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EVALUATION OF INVENTORY MANAGEMENT POLICIES
AT NAVAL SHIPYARDS

by

Rory L. Souther

June 1988

Thesis Advisor: Joseph G. San Miguel

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This thesis examines existing inventory management policies at naval shipyards. An evaluation of the efficiency of existing policies for obtaining and excessing materials was emphasized, and recommendations for improvement were provided. Results indicate that changes can be implemented that would decrease the quantity of material ordered and excessed without creating overhaul and repair delays. Such action would reduce the overall investment in shipyard inventories.

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Evaluation of Inventory Management Policies at Naval Shipyards

by

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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

Although the overall shipyard workload has decreased, material inventories at naval shipyards have grown significantly in recent years. Inventories at the eight naval shipyards increased 63 percent (adjusted for inflation) between 1979 and 1983, and 24 percent between 1984 and 1987. Little action has been taken to reverse this trend even though the problem has been the subject of numerous studies since 1978.

This thesis examines existing inventory management policies at naval shipyards. An evaluation of the efficiency of existing policies for obtaining and excessing materials was emphasized, and recommendations for improvement were provided. Results indicate that changes can be implemented that would decrease the quantity of material ordered and excessed without creating overhaul and repair delays. Such action would reduce the overall investment in shipyard inventories.

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I. INTRODUCTION

For many years, the major objective of naval shipyards has been to complete ship overhauls and repairs on-time or early, with the dollar costs of such repair work being a secondary consideration. Most inventory management issues are reduced to ensuring that sufficient material is on-hand for production support. Zero stockouts are assumed. The costs attributed to overhaul are considered to exceed all other costs, including the cost of investing in and holding inventory.

An extension of this maintenance philosophy required that shipyards obtain 100 percent of the material required to support repair or overhaul work on specific vessels prior to a ship's arrival [Ref. 1: para. 4.1.1]. Material requirements are based on expected or planned overhaul work, and under existing Naval Sea System Command (NAVSEA) disposal policies, the material must be retained in inventory, identified to a specific customer job order, until that job order is formally completed [Ref. 2: p. 6-7-22]. As a result, material is often ordered and held in inventory to support future work when identical material exists in inventory.

Shipyards additionally lack a definitive policy which contributes to the adjustment of inventory levels and mix based on workload changes. As ship types and type of repair change over time, existing inventory stocks are not readily purged of obsolete material items. This "lost" inventory investment further increases holding costs and prevents the diversion of this material to alternative uses in other shipyards, or for operational support.

Numerous players are involved in the material management process at naval shipyards: the planning department identifies the material needs; the supply department obtains, holds, and issues the material; and the production department is the ultimate user. For the most part, this organization fails to integrate the inventory management effort to coordinate the process, which would potentially result in the release of material to other uses in a timely manner.

These issues have contributed to a significant increase in inventory levels at naval shipyards in recent years. Considering the existing fiscal limitations being experienced throughout the Department of Defense (DOD) and government, policies and actions are necessary which will reduce the future financial and managerial investment in inventory at naval shipyards.

A. NAVAL SHIPYARD MISSION

The Naval Sea Systems Command has the overall responsibility for the maintenance of Navy ships. As such, it has assigned the following tasks and functions to the eight existing naval shipyards:

1. Providing logistic support to activities and units of the Operating Forces of the U. S. Navy and naval shore (field) activities, as assigned by competent authority.

2. Performing authorized shipwork in connection with the construction, conversion, overhaul, repair, alteration, activation, inactivation and outfitting of naval ships and service craft.

3. Performing authorized repairables work in connection with repair, restoration, refit, refurbishment and overhaul of systems, equipments, components and modules as scheduled.

4. Designing naval ships, when so designated.

5. Operating as planning yard for ship alterations and preparing allowance lists for ships under construction and conversion in accordance with instructions issued by the Naval Sea Systems Command.

6. Performing research, development, test and evaluation work, as assigned.

7. Serving as stock point for designated material, as assigned.

8. Providing accounting, civil payroll, savings bond, public works, industrial relations, medical, dental, berthing, messing, fire prevention and fire protection, security and other services to naval shore (field) activities and other government agencies, as assigned.

9. Performing manufacturing, as assigned.

10. Accomplishing shore-electronics work; as requested by the Naval Electronic Systems Command.

11. Preparing and maintaining development, logistic support, disaster control and other plans, as assigned.

12. Performing work for other U.S. Government Departments, private parties and foreign governments, as directed by competent authority. [Ref. 3: p. ii]

All tasks and functions described above are not necessarily applicable to each naval shipyard. The relative applicability depends on the assigned maintenance capabilities of the individual shipyard. For example, all naval shipyards have the capability to perform maintenance work on conventionally powered ships, and specific shipyards have been additionally assigned unique maintenance capabilities, such as the repair of nuclear-powered surface ships (see Table 1).

Ship overhaul and repair work are also conducted at numerous private shipyards both within and outside the continental United States. This work is monitored by assigned Supervisors of Shipbuilding that ensure contract compliance and quality of work. Although the missions of private shipyards are often similar to the missions of naval shipyards, their specific activities are beyond the scope of this study.

B. NAVY INDUSTRIAL FUND

The Navy Industrial Fund (NIF) finances industrial and commercial activities that produce or furnish goods or render services to other activities on a

TABLE 1

MAINTENANCE CAPABILITIES OF NAVAL SHIPYARDS

Shipyard	Aircraft carriers	Surface nuclear ships	Nuclear submarines
East Coast:			
Charleston			X
Norfolk	X	X	X
Philadelphia[a]	X		
Portsmouth			X
West Coast:			
Long Beach[a]	X		
Mare Island			X
Pearl Harbor[b]			X
Puget Sound	X	X	X

[a]No nuclear maintenance capability.

[b]Also makes emergency repairs to all ships in the Pacific and overhauls all ships homeported in Hawaii.

Source: United States General Accounting Office Report, Reductions in the Civilian Work Force at Naval Shipyards, November 1986.

reimbursable basis [Ref.4: p. H-1]. As such, the NIF provides the working capital necessary to finance shipyard operations, including shipyard material inventories. At present, naval shipyards bid for certain types of overhaul and repair work in competition with commercial activities, using the NIF to finance all costs required to support work awarded. All work performed is documented on individual job

orders which also include allowances for overhead costs. The shipyard is reimbursed by the customers' expendable maintenance funds based on periodic (at least monthly) billings as jobs are completed and work is verified as acceptable by customers. Figure 1 demonstrates how job order costs are determined and billed to customers. DOD Directive 7410.4 specifies that customers of an industrial fund activity may be:

1. Operating force commands, or mission units thereof, operation agencies, commodity commands, inventory control points, weapons system or project managers or any Department of Defense components having missions and responsibilities separate from management and operation of the industrial fund activity;

2. Military personnel, private individuals and concerns and other government agencies as authorized. [Ref. 4]

Material costs are typically reimbursed at actual cost regardless of the billing method used.

Industrial fund accounting is designed to serve as a management tool which provides for the strict accounting of costs incurred in ship repair. Standard cost accounting practices are used, including variance analysis, in an effort to improve the efficiency and effectiveness of the industrial fund activity.

Industrial Funds are designed to:

1. Provide a more effective means for controlling the costs of goods and services required to be produced or furnished by industrial and

