective action
- to show the effects of corrective action while it is being taken
- to assure waterfront managers their assessment of the situation is being provided to the shipyard's general management

The concept stated above does not elaborate on some basic questions. To whom are the cost and schedule indicators to be provided? What are the decision needs of management? Will the system identify only problems which are controllable by appropriate management levels? Some assumptions will have to be made regarding these questions.

This chapter will analyze the current system to determine if it fulfills these goals as presently structured.

1. The Indicators

This section will review the accuracy of inputs and validity of uses for the cost and schedule performance indicators.

a. The Cost Performance Indicators

(1) Earned Value Index. The notion of an Earned Value Index, dollars of revenue earned for dollars of costs expended , is an appealing one. The underlying inputs to such an index must be valid, however, if the appeal is to be justified, and the index must actually and accurately measure some quantity or factor which managers can control for it to be useful.

The EVI inputs, as noted in Chapter III, are budgeted hours, actual hours expended and physical progress. Are they valid?

Budgeted hours are based on two components, the Class Estimating Standards and shop Performance Factors. As noted in Chapter IV, the Class Estimating Standards are not derived at the Shipyard, but are directed by NAVSEA with only minor adjustments allowed. Moreover, the shop Performance Factors used in the computation of budgeted hours are not the actual historical Performance Factors. Thus, the budgeted hours reflect neither MINSY's management standards nor accurate past performance. The basic measurement mark, budgeted hours, has no real meaning in a cost control sense. It is not an accurate benchmark.

Actual hours expended are submitted by the foremen. It is imperative that these actual hours be accurately charged to the right job so that the computer will credit them accordingly. MINSY has an internal review section which audits direct labor charges for charging accuracy. Based on the most recent audits, the internal review section estimates only about 70% of the direct labor charges are accurate. The remaining 30% are mainly attributable to unintentional error. There has only been one instance to date where disciplinary action for intentional mischarging has been recommended by the internal review section.

The final input is physical progress expressed as "percent complete". If a job is small, less than two to three weeks or 500 manhours, then a general estimate is satisfactory. This general estimate is strictly judgmental. If the job is bigger than two to three weeks or 500 manhours, the foremen are supposed to break it down into increments of work. These increments are defined by individual foremen and are also strictly judgmental. The following example from the C/SCS Desk Guide is a representative illustration of the method.

TABLE IV. Physical Progress Computation

KEY OP: Repair Four Vent Fans

Major Steps	Budgeted M/H	% Complete	Cum%
Disassemble	100	17	17
Inspection and Report	20	3	20
Bake Stator	50	8	28
Groom Rotor	55	9	37
Replace Brushes	75	13	50
Replace Bearings	75	13	63
Reassemble	150	25	88
Test	75	13	101
	600	101	

The foreman must now translate the above work breakdown into ten percent key op completion increments. The Desk Guide example provides the following breakdown.

TABLE V. Physical Progress in Ten Percent Increments

Increment	Work Description	Cumulative %
10	Disassemble (First 2)	17
20	Finish Disassemble, (remaining 2)	20
	Inspect & Report	
30	Bake Stator	28
40	Groom Rotor	37
50	Replace Brushes	50
60	Replace Bearings	63
70		
80	Reassemble (First 2)	
90	Reassemble (Remaining 2)	88
100	Test	101

In the above example, the foreman would associate his percentage completion in manhours with the nearest completion percentage by major step. This will create some reporting problems as work progresses.

For example, the foreman estimated it would take 100 manhours to disassemble all four vent fans and 20 hours to complete the inspection and report. This 120 manhours accounts for twenty percent of his budgeted manhours and correlates nicely with his computation of twenty percent physical progress. However, consider that the four vent fans are disassembled at the time he reports his physical progress, but he will not start the inspection until the next day. He has expended 100 manhours and only completed ten percent of the key op. As derived in the following equztion, this will give him an EVI of .60.

$$600 \text{ M/H budgeted} \times 10\% \text{ complete} \div 100 \text{ M/H expended} = .60 \text{ EVI}$$

If he completes the inspection and report within his twenty manhour budget by the next day, his EVI will jump to 1.0. There was never a performance problem here, only a reporting one. This problem will occur again at the reassembly stage where reassembly is stretched over two increments. This reporting problem will be increasingly evident in tracking longer key ops.

The figures in Table VI below are representative of key op durations for ships in overhaul at MINSY. Based on these figures for ships currently being overhauled at MINSY, 60% of the key ops extend two or more weeks. Thus, more than half the key ops in an overhaul are vulnerable to this reporting problem.

TABLE VI. Key Op Durations

Duration	Number Key Ops	% of Key Ops	Cum %
1 week or less	2678	38.0	38.0
1 - 2 weeks	1565	22.0	60.0
2 - 3 weeks	507	7.0	6.0
3 - 4 weeks	1045	15.0	82.0
4 - 5 weeks	101	1.0	83.0
5 - 6 weeks	478	6.7	89.7
6 - 7 weeks	34	.5	90.2
7 - 8 weeks	257	3.6	93.8
8 - 9 weeks	60	1.0	94.8
9 - 10 weeks	58	.8	95.6
10 - 11 weeks	21	.3	95.9
11 - 12 weeks	192	2.7	98.6
12 - 60 weeks	128	1.8	100.4

Another problem with the method employed for reporting percentage of work completed is the use of ten percent increments. Such large increments invite equally large variations in EVIs. In the example above, consider the point at which the foreman has expended sixty three percent of his budgeted manhours and has completed replacing the bearings. His real EVI should be one. Does the foreman report sixty or seventy percent completion? His EVIs would be as computed below.

$$\frac{600\,Manhours\ Budgeted \times 60\%\ Complete}{375\ Manhours\ Actually\ Expended} = .96\,EVI$$

$$\frac{600\,Manhours\ Budgeted \times 70\%\ Complete}{375\ Manhours\ Actually\ Expended} = 1.12\,EVI$$

This sort of discrepancy will carry on throughout the overhaul. The problems identified in this small key op will be magnified in key ops of longer duration where the manhour percentages do not align as nicely with the major steps in a given process. The ten percent increments are used because the C/SCS inputs are transferred from the Shipyard MIS database which only allows a one field data entry for physical progress reporting.

The above observations certainly cast doubt on the valididty of the EVI as a performance indicator. The "budgeted hours" upon which they are based are not a performance goal, labor charging is only 70% accurate, and the ten percent completion reporting increments prevent smooth tracking of EVIs. This is not to say that an EVI cannot be a valuable performance indicator. However, as currently computed it is not. There is a benefit to the current reporting structure which bears mention. The EVI receives high level attention at MINSY. As the EVI becomes more important, the quality of the inputs from which it is derived will probably improve. Eventually, charging errors will cease to be a problem. Additionally, some of the institutional problems of work structure and work center organization will disappear. At this point, the EVIs will be valuable as a data base for trend analysis. They will still be of limited value themselves for reasons discussed above, but these problems will be constants so the trend will be valuable to management.