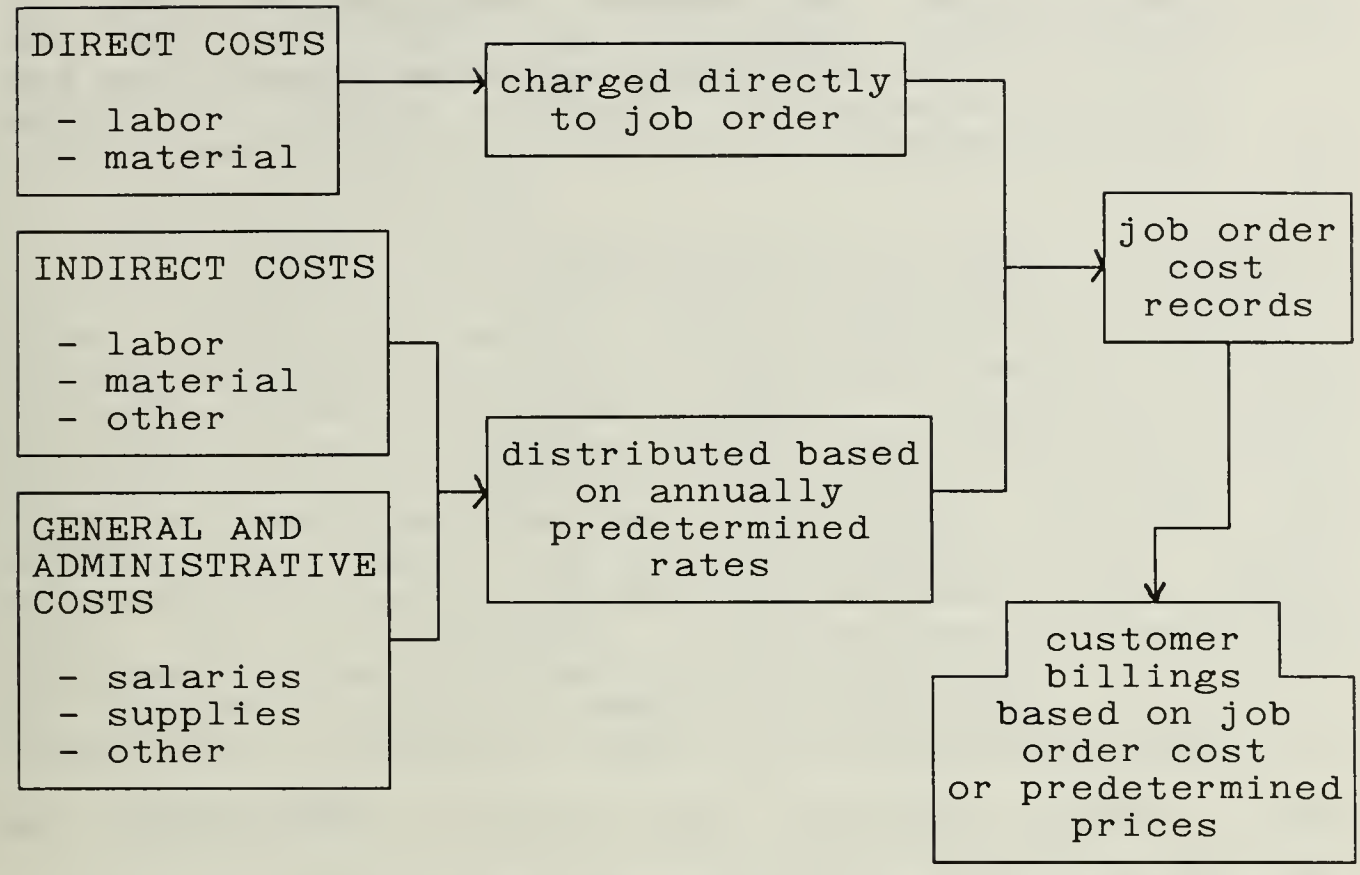


Figure 1. Job Order Costs Under Navy Industrial Fund

commercial type activities and a more effective and flexible means for financing, budgeting and accounting for the costs thereof;

2. Create and recognize contractual relationships between industrial and commercial type activities and those activities which budget for and order the end product or services, in order to provide management advantages and incentives for efficiency and economy;

3. Provide to managers of industrial and commercial activities the financial authority and flexibility required to procure and use manpower, materials and other resources effectively;

4. Encourage more cross-servicing among the military departments and among their operating agencies, with the aim of obtaining more economical use of facilities;

5. Support the performance budgeting concept by facilitating budgeting and reporting for the costs of end products, and thus underlining the cost consequences of decision making, including choices between alternatives in such items. [Ref. 5: para. V]

As the efficiency of the industrial fund activity improves, the cost per unit of the services provided by the activity decrease. This results in lower costs for the customer, which in turn reduces fleet operating costs. Inefficiencies in industrial fund operations in the early 1980s was evidenced by increased reliance on civilian contractors for less expensive ship repair work. This situation has changed in the past few years, however, with Navy activities being awarded increasing amounts of work. In this instance, as in many others throughout government, the addition of competition for ship repair contracts has forced shipyards to monitor costs more closely, and take positive action to reduce costs as much as possible.

C. RESEARCH OBJECTIVES

This thesis will attempt to identify the causes of inventory growth at naval shipyards, as well as identify potential material procurement and inventory management alternatives which will reduce the future investment in shipyard inventories. Recommendations for change will be consistent with the overall maintenance objectives of naval shipyards, considering

the goal to complete overhaul and repair work within the scheduled time at minimum cost.

D. SCOPE OF THE STUDY

This thesis will concentrate on current efforts at naval shipyards and at Naval Sea Systems Command to identify inventory growth problems. Management policy actions previously taken to restrict or reduce the size of inventory, as well as actions planned in the future, will also be included. Alternatives not previously considered will be proposed and evaluated.

E. LIMITATIONS

The inventory management problems in existence at naval shipyards are representative of the inventory management problems being experienced throughout DOD. This thesis is not, however, intended as a study of DOD inventory management policies due to the scope and time limitations that exist for this thesis. Naval shipyards were selected for study due to the availability of data and the perceptions of the author that a valid study could be conducted within both the time and financial constraints which impact upon the conduct of this work. The recommendations for change resulting from this study will hopefully provide workable alternatives to a well known, complex problem.

F. ORGANIZATION

Chapter I introduces the missions of naval shipyards and describes how shipyard operations are financed by the Navy Industrial Fund. Also included is a description of shipyard job order cost determination and a discussion of the manner in which the Navy Industrial Fund is ultimately reimbursed, by the customer, for the services provided. The objectives, scope, limitations and organization of this study are also presented.

Chapter II addresses the maintenance philosophy of naval shipyards as well as the manner in which overhaul and repair schedules are created and costs controlled. In addition, the major categories of shipyard inventories are identified, including the procedures used to procure and manage material. The various factors which contribute to inventory costs are also discussed.

The tremendous growth in inventory at naval shipyards, and within the Department of Defense, has been the subject of several independent studies. These studies, conducted by the U.S. General Accounting Office and the accounting firm Coopers & Lybrand, are consistent in the identification of the magnitude and causes of the problem. The results of these studies are addressed in detail in Chapter III.

Chapter IV addresses the methodology used for the conduct of this study. Included is a discussion of the types of data obtained, the sources of this data and the extent to which the various types of data were relied upon.

Chapter V contains data which identifies the shipyard inventory growth on a yearly basis for the five years ending in 1987. This data includes total inventory value, inventory as a percent of operating costs, days inventory on-hand, direct material as a percent of direct cost, direct material charged per direct manhour and direct material reject rates. This data is presented to demonstrate the various elements that are included in the inventory management process at naval shipyards. Alternatives to improve the management of inventory are discussed and include current initiatives being implemented at shipyards which are intended to reduce the investment in inventory.

The final chapter summarizes the results of this study and offers specific recommendations for reducing the overall investment in shipyard inventories.

II. BACKGROUND

A. MAINTENANCE PHILOSOPHY

As stated in the Introduction, naval shipyards historically operated with the primary goal to complete ship overhauls and repairs on-time or early. As a result, extensive overhaul pre-planning was performed which included the early ordering of all material required to support the repair work. Ship overhauls are extremely labor intensive, and in an attempt to complete the work as early as possible, schedules were reduced and large amounts of overtime labor was devoted to the overhaul project. As might be expected, this resulted in high overhaul costs which were primarily borne by the customer, the operating forces. This cost was never considered excessive, however, because the implied cost (exact dollar estimate undetermined) of being without the operational ship with respect to fleet readiness and national defense was always deemed to exceed any cost incurred for overhaul or repair.

However, as budget deficits skyrocketed in the early-to-mid 1980s, overhaul costs gained increased attention in Congress and the media. This attention, combined with a decline in private shipyard business, brought increased congressional requests for ship

repair at private shipyards. This situation resulted in the initiation of competitive bidding between private and public shipyards for overhaul work. And although both activities were forced to reduce costs, naval shipyards initially experienced difficulty in reducing costs to the extent required to receive contract awards. Fortunately, this trend has changed and now private shipyards are finding it increasingly difficult to compete with naval shipyards, particularly with respect to work on nuclear powered vessels.

Several factors contributed to the naval shipyards' ability to reduce costs. The first of these, congressionally mandated competition, was extremely successful as discussed in the preceding paragraph. A second initiative involves a revised maintenance philosophy which extends the periods between overhauls for certain classes of ships and eliminates overhauls for other classes of ships. Extended operating cycles have been made possible primarily through the construction of propulsion plants and equipment that are more easily maintained through routine, periodic maintenance. Additionally, overhauls have been reduced through the implementation of frequent, short-term (2 to 4 month) maintenance periods throughout the life of certain ship classes. These short-term maintenance periods are used to either sustain the material

condition of a ship between overhauls (selected restricted availability) or to accomplish maintenance in segments over a series of shipyard visits (phased maintenance availability) [Ref. 6: p. 11]. Ships assigned to selected restricted availabilities (SRAs) are enabled to operate longer between overhauls, and ships assigned to phased maintenance availabilities often forego overhaul altogether.