We will assume that the structure of the EVI can be effectively changed to produce an accurate perfomance indicator. The next question is whether it is a valid cost peformance indicator. In order for the EVI to be a cost performance indicator it must relate manhours expended with those budgeted hours remaining as well as the overall overhaul schedule. Consider the above key op example, again.

Assume the foreman has just completed baking the stator ar is reporting 30% completion. However, it took twice as long as planned to complete this step so he employed an additional fifty manhours. He would have a .82 EVI. Now consider that this fifty manhour inefficiency is not made up by exceptional efficiency in another phase of the job. Because this fifty manhours will represent an increasingly smaller percentage of the total manhours expended throughout the job, the EVI will get larger (i.e., better) even though no improvement in performance has occurred. This is illustrated in Table VII below.

TABLE VII. Physical Progress with One Instance of Work Slippage

% Complete	M/H Allowed for % Completed	Initial Inefficiency	Actual M/H Expended	EVI
30	170	50	220	.82
40	225	50	275	.87
50	300	50	350	.86
60	375	50	425	.85
70	-	-	-	-
80	450	50	500	.96
90	525	50	575	.94
100	600	50	650	.92

The EVI would have appeared to improve from .82 to .92. Since there is no schedule data, the duration of this key op is unknown. It could range from a week to three months or more. The point is that successive reports will indicate some improvement where none has occurred, thus masking the need for corrective action. In this case, the EVI was not useful in monitoring cost performance.

(2) % BAC. This figure is intended to indicate the percentage by which actual manhours expended will be over or under budgeted manhours if present performance continues. Since %BAC is the inverse of the EVI, the problems noted above in EVI accuracy cast identical doubt on the accuracy of %BAC. For the sake of further analysis of this figure, the same assumptions regarding the ability to correct these deficiencies made above will be assumed here.

Accepting the above assumptions, can %BAC be an accurate or useful projection of actual manhours to be expended? As a projection tool, %BAC is basically a simple regression using one data point, manhours versus percent complete, and the slope represented by the %BAC. There are some obvious deficiencies in such a regression. The most notable will occur in the early stages of the overhaul. First, problems encountered in early work will inordinately skew the regression line. Second, regression analysis is useful in explaining relationships within a relevant range bounded by the data sets and not very useful in trying to extrapolate these relationships outside the range. The two graphs below were constructed from data contained in weekly C/SCS reports and represent reported %BACs for two ships at various percentages of overhaul completion.

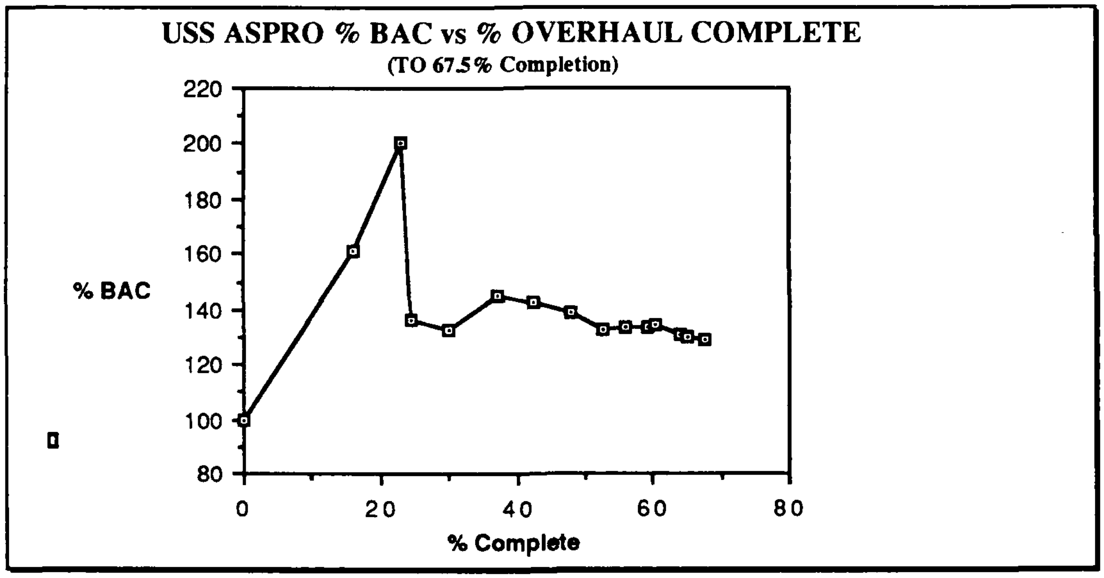

Figure 5. USS ASPRO Percent BAC vs Percent Complete

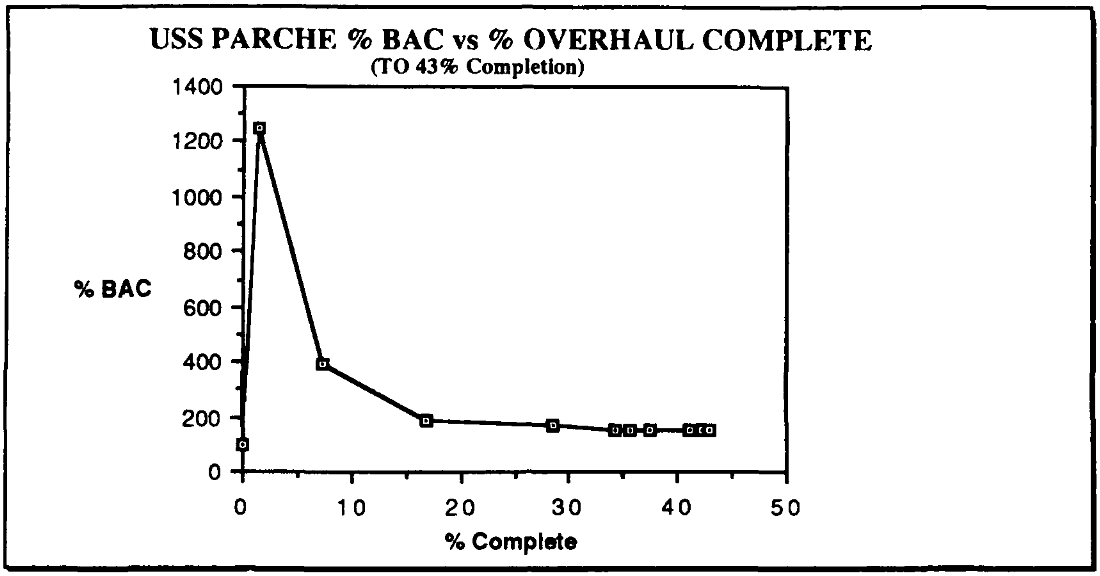

Figure 6. USS PARCHE Percent BAC vs Percent Complete

As these two graphs illustrate, %BAC figures are grossly exaggerated in the initial phases of an overhaul. Even up to the 50% completion point, the figures still project overruns in excess of 100%.

One reason which might help explain this inaccuracy is the shape of the work curve. The graph of manhours expended vs. time expired is curvilinear.