According to a 1986 General Accounting Office (GAO) report:

> By 1982, the Navy had placed nine classes of surface combatant ships on extended operating cycles. For some of these, the period between overhauls was extended from 37 to 60 months; according to a shipyard official, in 1984 the time between overhauls for some of the others was extended from about 40 to 60 months or more. The official also said that in 1986 the Navy removed 88 of these ships from the overhaul schedule for fiscal year 1987 and beyond and that the Navy intends to do only short-term maintenance to keep the ships in operation until they become obsolete. [Ref. 6: p. 11]

This change in maintenance philosophy has resulted in extended ship operating cycles, uniform shipyard workloads, a reduction in the shipyard labor force and lower costs through greater economy and efficiency.

B. COST AND SCHEDULE CONTROL

Ships designated for overhaul or repair are typically assigned to particular shipyards between 12 and 18 months prior to the scheduled start of overhaul.

Once this assignment is made, maintenance personnel from the ship's Type Commander (TYCOM), for example Commander Submarine Force U.S. Atlantic Fleet (COMSUBLANT), begin working with the planning department of the assigned shipyard to define the specific work desired during the designated maintenance period. The result of this effort is numerous work packages which define, by ship system, the overall work effort required. Work packages are reduced to job orders which describe in detail the work to be performed and serve as a means for documenting maintenance costs. Each job order identifies the material required to support job completion and is used by the planning department in the preparation of Job Material Lists (JMLs). These JMLs are subsequently submitted to the shipyard supply department for material requisitioning, with the goal of obtaining all required materials prior to the scheduled start of work. As might be expected, this goal is often difficult to attain.

Job orders also serve to identify individual work elements to overhaul key events. A key event is a designated point in the overall sequence of work which the shipyard or higher authority has determined to be a significant milestone for timely work completion. Key events typically define the critical path of the

overhaul process, and as such are monitored closely by everyone concerned with overhaul progress. Although several hundred such events are usually defined for purposes of work status determination, those depicted in Figure 2 are the most significant key events for a nuclear powered submarine overhaul. The time period indicated represents the number of months after ship arrival that the particular key event is expected to begin.

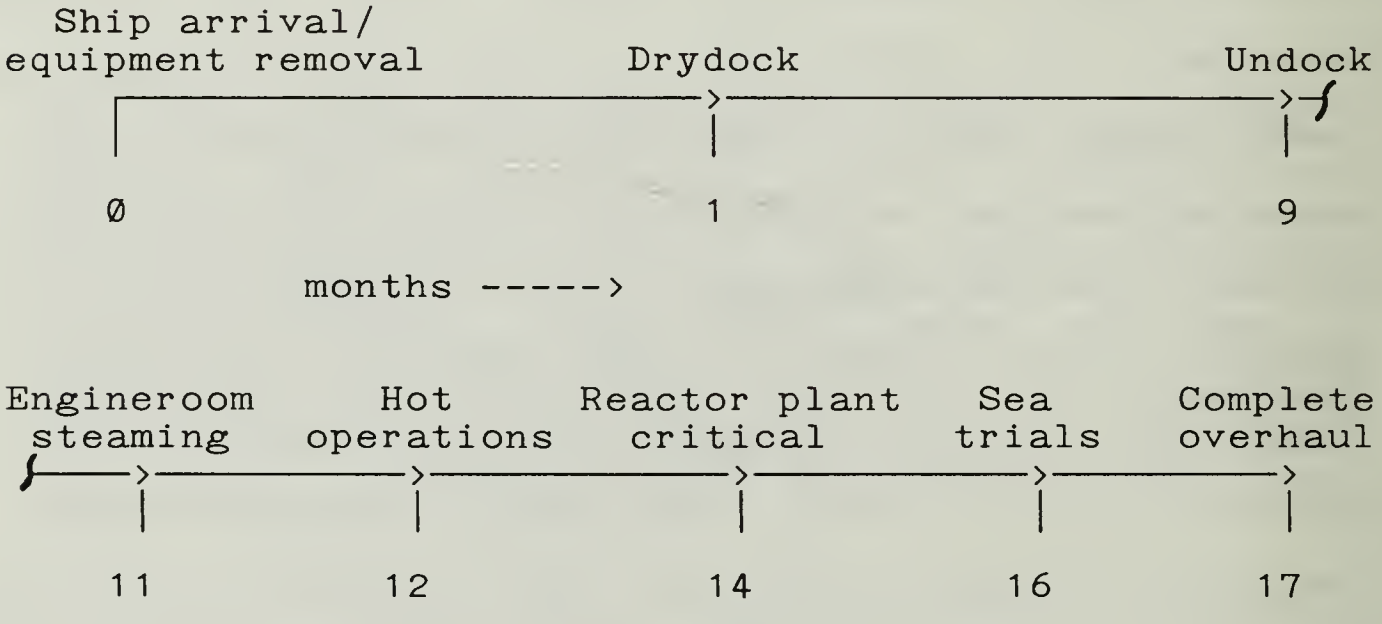


Figure 2. Submarine Overhaul Key Events

It is during the time period depicted in Figure 2 that the majority of material is drawn from inventory by the production department and transferred to the shipyard work-in-process (WIP) account for that ship. When used properly, the job order serves as a management tool that permits work supervisors to ensure

that all material is on-hand prior to the beginning of work. If the required material is not on-hand, the production department notifies the supply department that material expediting action is required. In addition, previously unidentified (emergent) material requirements are identified throughout the overhaul and requisitioning action initiated as necessary.

Four interrelated management constraints similar to those experienced in private industry must be considered by shipyard management [Ref. 7: p. 19]. These are: available manpower, authorized work, schedule adherence and estimated cost. With regard to available manpower, the shipyard must determine the number of personnel and the skills required based on the forecasted workloads identified from the existing work packages. Therefore, work packages must be well written and defined to the maximum extent possible. Insufficient manpower estimates will result in cost increases due to either maintenance delays or requirements for overtime labor.

The shipyard has little control over the second constraint, authorized work [Ref. 8: p. 37]. Although the shipyard provides input, work packages are developed based on maintenance requirements determined by higher authority, such as equipment modernizations and changes directed by Naval Sea Systems Command. The

shipyard input is limited to communications with the ship's Type Commander and usually includes problems identified during shipyard pre-overhaul inspections and testing, or during overhauls of similar types of ships. Early identification of previously unidentified maintenance requirements is essential due to cost and schedule impact.

Scheduling, and therefore schedule adherence, is mandated by the Chief of Naval Operations as recommended by Naval Sea Systems Command based on U.S. and North Atlantic Treaty Organization force composition requirements [Ref. 8: p. 31]. Factors such as the age and type of ship, ship operating cycle (time elapsed since previous overhaul or repair), extent of maintenance to be performed and typical shipyard performance for maintenance in a certain ship-type all determine the length of overhaul. When an overhaul is completed on-time or early, the customer benefits through the avoidance of work delays in other vessels, the avoidance of increased costs which are ultimately borne by the customer as well as the opportunity cost avoided when the ship is returned to the operational fleet. An efficient mix of resources is required, however, which will minimize the dollar cost of the overhaul through minimization of overtime labor and rework.

The fourth management constraint, estimated cost, has a direct relationship to authorized work. Future costs are estimated on the basis of existing man-day labor/overhead rates and estimated material costs. Then, considering a fixed budget amount for overhaul work, a priority work package is developed to remain within the budget. The ship's crew often performs minor work that will not be performed by the shipyard in order to complete all work within the estimated cost.

In summary, the basic premise of cost and schedule control is to complete the desired repair work in the required time period at minimum cost. Control is exercised through the development of work packages, job orders and key event schedules which serve as the foundation for defining manpower requirements and determining cost estimates. Schedule adherence is paramount to controlling costs due to the negative impact on dollar costs and adverse delays in overhauls or repairs of other ships.

C. INVENTORY MANAGEMENT

As discussed in the preceding section, shipyard planning department personnel (planners and estimators) determine direct material requirements based on customer job orders. Required materials are recorded on Job Material Lists which are then submitted to the

supply department for requisitioning action. This is the first and most important step for creating a material commitment and requisition record.

> Material commitments are for local management and are not part of the official NIF accounts. While material control begins with forecasting, planning, material reservation, etc., based on demand and other requirements information, records control at the Navy Industrial Fund activities begins with specific material ordering or commitment action, i.e., job material list, bill of material document. With the addition of material status and other in-depth information, the requisition record has become an important vehicle of control relative to the various phases of material processing; i.e., material availability, status follow-up, receipt delivery and cost accounting. It has been determined that a single requisition record is the most economical means of recording the various data elements involved in the material ordering process. [Ref. 2: para. 60703.A]

This material is usually placed on order shortly after the need is identified, often 12 to 18 months prior to the start of overhaul. Upon receipt, this material is identified to the specific customer job order and placed in the Direct Material Inventory (DMI) account which is managed by the supply department.

> DMI is material held in storage, earmarked for a specific customer pending issuance to work-in-process. The dollar value of this material is held in the DMI account and not charged to the customer until issued for installation or fabrication. DMI is an inventory account used to provide accountability for material between the time it is received from the supply system or from outside sources and the time it is used on the job. DMI is needed to keep material costing in line with physical completion and to

eliminate, as far as possible, the customer being charged for material which was not used on the job. [Ref. 2: para. 60709.B.1]

This material is charged to the customer's job order and to work-in-process when issued for use during the overhaul. DMI material is issued to production shops on the basis of a shop request. The production department then becomes responsible for the material until it is used on the job or returned to the supply department as excess. DMI material is only to be drawn when the need is known and when the material will be used within 30 days after being drawn from inventory [Ref. 2: para. 60709.C.2].

The DMI account is screened upon completion of a customer job order and prior to final billing. Any unused material is assigned to another customer job order if the material can potentially be used for that job. If the material is required to fill a Shop Stores requirement, then the material is transferred to the Shop Stores Inventory account. In those instances where the material cannot be assigned to either of these accounts, and the planning department determines a potential need for the material during the subsequent 24 months, then the material is assigned to the Unassigned Direct Material (UDM) account, or returned to the supply system if no further use is expected.

The DMI account is the largest (in terms of dollar value and number of line items) of the three inventory accounts maintained by the supply department. Physical inventories are conducted when the shipyard Comptroller determines that conditions require an inventory to be taken. Existing inventory accuracy goals require that DMI be at least 90 percent accurate in fiscal year (FY) 1988, 95 percent accurate in FY 1989 and 98 percent accurate in FY 1990.

The Materials and Supplies Inventory, commonly referred to as Shop Stores Inventory, is the second major inventory account and consists of commonly used material to support current manufacturing, repair, maintenance and general use.

> The primary purpose of the shop store is to facilitate the issue of material which is needed for current operations. Therefore, stock is specialized, stock control and issue procedures are simplified, and the store is operated by personnel familiar with the material stocked. Material is stocked based on recurring or forecasted demand and shop store items may meet single customer requirements. [Ref. 2: para. 60706.A]

The supply department establishes and maintains stock levels based on usage, safety stock requirements, expected production and/or planning department requirements and funding limitations. Stock levels are based on historical consumption and forecasted requirements as follows:

1. A 90 day demand level of high volume/low cost consumable items such as office supplies, paint, rags, etc.

2. A 150 day demand level of raw material such as sheet steel, bar stock, etc.

3. A 180 day demand level of forecasted material to support future production.

4. Seasonal bulk items such as coal, oil, etc. [Ref. 2: para. 60706.D.1]

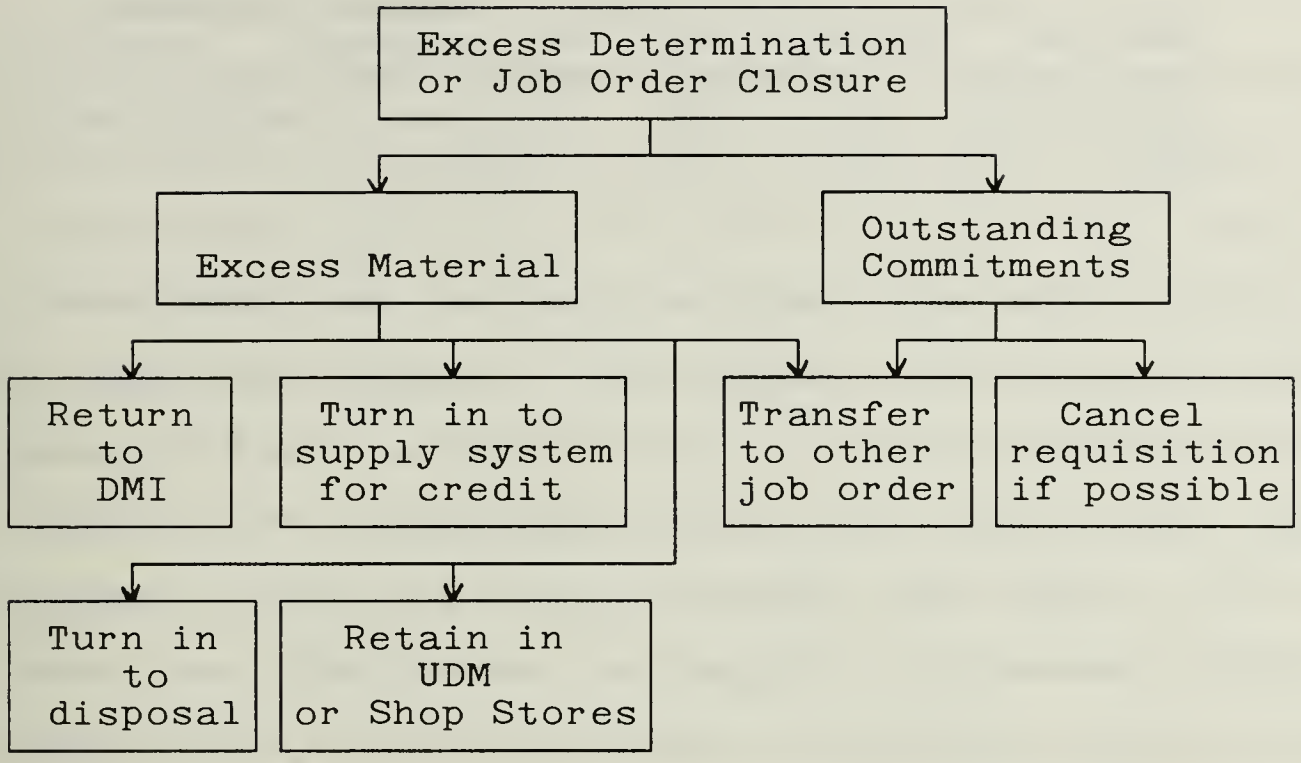
Standard U.S. Government stock material assigned National Stock Numbers (NSNs) is required to be utilized to the maximum extent practicable. In addition, material co-located in both Shop Stores and DMI should be consolidated and carried in the Shop Stores Inventory based on historical demand. All inactive Shop Stores items are returned to supply system stock if in ready-for-issue (RFI) condition, or disposed of if in not-ready-for-issue (NRFI) condition. Physical inventories are required semi-annually. Existing accuracy goals require that this account be at least 75 percent accurate in FY 1988, 85 percent accurate in FY 1989 and 90 percent accurate in FY 1990.

Unassigned Direct Material (UDM) Inventory is the third major shipyard inventory account. As the name implies, this inventory account consists primarily of excess material formerly assigned to the DMI account. This material is either excess to the required DMI inventory levels or represents material returned

(unused) but no longer required after completion of a customer order. Such material is transferred to the UDM account if there is a foreseeable need for that material within the subsequent 24 months or if the material historically requires a long procurement leadtime. All new material orders are screened against the UDM account, and transferred to DMI under a requiring job order or to Shop Stores on the basis of demand. Items remaining in the UDM account for longer than two years are typically returned to supply system stock or disposed of if obsolete. Physical inventories of material assigned to the UDM account are required annually. Inventory accuracy goals for this inventory account are the same as those assigned to the DMI account.

In general, all shipyard material not charged to work-in-process or pre-expended bins should be recorded in one of the three inventory accounts described above. Material excessing procedures are depicted in Figure 3 [Ref. 9: p. 19].

Shipyard inventories are identified to two material categories: Navy Industrial Fund (NIF) material and non-NIF material. The three inventory accounts described above belong to the NIF material category as defined below.



Source: Corporate-Tech Planning, Inc., Material Management System Supervisory Management Course, prepared for Norfolk Naval Shipyard, 1985.

Figure 3. Excess Material Processing Procedures

1. NIF Material. NIF material consists of all materials or supplies owned by a naval activity operating under the industrial fund. Ownership by NIF is considered analogous to material paid for from NIF cash and material donated to NIF....NIF material may be physically located at the NIF activity, a private contractor or other similar location, or in an in-transit status with location unknown. In any event, all NIF material must be recorded in the NIF accounts: Material and Supplies Active--Account 1421; Material and Supplies Insurance--Account 1422;...Direct Material--Account 1431; Unassigned Direct Material--Account 1432....

2. Non-NIF Material. Non-NIF material consists of that material owned by the NIF activity's customers, currently in the NIF activity's custody, and is to be used in relation to work performed by the NIF activity or ship's force.