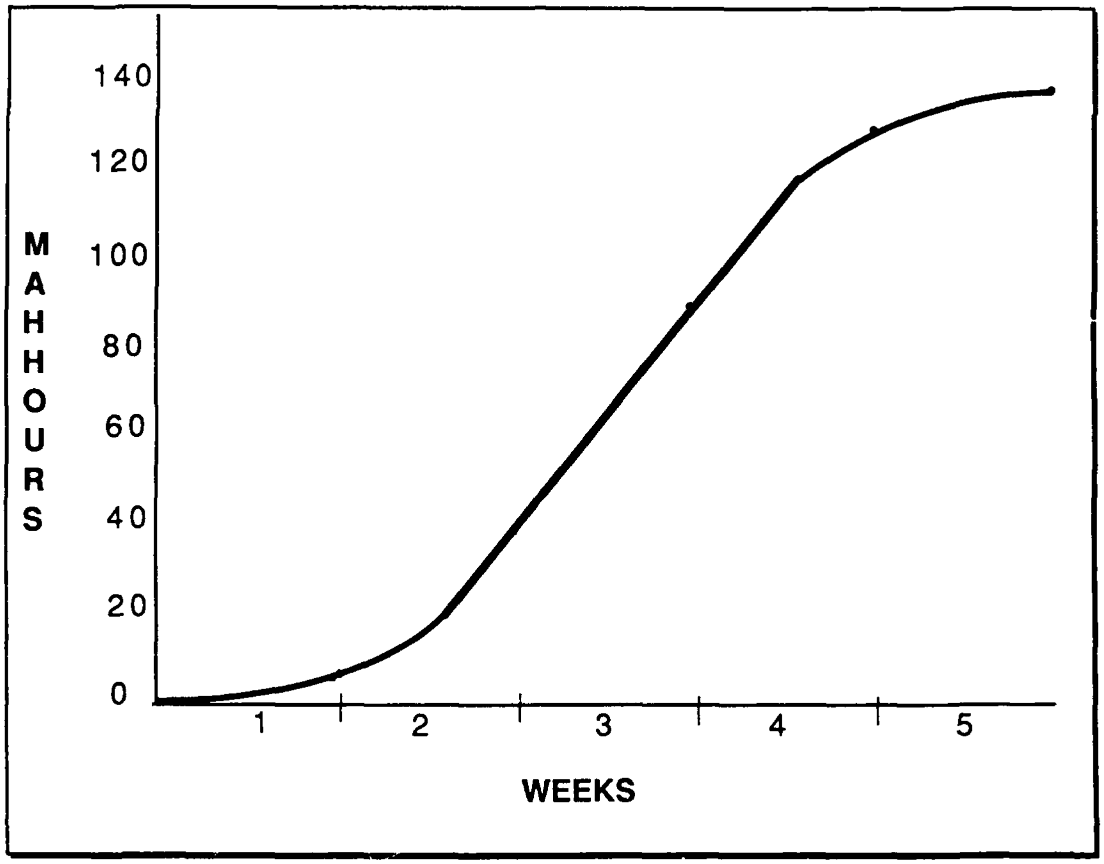

Figure 7. Budget at Completion Computation Assuming Past Performance Will Continue

The %BAC, as stated above, is a linear regression. This problem will be discussed at greater length in Chapter VII. The point to be made here is that %BAC is not a useful tool for predicting actual manhours required to complete an overhaul.

b.The Schedule Performance Indicators

(1) <u>Estimated Completion Date.</u> The estimated completion date is computed in a three step process.

$$\frac{\textit{\% Complete}}{\textit{Work days between actual start date and today}} = \textit{\% Completed Each Day}$$

$$\frac{\textit{100\% Complete}}{\textit{\% Completed each day}} = \textit{Total Days to Complete}$$

Actual Start Date + Total Days to Complete = Estimated Completion Date

As stated in the MINSY C/SCS Desk Guide, "This prediction is based on the present rate of completion continuing from today until the key op is complete." The problem is that the computation does not produce a current completion rate. It produces an aggregate completion rate to date. Thus, it does not reflect current completion trends. Consider the example in Table VIII of a ficticious key op with a ten week (50 working days) duration which started on D+1. In the third week only eight percent of the work is accomplished vice ten percent. This slippage is not regained in the remaining seven weeks, however, the required ten percent per week is accomplished.

TABLE VIII. Completion Date Estimate with One Time Work Slippage

	% Complete	Work Days since D+1	% Comp each day	Total Days to Comp	Est Comp Date
Week 1	10	5	2.0	50.0	D+50
Week 2	20	10	2.0	50.0	D+50
Week 3	30	15	2.0	50.0	D+50
Week 4	38	20	1.9	52.6	D+52.6
Week 5	48	25	1.92	52.0	D+52
Week 6	58	30	1.93	51.7	D+51.7
Week 7	68	5	1.94	51.5	D+51.5
Week 8	78	40	1.95	51.3	D+51.3
Week 9	88	45	1.96	51.1	D+51.1
Week 10	98	50	1.96	51.1	D+51.1

Notice that the estimated completion date computed at the initial work slippage was 1.5 days different than that which actually resulted. (Estimated Completion Date at end of Week 3 is D+52.6. Estimated Completion Date at end of Week 10 is D+51.1. 52.6 - 51.1 = 1.5 days.) In actuality, with progress being reported in ten percent increments, this work slippage would never be evident until the final 1.1 manday overrun was faced at key op completion. This is because the work would be reported complete to the nearest ten percent increment. Therefore, the Estimated Completion Date would always be D+50. The slippage would not be evident until the key op was not closed out on time. At that point there would still be 1.1 days of production work required to complete the job.

Now consider Table IX with the same slippage in week three, but this time it will be the start of a trend which will continue.

TABLE IX. Estimated Completion Date with Continuous Work Slippage

	% Complete	Work Days since D+1	% Comp each day	Total Days to Comp	Est Comp Date
Week 1	10	5	2.0	50.0	D+50
Week 2	20	10	2.0	50.0	D+50
Week 3	30	15	2.0	50.0	D+50
Week 4	38	20	1.9	52.6	D+52.6
Week 5	46	25	1.84	54.3	D+54.3
Week 6	54	30	1.8	55.5	D+55.5
Week 7	62	35	1.77	56.4	D+56.4
Week 8	71	40	1.78	56.3	D+56.3
Week 9	79	45	1.75	57.0	D+57
Week 10	87	50	1.74	57.5	D+57.5

The difference between the estimated completion date at the end of the ten weeks for the trend slip is 6 days more than for the one time slippage. As in the previous report, the ten percent reporting increments would cause even greater confusion. If the foreman wanted to hide his work slippage, he could round his completion percentages up to the nearest ten percent. The work slippage would not be apparent until Week 9 when the work was actually five and one half mandays behind. (Week 9 is the first week when the completion percentage could not be rounded up to the expected level.) A report which accounted for current performance trends rather than an aggregated historical performance point would be more useful.

(2) Estimate to Complete Variance. This figure is calculated as follows.

Scheduled Completion Date - Estimated Completion Date = Variance

Notwithstanding the problem with the Estimated Completion Date which was noted above, this variance factor should be accurate. However, the report does not provide any indication of the criticality of unfavorable variances. If a foreman wishes to regain his schedule he must incur more manhours (unless he finds some extraordinary efficiency somewhere). These manhours will cost money and drive his EVI down. It may be necessary to expend additional manhours to regain schedule if the unfavorable variance affects a critical path in the schedule. If it does not, however, it may be cost ineffective to regain the slippage. The decision to regain schedule slippage is one which the foreman must make, but he is not provided with critical path information. Thus, real time cost decisions cannot be made at his level.

Additionally, the variance and its underlying estimated completion date are subject to the same dependence on physical progress reporting which was discussed as a problem with the EVI above.

2. <u>Taking Informed Corrective Action.</u>

In order to take informed corrective action, the monitoring system must identify deficiencies which management can control and correct. The EVI identifies variances between "budgeted" hours and actual hours. The "budgeted" hours, however, do not represent a real management target. They have not been derived from waterfront input, nor are they management's best estimate of expected cost. Rather, they are a hybrid of corporate level standards (NAVSEA acceleration factors) and a "least deviation" adjustment by the Shipyard. Moreover, they do not include the schedule component of the real costs the Shipyard will bear. Therefore, the EVI identifies variances against an unreal target and only provides one part of the information necessary to take informed cost control corrective action.

3. Showing the Effects of Corrective Action While it is Being Taken.

There are two problems with the current system which hinder meeting this goal. First, as discussed above, physical progress is only reported in ten percent increments. This creates a reporting lag in longer key ops and reporting jumps in shorter ones. Second, the C/SCS reports are printed weekly. Roughly 38% of the key ops in an overhaul are completed in one week or less. Thus, the system does not support tracking almost one half of the production work during an overhaul.

4. Waterfront Managers' Assessments Provided to Shipyard General Management.

This goal is met at the bi-weekly cost review meetings. The senior line management represent their line foremen in a discussion of current EVIs with the Shipyard Commander. As stated earlier, the primary benefit of this senior level review is the attention it brings to the inputs from which the EVIs are computed.

VI. MANAGEMENT PERCEPTION OF C/SCS

A. SOURCE OF INFORMATION

This chapter identifies management attitudes, perceptions, and use of C/SCS. As noted in Chapter I, personal interviews with managers at each level of the line organizational structure were not possible. The authors were informed that interviews with even one or two managers of each level would be costly in terms of the use of their time. The authors considered attempting to arrange interviews outside of the managers' working hours, but realized that such an arrangement would require several more visits to Mare Island for which travel funds were not available. Therefore, the majority of the observations discussed below are based on information provided by staff managers who have been associated with the planning, implementation and monitoring of the system.

Much of the information was obtained from interviews with Mr. Roy Burchell, the senior cost analyst of the Comptroller Department. His knowledge of management perceptions about the system stems from over two years of discussion, observation and association with all levels of waterfront managers in their use of C/SCS. Mr. Burchell also provided the authors a sampling of the results of a recently conducted internal survey of line management understanding and acceptance of the C/SCS. Only a small number of the actual survey sheets were available, but we feel that some of the comments are worthy of mention.

The survey consisted of face to face interviews between members of the audit team and the managers. Since support of C/SCS is mandated within the shipyard, managers may have been prone to provide positive answers due to a lack of anonymity. This potential bias should be considered when interpreting their responses.

The authors gained additional insight from interviews with staff managers involved with the planning, implementation and monitoring of the system. They expanded on the findings of the survey, providing their analysis of some of the problems identified.

Finally, the authors attended two of the biweekly cost analysis meetings which provided first hand observation of the attitudes of all levels of managers toward C/SCS.

B. LINE AND STAFF MANAGEMENT PERCEPTIONS OF C/SCS

The survey results, discussions with staff managers and observations at the cost analysis meetings support the discussion below. Four basic areas of actual or potential problems are identified. They include concerns about report timeliness, understanding and use of the system, charging accuracy and line management acceptance of the system.

1. Timeliness of Reports

Distribution of reports was identified as a significant problem. As previously noted, managers have to arrange to pick up copies of the reports they desired. Additionally, although new reports are being generated, there is no method of informing those who may be interested in the use of the reports of their existence.

Line management receives C/SCS reports through hard copy distribution on a weekly basis. Labor charging and physical progress data are collected daily through the MIS mainframe. Line managers have access to remote terminals connected to the mainframe and can readily retrieve information stored therein. However, there are no remote terminals tied to the Hewlett Packard minicomputer to offer online access to the C/SCS information. Further, since labor and progress data must be transferred by magnetic tape to the C/SCS computer, daily updates of C/SCS reports are not made. Inability to access online data decreases the timeliness and accuracy of the reports.

Every manager interviewed acknowledged use of one or more of the C/SCS reports. Most indicated that they received the reports on Monday or Tuesday of each week. A few said the reports arrived as late as Wednesday or Thursday and one shop foreman complained that he had not received a report in six weeks. The response of the latter foreman did not indicate whether he was unaware that it was his responsibility to ask for the report or was aware and simply did not bother to make arrangements to retrieve it.

2. Management Understanding and Use of the System

All shop foremen declared they had received training in C/SCS and the majority felt the training was adequate. One indicated that more emphasis was needed on understanding and using the reports. Middle and upper level managers indicated the need for specialized C/SCS training for their benefit.

Relatively few of the Superintendents indicated their use of C/SCS to identify cost and schedule problems. Those who did use the reports for that purpose could only identify cost problems. None of the Superintendents felt they were allowed input to the budgeted hours used in C/SCS.

All of the Group Superintendents supported the concept of Work Center 29 though some felt that there was a negative stigma associated with admitting to having excess labor available. One said that his General Foremen were hesitant to use Work Center 29 because it was often difficult to get their good men back when work levels increased and their labor was needed. Most of the Shop Superintendents said they had used Work Center 29, but primarily for light duty personnel. Only one said that he sent excess labor there.

The majority of the Superintendents understood that shop performance factors were the primary difference between the SCAR and the C/SCS budget figures. However, only one Shop Superintendent could identify his performance factors.

The major problem identified by General and Line Foremen was inadequacy in the Work Breakdown Structure. None felt they had the opportunity to provide inputs to key operation structure. Line foremen indicated they often had key ops that worked toward more than one milestone. They complained that lack of involvement in the planning and estimating process required them to seek changes to key op structure and budget allowances while the job was in progress.

3. Charging Accuracy

Group and Shop Superintendents indicated reliance on the Internal Review division to enforce charging accuracy. A few used additional methods such as weekly meetings and spot checks by their general foremen. Many Superintendents said they used C/SCS reports to determine if their subordinates were reporting physical progress. Others relied on general foremen to enforce physical progress reporting.