> This includes Government Furnished Material..., material financed by the customer,...material purchased with customer funds that is excess upon completion of a job, awaiting disposition or authorization by the customer to retain for future use. [Ref. 2: para. 60701]

Naval shipyards record and control the procurement, receipt, movement, inspection, storage, and issue of material with the use of an on-line data processing application known as Material Management (MM) [Ref. 9: p. 17]. The MM subsystem is integrated into the shipyard management information system (MIS) and serves as a ready reference for information dealing with shipyard material inventories. Data terminals are located throughout the shipyard, including production shops. Material availability and order status are readily determined by entry of stock, requisition or job order numbers. MM facilitates the management of the shipyard inventory accounts.

The MM subsystem also aids in the identification of excess material by creating excess materials listings at the completion of overhaul work. These listings are then reviewed by responsible personnel within the production department for evaluation of any potential future use for the material. Figure 3 demonstrates the alternatives available to decision makers. MM also collects historical material usage data for use by both supply and planning department personnel.

D. INVENTORY COSTS

Although most shipyard management data is directly concerned with the dollar (cost) investment in inventories, numerous other costs exist which must be considered, as well as controlled, if the overall inventory investment is to be reduced. Specifically, the variable costs to order and hold individual items must be minimized subject to the constraint that required material will be on-hand when called for. The cost attributed to not having material when required, otherwise known as shortage or stockout cost, varies depending on the significance of the particular item to the task at hand. Actual shortage costs are difficult to determine, and in practice are a function of the average number of days forecast for delay in the availability of material and the availability of funds for inventory investments [Ref. 10: p. 2]. As a result of this uncertainty, decisions relating to implied shortage costs require a great deal of experienced judgment. The cost of labor that remains idle due to the lack of material is frequently used to determine actual shortage cost for individual jobs.

Department of Defense Instruction 4140.39, "Procurement Cycles and Safety Levels of Supply for Secondary Items", establishes basic Department of Defense policy for the minimization of total variable

ordering and holding cost, subject to the constraint of an implied shortage cost, for naval systems commands, inventory control points and project managers [Ref. 10: p. 1]. The concepts presented in this directive are equally applicable to naval shipyards and are utilized in the determination of economic order quantities for individual items.

The cost to order an item of material is dependent on the procurement method used. The cost to order includes the cost to prepare and process the material request as well as the cost devoted to processing the material upon receipt and placing the material in the appropriate warehouse location. The cost of ordering material procured under purchase contract is usually greater than the cost of ordering standard-stock material due to the additional cost of contract preparation and administration. Because fixed costs are essentially uncontrollable, only those costs that vary as a function of the number of orders placed should be identified for cost reduction analysis. [Ref. 10: encl. 3]

The variable cost to hold items of inventory reflects the monetary penalty of holding inventories in anticipation for future use. The variable cost to hold inventory consists of a charge for the investment of capital, losses due to obsolescence, other losses of

on-hand assets and storage costs. These elements are defined in Department of Defense Instruction 4140.39 as follows:

1. Investment cost. The view taken towards the investment of funds in inventory is that each public dollar so invested represents a dollar of investment in the private sector foregone....An annual charge of ten percent of the average on-hand inventory will be made....

2. Cost of losses due to obsolescence. ....include losses of material due to all causes that render the on-hand material superfluous to need. Thus this element will include losses due to technological obsolescence, over-forecasting of requirements, deterioration beyond the point of use, and other causes....

3. Other losses. This element is intended to cover losses due to such causes as pilferage, shrinkage, inventory adjustments, etc....

4. Storage cost. This represents both the "out-of-pocket" costs incurred in the keeping of inventory and the amortized cost of the storage facilities. The cost of storing the inventory itself includes: care of material in storage, rewarehousing costs, cost of physical inventory operations, preservation and packaging, training of storage personnel, cost of warehousing equipment and pro-rated base services and overhead costs. The sum of these annual costs divided by total average on-hand inventory...gives the "out-of-pocket" storage cost rate.... [Ref. 10: encl. 4]

The obsolescence loss rate is computed by dividing the value of transfers to disposal by the value of on-hand plus on-order assets. The rate of other losses is based on a three-to-five year moving average wherein the adjustment, if positive, is set equal to zero. Storage costs are estimated to be one percent of the

total inventory value. The Navy's inventory control points estimate the total annual holding cost to be 23 percent of the dollar value of each item held in inventory, and therefore total annual holding cost for those activities is equal to 23 percent of total inventory value.

Shortage costs, when used for budget computations, are a function of the performance goals established to meet operational readiness and operating tempo objectives. When used in daily operations, shortage cost is a function of funding levels or other management decisions relative to short-term management objectives. In those instances when a desired level of performance is specified in terms of the number of days permissible for the delay of work prior to material availability, the shortage cost becomes fixed and directly impacts the funds required for investment in inventory such that larger inventory investments will be required. Conversely, if the funding level is predetermined, the shortage cost becomes fixed and the level of performance is directly affected. [Ref. 10: encl. 2]

These cost elements are useful when determining economic order quantities (EOQ) and making other management decisions regarding individual items. However, computations become cumbersome when these

elements are applied to management decisions regarding overall inventory investment.

E. SUMMARY

The large federal budget deficits of the 1980s have created the need to control government spending, particularly when that spending is excessive or wasteful. As a result, naval shipyards have been forced to exercise greater control over the cost of ship repairs and overhauls. Part of the effort to control costs is reflected in recent changes in ship maintenance philosophies. These changes primarily exist in more frequent, brief maintenance periods and fewer extensive, long-term overhauls.

The key to cost reduction is through cost and schedule control while completing the repair work in the required maintenance time period. Such control exists in well-defined work packages, well-written job orders and key event schedules which are routinely followed. Job orders serve to identify the material required to perform overhaul and repair work, while specific key events determine the timing of the material requirement. The failure of any of these elements will potentially result in the inability to complete work when required, which in turn may result in undesirable cost increases.

Most shipyard material is recorded in one of three inventory accounts: Direct Material Inventory (DMI), Shop Stores Inventory and Unassigned Direct Material (UDM) Inventory. DMI material is obtained for use in the repair of specific vessels, and Shop Stores material is stocked by the shipyard based on recurring demand and common use. The Unassigned Direct Material account consists of "excess" material, formerly assigned to one of the other inventory accounts, for which a potential future need exists. If not used within the first 24 months from the time that the material is transferred to the UDM account, the material is returned to supply system stock or transferred to disposal. Monetary credit is received for the value of inventory returned to the supply system.

Shipyards utilize an on-line data processing system known as Material Management (MM) to record and control the procurement, receipt, movement, inspection, storage and issue of material. Fully integrated into the shipyard management information system, the MM application is at the center of shipyard material management efforts.

These concepts are the basis for understanding the inventory management problems discussed in the remainder of this study. In addition, these concepts

provide the framework within which any corrective action must occur.

III. PREVIOUS STUDIES

A. GOVERNMENT REVIEW

Inventory management problems at naval shipyards were cited by the U.S. General Accounting Office (GAO) as early as 1978 [Ref. 11]. At that time, the GAO reported that more efficient material management practices were needed in order to overcome existing weaknesses in shipyard material requirements determination. Specifically, the report recommended that procedures be implemented which would utilize historical material usage data for determining future (planned) material requirements, as well as procedures for identifying and recording excess material. They also recommended that physical inventories be taken at specific shipyards where inventory records were found to be inaccurate. The shipyards responded by developing applications within the shipyard management information system which would provide historical usage data to planning department personnel.

Between 1979 and 1983, the value of inventories at naval shipyards increased from $250.8 million to $523.4 million--an increase of 63 percent adjusted for inflation [Ref. 12: p. 23]. This prompted the GAO to conduct another review to evaluate the effectiveness of

material management activities within the shipyards. This review, published in May 1985, was conducted between November 1983 and October 1984 and consisted of work performed at four naval shipyards and at NAVSEA headquarters. Two privately-owned shipyards were also visited in order to determine how shipyard materials are managed in the private sector. The GAO discovered that the problems existing in 1978 continued to be problems in 1984, although corrective action had been taken based on the 1978 report.

The GAO discovered that historical data for direct material was incomplete, inaccurate and not being utilized for material planning. Data was being maintained for material issued throughout overhauls, but data regarding material actually used was not accumulated. In addition, the data base failed to include items manufactured within the shipyard for installation on overhaul vessels. Without accurate data regarding material actually used, the shipyards continued to order material for future overhauls that was not actually required. [Ref. 12: p. 4] This problem was further complicated by the fact that unused material was not routinely returned to the storeroom. This material usually remained in production shops unrecorded on inventory records. Long Beach supply personnel estimated in June 1984 that the value of

excess materials at that shipyard was well over $14 million [Ref. 12: p. 9].