Some possible causes of charging inaccuracies were identified by staff managers. There exists a probability that line managers may feel coerced to mischarge in order to boost their EVI. Only one of the foremen interviewed admitted to this type of pressure, but it is not unreasonable to expect that others are subject to the same pressure.

There is also some indication that foremen intentionally mischarge in order to avoid having charges applied to their overhead budget. Although overhead is not controlled by C/SCS, it is the subject of close scrutiny and foremen are pressured to remain within the budgeted amount. If a foreman feels the need to improve a particularly bad EVI, there is room for some manipulation of the system. For instance, he could report a key op complete when there is still work remaining. Then, his alternatives for charging the remainder of the work are to mischarge to another key op or charge to the closed key op knowing that the computer will eventually change that charge to overhead. But since he does not want to increase his overhead, his best alternative is to mischarge.

The Internal Review division has uncovered a number of these intentional mischarges. Those found to be intentionally mischarging are subject to discipline. According to the head of Internal Review, past actions have been mild, usually a verbal warning. However, Internal Review has taken a more active role in monitoring the disciplinary actions with the intention of notifying the next line of management if more serious discipline is warranted.

4. Management Acceptance of the System

Senior staff managers feel that C/SCS has generally been accepted by the waterfront line management. However, there are indications that an increasing number of managers are becoming disillusioned with the system. Managers are beginning to realize that they are being measured against budgets and work breakdown structures which have been developed without their input.

One of the most dominant topics of discussion at the biweekly cost analysis meetings is closing key ops to charges. Weeks after a milestone is reported complete, numerous key ops associated with the milestone remain open to charges. The faulty work breakdown structure is the most prominent explanation given by the foremen. There is an avenue available for the managers to have the key op aligned to another milestone, but there appears to be growing resentment toward having to take such actions. There are also complaints that problems identified are corrected for the hull in process, but the same problems appear on subsequent hulls.

Inaccuracy in reports and unreasonable budgets are two other areas mentioned by line management during the meetings. In defense of a particularly low EVI, one manager noted that there was a failure in the computer which he had been attempting to have corrected for four weeks. Another manager indicated that the manhours budgeted for his shop were far below the amount that had been budgeted for the same work in the past.

The overall tone of the meetings showed defensiveness on the part of the line managers being asked to defend their low EVI's to the Shipyard Commander. There was also the feeling that an adversarial relationship existed between the planners and estimators who prepared the budget inputs and the production line managers who executed the plan.

There is increasing frustration among managers who, in good faith, attempt to input accurate charge and progress data and then get back reports that present an inaccurate assessment of performance. Upper level line managers are most interested in the percent budgeted at completion indicator. However, they do not feel that the figure is reliable until the overhaul is approximately half finished.

In conclusion, it appears that upper level line management are not totally supportive of C/SCS. Their responses to the survey indicate that they do not fully understand the system. Perhaps specialized training for them will increase their awareness and support. However, these upper level managers may have enough understanding of the system to recognize the arbitrariness of both the inputs and outputs of the system. If so, it is unlikely that they will increase their support until the problems are eliminated.

Lower level line managers seem to have a far better understanding of the system. It seems that many of them readily accepted the concept and expected that the system would be useful for them. Unfortunately, a trend of increasing disillusionment with the system is now visible. If those managers who have been striving to make the system work properly observe others manipulating it and not being penalized, they are likely to discontinue their support.

VII. RECOMMENDATIONS

The previous two chapters have identified myriad problems with the implementation of the C/SCS at MINSY. This chapter will address recommendations which the authors believe will provide a better cost/schedule control system. These recommendations are made without regard to incremental costs involved in their implementation. They are made strictly from an overall system effectiveness standpoint in which the benefits are assumed to exceed the added costs. The cost effectiveness of these recommendations is appropriately the subject of additional thesis research. Additionally, the recommendations contained in this chapter deal with direct labor only. Overhead and material control are beyond the scope of this thesis.

The recommendations provided below are organized in the following framework:

- Computer support for an effective system
- Improved estimating process
- Making the current reporting structure more useful
- Interfacing the current system with the overhaul schedule

A. COMPUTER SUPPORT FOR AN EFFECTIVE SYSTEM

There is an often noted tendency for managers to believe that any management problem can be solved by a computer based information system. This has proven to be untrue in many instances. Moreover, in those instances where a computer system might actually be required, the actual system implementation has been inadequate. The authors recognize both these verities. It is not blithely, then, that we recommend an improved computer support system for MINSY. As will be discussed below, the type of information processing and presentation needed lends itself ideally to the use of a computer. The general sort of capabilities and uses for improved computer support will be discussed, however, no specific system or equipment will be recommended. Such recommendations are more appropriately made by persons with computer system and Management Information Systems expertise. This is another area for further research which will be recommended later in the chapter. The authors' intentions are to describe a scenario for computer assisted decision making devoid of any particular hardware or software decisions.

The discussion of the recommended computer support system will be divided into three categories: the data base, equipment capabilities, and reports.

1. The Data Base

The information stored in the data base should be complete enough and structured in a manner to provide assistance in the following management activities:

- Workload forecasting (currently available)
- Overhaul cost estimating
- Actual cost monitoring
- Real time work progress monitoring

a. *Workload Forecasting*

The system currently in use provides this capability. As this aspect of Shipyard planning has no significant impact on the value of the C/SCS as a cost monitoring tool, it has not been discussed in this paper. Therefore, no recommendations are considered appropriate. This capability is mentioned here because it supports the overhaul cost estimating process described below.

b. *Overhaul Cost Estimating*

Consider the following scenario. A ship is scheduled for an overhaul at MINSY. The OWP is received. The P & E Section requests a computer run estimating the cost of the overhaul. The computer provides an estimate, broken down by milestone and key op, of the cost to complete the work identified in the

OWP. All the required key ops will also be printed. Let us look at the data base and its manipulation which made this estimate report possible.

The baseline OWP for 637 Class submarines is a function of both ship age and position in overhaul cycle. (MINSY is primarily involved in overhauling 637 Class submarines. They will shortly overhaul their first 688 Class, but will remain in the 637 Class overhaul business as their primary function.) The baseline OWP for similar ships, then, is identical. These OWP work descriptions will be in the data base. MINSY's scheduled workload will be in the data base. The available manpower, historical work center performance factors , and MINSY's direct labor standards will also be in the data base.

When the estimate is requested, the computer will first compare the current workload with the manpower pool to determine which work centers are available to acomplish the work. If there are inadequate resources available, an algorithm to determine the number of additional workers required will be applied. When the computer has identified which work center will perform the work, it will accelerate the MINSY standards by the work centers' performance factors to determine the actual mandays the work centers will require to complete the work. (This step is intended to provide a more accurate manday estimate. A separate goal of management would likely be to reduce all performance factors to 1:1 so that all work centers meet the standard.) The computer can then generate a full list of key ops, by milestone, with their manday/manhour estimates which truly reflect what the Shipyard expects to expend in completing those jobs. This process will produce a more accurate manday (labor quantity) estimate than is currently achieved. This more accurate labor quantity estimate may lead to a more accurate cost estimate as decsribed below.

The computer may provide a more accurate cost estimate if the manhour requirements in the data base are broken down by paygrade. Shipboard maintenance cards are broken down in this manner. Every key op could then be costed at a standard worker rate for the actual paygrade expected to perform the work in accordance with the standard. Such information could also be useful in follow-on variance analysis to determine if unfavorable variances can be accounted for in part by the use of higher priced labor than the standard allowed (labor price mix variance).

In addition to the cost estimate, the computer can also print all the key ops which are now prepared manually. It is not unusual for planners to duplicate copies of old key ops and put the current ship's name on them. This is because the work is so similar for ships of the same Class. This redundant effort could be eliminated if the computer printed the key ops.

c. Actual Cost Monitoring

Monitoring costs by mandays provides an average direct labor dollar estimate of expenses incurred. The payroll records collect timecard data by individual worker. All direct labor charges must be made against an open job. Therefore, the data exists to aggregate the timecard charges and produce a dollar figure of direct labor dollar charges against all key ops. An aggregation of dollar charges is currently compiled quarterly for reporting to NAVSEA. However, the information is not routinely included in the C/SCS reports. The "cost" portion of the C/SCS is reviewed in manday terms not dollars. Waterfront managers manage people, not dollars. Yet their management of work assignments may lead to unfavorable labor "mix" variances. The appropriate waterfront managers must be sensitive to these mix variances as they assign work. Actual dollar monitoring can allow the timely identification of cost overruns attributable to such practices as using overqualified (and expensive) labor to accomplish work.

d. Real time Work Progress Monitoring

As noted in Chapter Five, almost half of the key ops in an average overhaul are of one week or less duration. Weekly reports offer no support to management in monitoring work progress. What is needed is an online system which can be updated at least daily to provide real time information to the responsible manager. The data base, then, must be capable of being updated by and providing current information to online terminals. The mainframe computer does have remote terminals throughout the Shipyard, but the C/SCS information is processed on the HP 1000 which does not have remote terminal access.

2. Equipment Capabilities

The current system has three major failings. The mainframe does not have sufficient memory to store the data base required above. The remote terminals do not access the C/SCS software for data input and information retrieval. The C/SCS and ARTEMIS scheduling systems are not linked directly to the mainframe. In order to establish the ability to manipulate a data base as described above, a different hardware system is needed. Whether that different system uses the current hardware with expanded memory or all new hardware is not material. The point is that there should be one mainframe with adequate memory. All computer support should eminate from this central memory/data base. Waterfront managers (most likely at the General Foreman level) must have remote terminals where their subordinate managers can update work progress and they can retrieve timely information to use in monitoring that work progress.

3. Reports

The fewer reports generated by any system, the less time taken reading reports, and the more time available for managers to manage. This seems like a reasonable maxim, but the sad truth is that report generating systems generally swamp their users with reports. This is certainly true at MINSY. The list of titles of computer generated reports is almost three inches thick. There should be more use made of selected dissemination of information. Perhaps a better phrase is "exception reports". Managers do not need reports which are cluttered with performance information on the work which has been completed since the last report. Recall from Chapter Five that 44% of the key ops are one week or less in duration. If the job is complete, it should not be reported on the weekly report. The lower level line manager will know the status of his jobs by looking at his real time terminal information. When a job is complete he no longer needs to track it. Senior management does not need to wade through the work which has been accomplished on time to find that which has not. All that is necessary is a listing of those jobs which have not been accomplished on time--the exceptions.

In fact, if the waterfront manager has his real time updates, he should not need any reports on the subject routed to him. These paper reports are valuable to higher management levels which are not accessing the online terminals and are conducting higher level reviews with a less than daily frequency. The reports must be reclassified, then, to meet two criterion: management level of review, and duration of work covered in the report.

Those reports which are disseminated must be done so in a reliable manner. The current distribution system does not ensure all the waterfront managers get their report copies. If senior management wishes to impress subordinate levels with the importance of the C/SCS then it must take an equal interest in their receiving the reports.

B. IMPROVING THE ESTIMATING PROCESS

Setting aside the question of manhours/days rather than dollars as an estimating base, the current system for estimating resources required to complete an overhaul is still cumbersome and convoluted. An integral part of improving a cost/schedule control system is the improvement of the underlying cost estimating process from which the performance goals are derived.

1. Set a Shipyard Standard

In the parlance of the cost accountants and industrial engineers, the standard is the standard. It is not a figure against which acceleration factors are applied or any other manipulation is performed. The standards may be derived from any combination of applied mathematics deemed necessary, but once they have been derived they must stand as the benchmark until management refines them further. There are too many standards in the Shipyard estimating process. What is the Shipyard striving to meet, the P & E Estimate, the SCAR, or the PEC? A clear standard must be developed. Moreover, for proper NAVSEA management, these standards should be uniform for all eight Naval Shipyards. As was done for the 637 Class Estimating Standards, these uniform standards should be solicited from the shipyards. Unlike the 637 Class Estimating Standards, however, there should not be a different standard for each shipyard. As noted earlier, resources differ from one shipyard to another so variances can be expected. The variances which can be accounted for by resource differences are acceptable. It is the explanation of these differences that is most important to management. The uniform standard, however, will help to bring these acceptable variances to the fore so that the unacceptable ones may be culled and addressed.

The authors recognize that the estimating process is dictated by NAVSEA and that changing the process is not just a matter of the Shipyard deciding to do so. In fact, obtaining the new computer support system discussed above may prove easier than changing the way NAVSEA directs the estimating process be accomplished. The C/SCS is an internal system, however, and it may prove beneficial to the Shipyard to implement a true cost estimating process with its own standards for use in the C/SCS.

2. Measure Against the Standard

Once realistic standards have been established, all work can be measured against them. It will be clear that the goal is to meet the standard, not which standard.

Standards are used in industry as performance measurements. Against which of the above "standards" are Shipyard managers being measured? Are Shipyard managers being measured in terms of meeting performance goals? This is another area in which the C/SCS can be used if the standards are supported by management and realistic.

C. MAKING THE CURRENT REPORTING STRUCTURE MORE USEFUL

As it exists, the C/SCS is very limited in supporting any control over the Shipyard costs or schedules. The previous section identified improvements in computer support which should enhance cost and schedule control. The next section, dealing with interfacing the C/SCS reports with the schedule will add another needed dimension. This section will address improvements to the current reporting structure which will make it more useful as a monitoring tool.

Chapter V identified three major problems with the current C/SCS:

- Accuracy of Inputs
- Validity of Indicators
- Timeliness of Reports

Report timeliness has been addressed above. Accuracy of inputs and validity of indicators will be discussed below. Additionally, a problem with the integration of the C/SCS data collection structure and the Work Breakdown Structure will be discussed. This is a generic problem not associated with any particular aspect of the report. Therefore, it was not discussed in the analysis in Chapter V.