The failure to analyze historical usage data prevents the identification of the materials actually needed to perform overhaul work. As a result, some amount of unneeded material is ordered and placed in inventory and some required material is not ordered until the work is in progress. This creates excess material as well as increases the amount of material that must be ordered after start of overhaul. For example,

> ...Norfolk's electronics shop analyzed materials that had been ordered for four ships after overhauls had started and found that the production department had ordered about 64 percent of the 3,345 line items ultimately used. [Ref. 12: p. 5]

Such shortages reduce the overall efficiency of shipyard operations by requiring that production personnel delay or reschedule work while awaiting material. The GAO reported that

> ...one mechanic estimated that 350 of the 1400 labor-hours he spent overhauling high pressure air (compressors) could have been eliminated if the planning department had ordered all materials needed for the overhauls. [Ref. 12: p. 7]

This additional time was devoted to identifying required materials and preparing Job Material Lists.

The need to order material once work begins on particular jobs also increases costs due to the additional time required to manually process and expedite those additional requisitions. When material needs are properly identified prior to start of work, expediting actions are kept at a minimum and devoted only to those situations in which early identification of material was not possible. As revealed in Table 2, the amount of time devoted to expediting by supply personnel at Norfolk Naval Shipyard is exceptionally high, particularly in the receipt control and purchasing divisions. Time devoted to expediting normally results in time away from regular duties.

TABLE 2

MATERIAL EXPEDITING AT NORFOLK NAVAL SHIPYARD

Organization	Persons involved in expediting (number)	Time spent expediting (percent)
Receipt control	40	90
Stock management	6	75
Purchasing	13	60
Shop stores	6	50
Technical	13	5

Source: United States General Accounting Office Report, The Navy Can Improve Material Management At Naval Shipyards, May 1985.

Late identification of material often requires that requisitions be submitted at a priority higher than might otherwise be required had the material need been identified earlier. Priority abuses slow Navy supply system response times because high-priority requisitions frequently require manual processing at inventory stock points. OPNAV Instruction 4614.1F requires that no more than 50 percent of shipyard requisitions be categorized as high priority. In a separate study, the GAO found that six naval shipyards exceeded that guideline in August 1983, and all eight shipyards exceeded the guideline in July 1985 (see Table 3) [Ref. 13: p. 21].

Costs are also incurred in storing and managing excess (unused) material, the extent of which depends on the amount of unused material generated. The GAO report indicates that private shipyard officials believe that unused materials should not exceed five to ten percent of the materials ordered, whereas NAVSEA proposed a goal of 15 percent [Ref. 12: p. 8]. Unused material for overhauls at naval shipyards between January 1982 and March 1984 was 16.85 percent of the material ordered, and valued at $166 million. The amount of excess material ordered by individual shipyards varied between 6.78 percent and 44.43

TABLE 3

HIGH PRIORITY REQUISITIONS BY SHIPYARDS

Shipyard	Percentage assigned a high priority		
	Guideline	August 1983	July 1985
Norfolk	50	72.4	79.6
Portsmouth	50	51.1	75.0
Long Beach	50	81.2	65.4
Mare Island	50	79.3	63.8
Pearl Harbor	50	(a)	57.9
Philadelphia	50	71.7	56.6
Charleston	50	66.5	55.5
Puget Sound	50	(a)	54.5

[a]Did not exceed guideline

Source: United States General Accounting Office Report, Intermediate Inventories Can Be Reduced, October 1986.

percent. Table 4 contains the data obtained by the GAO for each of the shipyards.

Inventory accuracy, at least in the Shop Stores Inventory account, was also found to be a significant problem. A 1984 Naval Audit Service sample of 319 Shop Stores items at Norfolk Naval Shipyard indicated that on-hand balances were incorrect for 69 percent of the sample. Inventories of Shop Stores material, although required annually (at that time), were generally not

TABLE 4

VALUE OF NAVAL SHIPYARD EXCESS MATERIAL

Shipyard	Value of Material Received	Value of Material Unused[a]	Percent of material ordered
	(millions)		
Portsmouth	$ 67.3	$ 29.9	44.43
Long Beach	99.4	14.4[b]	14.49
Charleston	93.8	21.1	22.49
Pearl Harbor	82.8	14.7	17.75
Puget Sound	218.5	31.9	14.60
Norfolk	133.9	33.6	25.09
Mare Island	116.5	7.9	6.78
Philadelphia	177.7	13.3	7.48
Total	$ 989.9	$ 166.8	16.85

[a]In some instances the amount of unused material was understated because it was taken from shipyard reports prepared during overhauls. These reports did not include unused materials which were turned in after the reports were issued. NAVSEA officials noted that amounts reported also included some duplicate items because materials not used on one overhaul could be transferred to a future overhaul and still not be used.

[b]Includes $7 million in unused materials for the USS New Jersey. Long Beach had reported $307,000 in its financial statement, but the Navy Auditor General stated excess materials were worth $7 million.

Source: United States General Accounting Office Report, The Navy Can Improve Material Management At Naval Shipyards, May 1985.

being performed at all. Of Mare Island Naval Shipyard's 26 shop stores, three had not been inventoried since 1979, eight since 1980 and one since 1981. The results of the most recent inventories at Mare Island also indicated an error rate of 82 percent in one shop store and 91 percent in another shop store. The GAO inventoried 53 items valued at $72,000 at Mare Island and discovered that inventory records for 38 of the items, or 71.7 percent, were incorrect. [Ref. 12: p. 14] Data indicating the degree of disparity in individual inventory records was not available. For example, when records indicate an on-hand balance of 100 units when 101 units exist in inventory, an error exists but is less severe than if only 25 units exist in inventory.

Accurate inventory records are the foundation from which all inventory management action is taken. When inaccurate records exist, material reorders take place either earlier or later than they should and material shortages occur when the records show material on-hand but none actually exists. Material shortages often result in production delays, requiring costly manual requisition processing and expediting. Incorrect on-hand record quantities also impede the application of economic order quantities, which in turn results in less than optimal ordering and holding costs. Material

quantities in excess of immediate and projected requirements also increase material holding costs, preclude the use of material elsewhere within the Department of Defense, and cause additional inventory investments to be made within DOD for material that would otherwise be available were it identified as excess and returned to Navy supply system stock. Excess holding costs are also attributed to existing material that is not recorded in the inventory accounts.

Inaccurate inventory records are not unique to naval shipyards. This problem was known to exist throughout a number of Navy activities, and in the summer of 1984 (while the GAO shipyard review was being conducted) then-Secretary of the Navy John Lehman imposed a Navy-wide freeze on the disposal or transfer of excess material [Ref. 14]. The purpose of this freeze was to ensure that Navy activities were transferring valid excess material, which required that inventory records be verified prior to material transfer. This freeze was incrementally lifted, by Navy activity, throughout the following 12 months as actual excess material quantities were verified at the various Navy activities holding material stocks. However, this freeze was not lifted for naval shipyards

until February 1988, a situation which has enhanced the existing amount of excess material.

GAO believed that one of the major reasons material management problems existed at naval shipyards was because shipyards were not held accountable for implementing systems and procedures to improve material management. Shipyard personnel also were not held accountable for implementing required procedures and improving management efficiency. Part of the problem was the lack of well-defined standards such as goals for the percentage of direct materials ordered after the start of overhaul and the percentage of unused direct materials remaining at the completion of overhaul. The GAO recommended that such goals be established and that individual performance be measured against the accomplishment of those goals. [Ref. 12: pp. 18-19]

Problems very similar to those discussed above were found to exist throughout the Department of Defense and were addressed in testimony before Congress by the Comptroller General of the United States in October 1987. The Comptroller General cited the following problems that were found after comprehensive audits (347 reports) at 30 DOD locations over the previous five years:

> ...DOD does not have accurate data on which to base management decisions. Therefore, DOD needs to place increased emphasis on inventory management, particularly because of inventory growth over the past few years, which has added to previous problems. The value of DOD's inventory of secondary items, such as repair parts and supplies, is estimated at over $90 billion, almost twice as large as it was just 5 years ago. This inventory may be more than DOD needs or can efficiently manage. For example:
>
> 1. There has been a significant increase in the amount of secondary item inventories excess to requirements. At the beginning of fiscal year 1987, these excesses were valued at $29.5 billion, up from $10.2 billion in 1981.
>
> 2. DOD has bought large amounts of repair parts, in support of newly fielded systems, that are not needed to support the systems in the first few years of their operations.
>
> 3. DOD warehouses are being filled to capacity resulting in DOD relaxing its policy of not disposing of any item supporting a weapon system still being used. [Ref. 15: pp. 1-2]

DOD inventory error rates were consistent with the error rates previously presented for naval shipyards. Although shipyards are included in the preceding data, it is obvious that shipyards are only a small part of a very large and complex problem. Such a system, at least within an organization as large and complex as the Department of Defense, will never be perfect and some inventory problems will always exist that require management attention. The magnitude of the problem, however, makes it obvious that positive corrective action is overdue.