1. <u>More Accurate Inputs</u>

As stated in Chapter V, the inputs used in the C/SCS are budgeted hours, actual hours expended, and physical progress. If Shipyard standards (as described above) are applied as the "budgeted hours" for the C/SCS, then the accuracy of this input is no longer in question. Recommendations for the remaining two inputs follow.

a. Actual Hours Expended

The audit process for direct labor charging appears to be adequate. It is imperative that fraudulent charging be dealt with effectively and accurate charging be emphasized. The current level of charging accuracy, 70%, is not considered adequate to support a meaningful C/SCS. Charging accuracy should be a performance category measured in managers' evaluations. With appropriate management attention, the charging accuracy should improve.

b. Physical Progress

`1There were three major concerns with this input. First, there is no standard measurement system for reporting physical progress. Second, the current computer system only allows reporting physical progress in ten percent increments. Third, there is no effective audit procedure for physical progress reporting.

There must be a standard means for reporting physical progress. This is necessary so that supervisory management levels can compare progress in different work centers and be confident that the reported completion percentages reflect the same amount of actual progress. Also, it must serve as a common base for an effective audit program. This standard reporting process need not be standard throughout the Shipyard, but must at least be standard within shops.

Ten percent reporting increments are inadequate. The current software should be modified to allow for reporting in unit level increments. This will be particularly important if an online system is employed, and daily progress information is available.

The physical progress "audit" procedure currently employed consists of progressmen evaluating a total of ten key ops each week. There are two problems with this system. First, ten key ops is not a statistically significant sample from a population of roughly 28,000(4 ships x approximately 7000 key ops/ship). Second, the progressmen are not considered qualified to contest the physical progress reported by the foremen.[1]

The audit program needs to be improved in these two areas: conduct statistically significant sampling, and use qualified progressmen whose assessment of physical progress will be considered accurate.

2. More Valid Indicators

The indicators reviewed in Chapter V were the EVI and %BAC. For the sake of this discussion, it will be assumed that the recommendations for improving the accuracy of the inputs to these indicators have been adopted. The remaining step is to make them more valid.

a. EVI

There must be a method for distinguishing between one time inefficiencies and inefficient trends represented by an EVI. This can be accomplished by tracking the difference between the manhours allowed for the percentage complete reported and the actual hours expended. Recall the example in Chapter V, restated in Table XI below.

TABLE XI. Physical Progress with One Instance of Work Slippage

% Complete	M/H Allowed for % Completed	Initial Inefficiency	Actual M/H Expended	EVI
30	170	50	220	.82
40	225	50	275	.87
50	300	50	350	.86
60	375	50	425	.85
70	-	-	-	-
80	450	50	500	.96
90	525	50	575	.94
100	600	50	650	.92

The initial inefficiency will recurringly appear as the difference between the manhours allowed for the percentage completed and actual manhours expended. Now consider an example where a negative performance trend exists. In the example shown in Table XII below, the foreman will start to lose ten manhours per week beginning with the 30% completion report.

TABLE XII. EVIs with Continuous Work Slippage

% Complete	M/H Allowed for % Completed	Actual M/H Expended	EVI	Δ Btwn M/H Allowed and Expended
30	170	220	.82	10
40	225	275	.87	20
50	300	350	.86	30
60	375	425	.85	40
70	-	-	-	-
80	450	500	.96	50
90	525	575	.94	60
100	600	650	.92	70

This example clearly shows the inadequacy of the EVI in highlighting a downward trend in performance. However, the final column makes the trend obvious. To facilitate the stand alone use of the report, an additional column which indicates the difference since the last report would be helpful.

b. %BAC

The problem with the %BAC is that it is a straight line projection of a curvilinear function. This can never be a reliable projection tool. The basic assumptioon behind using the reciprocal of the EVI to project %BAC is that present performance will continue. This seems to be an unwarranted assumption, particularly if management is doing its job and taking effective corrective action. The more appropriate projection would be to project the work curve from the current EVI. This is illustrated below using the work curve introduced in Chapter V.

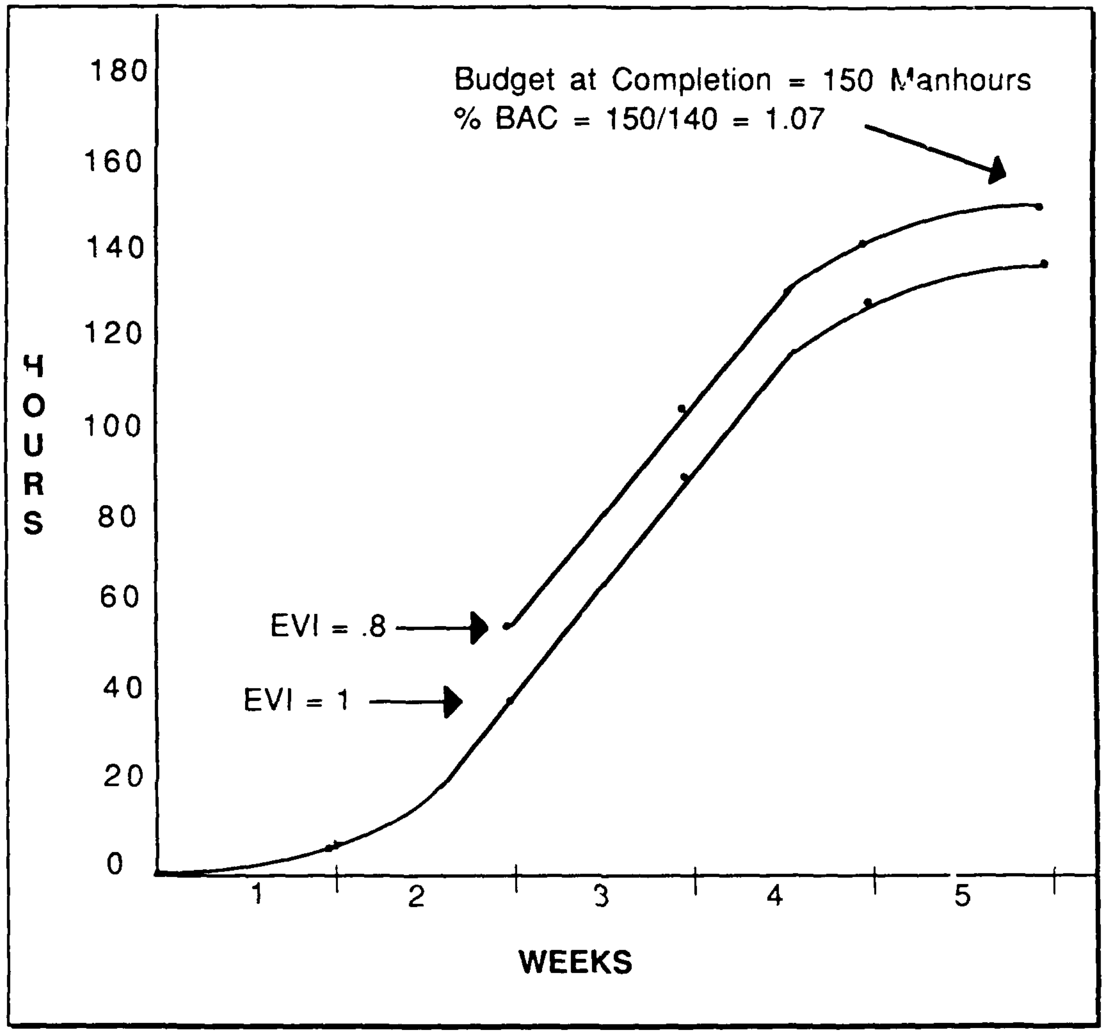

Figure 8. Budget at Completion Computation Assuming Past Performance Will Not Continue