B. INDEPENDENT REVIEW

To ensure an impartial and comprehensive analysis, as well as to derive the benefits of practices within the private sector, the U.S. Navy contracted with the public accounting firm Coopers & Lybrand for the performance of a management analysis of Navy Industrial Fund activities. This review, completed in June 1986, was directed at the eight naval shipyards. Over 1400 interviews, extensive independent observations and document analysis were conducted which resulted in approximately 300 issues with recommendations for change [Ref. 16: p. i]. Although the review was directed at all shipyard operations, a significant segment was related to the material and inventory management areas. As stated in the report:

> Problems in shipyard material management cut across functional boundaries within the shipyard and directly affect the shipyard's mission of overhauling and repairing ships on time, within cost and to requisite quality standards. [Ref. 16: p. MM-1]

The findings of this management analysis support the findings of the GAO which were previously discussed. For brevity, only new data from the Coopers & Lybrand report is presented in the remaining paragraphs of this section.

Coopers & Lybrand found a unique concern for material related issues within the naval shipyard

environment. Management, it seemed, was extremely apprehensive that delays or disruptions in repair work would result from the failure to have the proper materials on-hand prior to the start of work. The auditors believed that this "conservative" attitude is responsible for creating costly inventory management methods. These methods in turn create many of the problems that they are intended to prevent. The report determined that:

> This conservatism results in duplication of effort, excess identified and unidentified material inventories and increased numbers of indirect personnel assigned to material management functions. At the same time, effective control of material management processes is impeded by overlapping of organizational responsibilities, problems with the timeliness and accuracy of information system data, conflicting directives, inadequate or incomplete procurement technical data, separation of procurement from the user activity, outdated and ineffective inventory management and material distribution systems and the delivery of defective or out-of-specification material. [Ref. 16: p. MM-1]

The existence of these conditions result in excessive material costs not only in terms of inventory dollar value but also in procurement and carrying costs (which includes both labor and facilities) as well as increased costs due to schedule delays. Ultimately, such cost increases are passed on to the customer as part of shipyard overhead costs (see Figure 1 on page 7).

The auditors also discovered that about 25 percent of the material requisitioned during the pre-overhaul period was not on-hand prior to the beginning of the repair period. Thirty-five percent of the material actually required for an overhaul is ordered after the repair period begins, and 20 percent of that material is required to support work that is not identified during the pre-overhaul planning period [Ref. 16: p. MM-4]. Contributing to this problem is the existing materials planning, requisitioning and distribution process which involves various independent responsibility centers. The absence of coordinated effort causes a duplication of functions which in turn contributes to multiple material orders and prevents the assignment of responsibility when errors are identified. Material orders are written without consideration for timing of jobs during an overhaul, the sequence of those jobs or the ability to obtain material by the required start of work. Long-leadtime material (LLTM) orders are batched with standard stock orders and little or no followup is performed during the procurement process. As a result, material is often not available when called for and production delays occur. On the other hand, the early receipt of standard stock material unnecessarily increases the cost of material storing and handling when the material

remains idle for months or years awaiting the start of work. Improved scheduling, coordination and management would serve to decrease the costs and schedule delays created by this situation.

Several problems were identified in the materials planning and procurement process. Formal make-or-buy procedures, although in existence, are not consistently followed [Ref. 16: p. MM-12]. Procurement personnel are not a part of the make-or-buy decision process and are therefore not consulted regarding cost or procurement alternatives. Technical documents provided for requirements determination are incomplete or inaccurate for approximately 25 percent of the non-standard materials required, creating problems in writing procurement specifications [Ref. 16: p. MM-13]. As a result, data provided on Job Material Lists is frequently inadequate, requiring that 40 percent of the JMLs submitted be returned for additional information [Ref. 16: p. MM-13]. A significant deficiency recognized was the absence of any central procurement organization which coordinated major purchases for several or all shipyards. Such an organization could eliminate duplication of procurement actions as well as derive cost savings through quantity discount purchases.

Existing purchase regulations prevent the use of specifications which would single out a unique purchase source unless such action can be proven absolutely necessary. Without tailored specifications, material is often purchased that cannot by used without substantial rework [Ref. 16: p. MM-19]. During 1986, 13 percent of the material placed into use was rejected as non-functional. Work delays are often experienced because the true material condition is indeterminate until just prior to installation. Three shipyards must rely on other activities for procurement of non-standard material and as a result exercise little management control over this function.

C. SUMMARY

The inventory management problems at naval shipyards are numerous and complex. The financial impact of these problems is significant and positive corrective action is overdue. Specific guidance is required which will provide shipyards with specific management goals which will both improve performance and serve as a measure of performance. Material planning, which is currently 40 percent ineffective as measured against the existing policy to have all material on-hand prior to start of work, must be improved with better technical data for material identification and the analysis of historical usage

data for requirements determination. In addition, as discussed by Coopers & Lybrand, the policy requiring that all material be on-hand prior to start of work contributes to excessively high inventory levels which are accompanied by increased procurement and carrying costs. Material inventories and inventory records must by verified and corrected in order that sound inventory decisions may be made. Finally, procurement policies should be streamlined and activities coordinated in order to benefit from economies of scale.

IV. METHODOLOGY

The tremendous attention given to the inventory management issue within the Department of Defense in recent years has resulted in the publication of numerous reports on the subject. These reports are very consistent in the treatment of inventory management problems within naval shipyards, and were relied upon as a major source of research data. These reports, as well as other items of literature describing shipyard operations, were obtained from Naval Postgraduate School faculty, the Knox Library of the Naval Postgraduate School, the United States General Accounting Office and Charleston Naval Shipyard.

The literature was reviewed in detail in order to gain an understanding of naval shipyard operations and material management procedures. The documents relating to prior studies were then studied in detail and evaluated based on the relative findings in each report. These documents provided a detailed evaluation of the magnitude and extent of inventory management problems at naval shipyards. Key issues and concerns were identified in order to develop a framework for this study.

Additional relevant resource data was also obtained from Naval Sea Systems Command headquarters and Charleston Naval Shipyard. This data, reflecting historical inventory levels and operating costs at all eight shipyards for the five year period ended 30 September 1987, served as original source data which supports, in part, the findings of the prior studies. The primary purpose of this data was to determine the kinds of inventory management data utilized by responsible personnel to monitor performance as well as to provide a realistic basis for problem resolution.

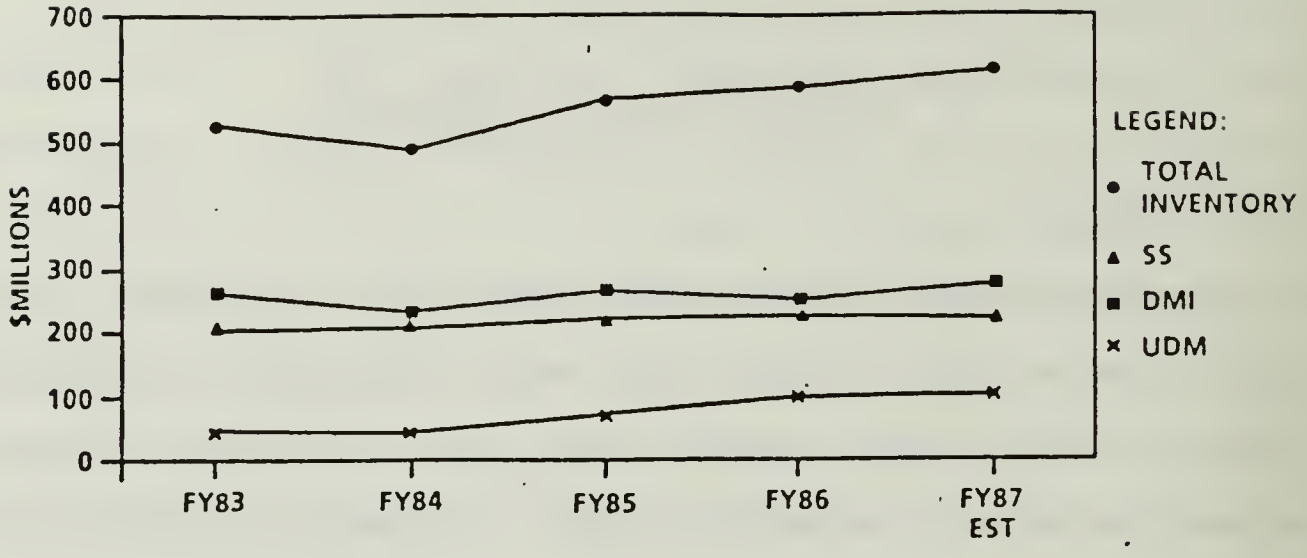
Personal (telephone) interviews were conducted with personnel responsible for inventory management decisions in order to clarify questions that arose during data analysis. Problems not otherwise identified in earlier studies were discussed to determine the validity of those issues. Alternatives for problem resolution were also discussed in order to evaluate the feasibility of proposed corrective action.