The graph in Figure 8 above demonstratess the projection of a %BAC if the assumption that past performance will not continue, but that its effects will remain. The .80 EVI represents 50 manhours expended at the end of week two rather than the 40 manhours allowed. The current method of computing %BAC would project a 25 percent overrun (100 ÷ 1.25). The graph shows that a seven percent overrun is more likely when the unwarranted assumption is dropped. This makes sense since the ten additional hours expended represents seven percent of the

140 manhour total for the key op. Thus, a simple and more realistic method of computing %BAC is just to compute the current overrun and aggregate it throughout the job.

3. Integration with the Work Breakdown Structure

The basic problems in the integration of the C/SCS with the Work Breakdown Structure are keyop sequencing and aggregation to milestones. Both these areas are recognized as problems by the cognizant personnel at MINSY. A new program, Phase Oriented Key Op Numbering System (POKONS) is aimed at correcting the problems with the sequencing of key ops. Resolution to the problem of key ops not aggregating to discrete milestones is not yet defined. The Industrial Planning Group was working on this problem, but when it was disbanded all the data collected was discarded. This is an area which needs prompt attention if the C/SCS is expected to provide performance information which will "roll up" from the key op level to the total overhaul.

D. INTERFACING THE CURRENT SYSTEM WITH THE OVERHAUL SCHEDULE

Perhaps the most critical shortcoming in the current C/SCS implementation is that it does not provide any interface between the manhour expenditures and the overhaul schedule. This is important because key ops on the schedule's critical path with low EVIs will cost more to complete than those not on the critical path. Once a key op's EVI has dropped below one, it will cost more than budgeted to complete. However, if that key op is on a critical path then additional expenses must be incurred to regain the schedule slippage. Additionally, key ops not originally on the critical path may become critical if their slack is exceeded. These are two real concerns which the C/SCS must address.

1. Identify Key Ops on the Critical Path

There should be a separate report for tracking critical path key ops. This report periodicity should reflect the duration of the applicable key ops, i.e., semi-weekly for one week key ops. Senior management must track all critical path key ops. If daily reports are required, so be it. The online system described in the beginning of this chapter must also provide some means for identifying which key ops are critical.

2. Watch Key Ops that May Define a New Critical Path

In those key ops not on the critical path, there should be some prescribed amount of slack which can acceptably be used before flagging management attention. When that point is reached, management will have to take some action to prevent the remaining slack from being used and moving that key op onto the critical path. This slack percentage should represent a remaining time period in which management will have the opportunity to note and react to the slippage. The exact percentage will be a function of key op duration, slack time, and report periodicity.

E. SUMMARY

The purpose of this thesis was to answer the questions posed in Chapter I. The following findings are summarized.

1. Current Status of C/SCS Implementation at Mare Island Naval Shipyard.

A system is implemented which conforms to many of the NAVSEA requirements. Emphasis has been placed on training and report generation. This status is discussed in Chapter III.

2. Direct Labor Estimation

MINSY employs a complex procedure with multi-stage adjustments to estimate direct labor requirements. This process is described in Chapter IV.

3. Input Data Accuracy

Inputs to the C/SCS are not accurate. The problems associated with data accuracy are presented in Chapter V.

4. Validity of Performance Indicators.

Performance indicators are not valid. Inadequacies of the indicators are discussed in Chapter V.

5. Usefulness and Timeliness of Reports.

The reports generated by the C/SCS do not provide particularly useful or timely information. This problem is discussed in Chapter V.

F. CONCLUSIONS

Restated in operational terms, the Cost/Schedule Control System implemented at MINSY has five major shortcomings:

1) The system is intended to assist management in controlling costs and schedules, but does not present information within the context of the cost/schedule relationship.

2) The current Work Breakdown Structure does not support the framework of the data collection system.

3) Adequate auditing procedures are not in place to insure accurate data input.

4) "Costs" are monitored in average labor dollars (mandays) rather than actual labor dollars.

5) The underlying cost estimates do not provide meaningful management goals.

The first flaw is largely a function of the system having been adapted from the contracting world. The C/SCS was designed for a program manager to assess contractors' abilities to meet required acquisition milestones. As can be seen from this thesis, the system does not directly lend itself to application in an environment where the user is actually trying to control costs rather than monitor expenses and schedules. One of the more obvious problems in transferring this system to shipyard management is in the failure of the Work Breakdown Structure to support it.

The final three flaws all relate to the Shipyard's historical attention to schedule rather than costs. The use of mandays as a "cost" figure, lack of audit procedures for physical progress reporting and the circuitous manhour estimation process all reflect a system designed to provide a stable long range planning environment for the customers rather than sound financial management for the Shipyard.

The current C/SCS is really not very useful in identifying or controlling costs. What it has done, however, is to highlight the above flaws so that they may be acted upon. With continued cost consciousness support from NAVSEA these flaws can be corrected.

Costs may never subsume schedule in the operational world. Long range ship employment plans are made based on overhaul schedules. The Navy's ability to respond to tasking with sustained presence is dependent upon the adherence to schedules. What may well come of the hightened interest in overhaul costs, however, is an appreciation for the real cost of customer induced schedule perturbations. Perhaps when faced with a million dollar bill for emergent repairs the Type Commander will accept some reduced capability for the interim prior to a more normal repair cycle when costs may be half that amount. Additionally, Congress may not be so quick to expect immediate tasking response when the ability to present them with an immediate bill for maintenance costs is available. In the long run, then, perhaps the most that can be hoped for this sytem is to heighten cost awareness at all levels of the Navy and Government.

G. AREAS FOR FURTHER THESIS RESEARCH

1. Computer Support Systems for Naval Shipyards

Future research might explore an appropriate system for use in the full implementation of the C/SCS as described in this chapter.

2. Cost Effectiveness of Recommendations Contained in this Thesis

Another study could determine the cost effectiveness of procuring the type of computer system recommended in this chapter, or one which might be recommended in the thesis above.

3. Actual Dollar Cost Performance Monitoring in Naval Shipyards

An exercise that could prove extremely beneficial would be to construct a periodic reporting system which would track the actual dollars expended in the overhaul of a ship at MINSY and compare that system with the C/SCS. The objective would be to compare the two and determine which provides a better management tool for controlling costs.

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