V. ANALYSIS AND DISCUSSION

A. OVERVIEW

Between fiscal years 1983 and 1987, the total value of inventory at the eight naval shipyards increased 18.37 percent, from $518.7 million to $614 million. Direct Material Inventory (DMI) increased 6.5 percent (from $267.5 million to $285 million), Shop Stores Inventory increased 12.05 percent (from $200.8 million to $225 million) and Unassigned Direct Material (UDM) Inventory increased 106.35 percent (from $50.4 million to $104 million). Total inventory actually decreased 4.9 percent between 1983 and 1984, but has steadily increased over the past three years. Figure 4 demonstrates the changes that have occurred in the three inventory accounts, as well as total inventory, during the five years ending in 1987.

Total inventory has increased as shipyards have made a transition to repair and overhaul work that is more expensive with respect to the material required. For example, naval shipyards are now performing the majority of the Navy's submarine overhauls. The advanced weapons, navigational and communications systems in existence on submarines and other vessels require more expensive repair parts and components.



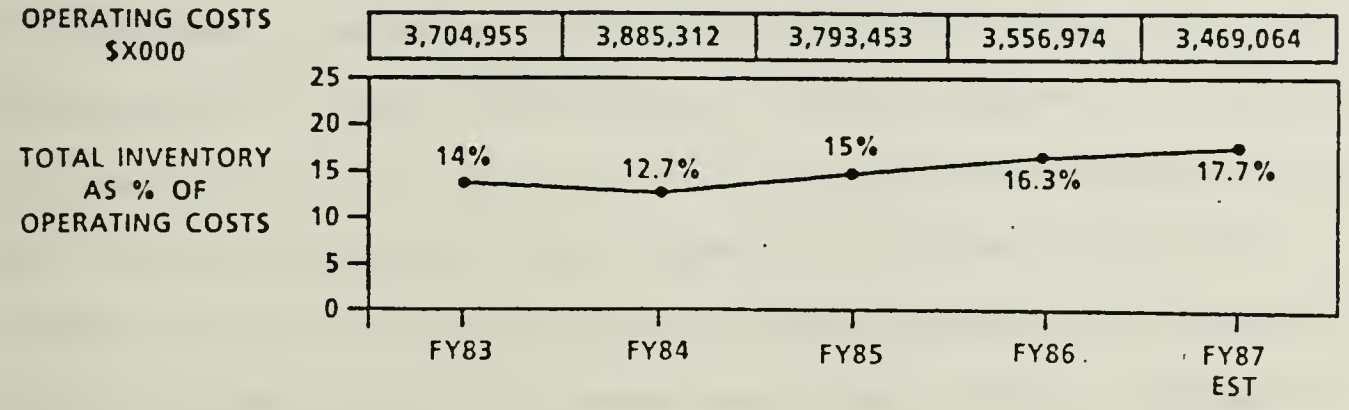
Source: Naval Sea System Command, August 1987.

Figure 4. Naval Shipyard Inventory Value, FY83-FY87

Submarines, in particular, require material which is tested and inspected extensively prior to acceptance and installation. As a result, procurement and handling costs are greater for those items. In addition, the moratorium on the transfer or disposal of material since mid-1984 has contributed to larger inventory levels which is reflected in the large growth in the Unassigned Direct Material account. The holding of excess material for more than 24 months after the completion of shipyard availabilities also increases total inventory value and has been a major contributor to the increase in days inventory on-hand from 245 days in 1983 to 433 days in 1987.

As a percentage of total shipyard operating costs, total inventory has increased from 14 percent to 17.7

percent between 1983 and 1987. Operating costs during this period decreased from $3.705 billion to $3.469 billion reflecting improved management efforts to control costs. Total inventory as a percent of operating costs during the five year period is presented in Figure 5.



Source: Naval Sea Systems Command, August 1987.

Figure 5. Total Inventory Value as a Percent of Operating Costs

Direct costs, as described in Chapter I, consist of direct material and direct labor components. In 1983, direct material charged to customers was 32 percent of direct cost, whereas by 1987, this ratio had decreased to 25 percent of direct cost. This downward trend is the result of two major factors: (1) the implementation of procedures for material requirements determination which utilize historical usage data, when available, and (2) the sourcing of increasing numbers of material

requirements to assets in the Unassigned Direct Material account and to potential excess assets in the Direct Material Inventory account. Both of these actions reduce the investment in inventory and ultimately reduce the costs passed on to the customer. During this period, direct material charged per direct manhour decreased from $7.00 to $6.00, while direct labor costs have decreased due to increased management effort to reduce costs in order to remain competitive with private shipyards.

Material rejection rates have decreased from 12.2 percent of total material ordered in 1983 to 11.1 percent in 1987. This decrease is an indication of increased utilization of reliable vendors in the purchase of material, including more stringent evaluation, prior to contract award, of an individual vendor's ability to satisfy material requirements. For example, 80 percent of the paint purchased by Charleston Naval Shipyard (CNSYD) during a recent period was rejected due to the failure to conform to military standards for shipboard use. Appropriate action was taken to ensure that vendors selected for future procurements could provide materials that meet military standards, and vendors unable to meet these standards were excluded from award consideration. In addition, technical data used to identify material for

procurement has improved such that procurement sources are better able to respond to procurement requests.

Shipyards have taken positive steps to improve inventory accuracy as demonstrated by the following data obtained from Charleston Naval Shipyard.

During fiscal year 1987, the Internal Review Office at Charleston Naval Shipyard verified the accuracy of the DMI and UDM accounts utilizing statistical sampling techniques. The DMI account was found to have an accuracy rate of 99.3 percent and the UDM account had an accuracy rate of 99.4 percent. The error rate of this sample was plus or minus 3 percent at a confidence level of 95 percent. The Internal Review Office did not verify the accuracy of the Shop Stores Inventory; however, Charleston uses a combination of inventory physical count systems to ensure the accuracy of this inventory account. The Supply Department performs a statistical random sample inventory of each storeroom during the first month of each quarter and utilizes the Penalty Cost Model daily during the second and third months of each quarter. Wall-to-wall storeroom inventories are performed only if the results of random sample inventories indicate that such action is warranted.

The Penalty Cost Model was developed by the Naval Supply Systems Command (NAVSUP) and has been

implemented at the naval shipyards for management of the Shop Stores Inventory account. This model utilizes data produced through routine transactions to determine economic order quantities and reorder points for the individual material items. Those items with high issue frequencies or high unit costs are then automatically selected for physical inventory at predetermined times (i.e., 30 or 60 days) prior to the computed reorder point. This ensures that physical inventory counts and inventory records are accurate prior to reorder. Such action prevents unnecessary investments in inventory when overages exist, and ensures that sufficient material is ordered to prevent production delays due to shortages. In addition, spot checks of Shop Stores items are routinely performed based on computer generated notices when a transaction mismatch occurs, or based on requests from individuals responsible for inventory management. The Penalty Cost Model, although it places less emphasis on day-to-day inventory accuracy than other inventory methods, has been used primarily in order to minimize the costs associated with periodic physical inventories. However, its use results in exceptionally low overall inventory accuracy rates because only those items requiring reorder are inventoried on a routine basis.

The overall accuracy of Charleston's Shop Stores account was 69 percent at the end of 1987, a significant improvement compared to the 50 percent accuracy rate experienced during 1986. This improvement results from increased management attention and the initiation of corrective action regarding previously identified Shop Stores Inventory problems. For example, to improve the flow of issue documents, a locked box system was installed throughout various warehouse issue points for the deposit of issue documents by warehouse personnel. These documents are periodically collected by designated personnel and delivered to individuals responsible for updating inventory records. This system has resulted in a decrease in the number of lost issue documents, and has contributed to increased inventory accuracy.

In February 1988, the Commander, Naval Sea Systems Command issued revised inventory management policies for implementation at naval shipyards [Ref. 17]. These changes were issued in response to the problems identified by the GAO and Coopers & Lybrand studies, and will eventually be incorporated in NAVSEAINST 7600.27, "The Navy Industrial Fund Financial Management Systems and Procedures Manual".

This directive requires that shipyards establish material handling procedures and methods which will

reduce existing inventory inaccuracies. Internal controls for the documentation of material from time of receipt to storage, and from storage to issue are to be included. All transactions must be recorded in the MM system, as much as possible, by the shipyard department/division accountable for the material. Ninety-five percent of the material not subject to formal quality assurance inspections must be processed to storage location, or to the customer (for direct-turnover material), within three working days from time of receipt. Individual shipyards are responsible to determine the adequacy of programs developed.

Shipyards are also required to establish programs to improve, as well as maintain, inventory accuracy. Included are specific performance goals for the three inventory accounts. Inventory accuracy for the Shop Stores account must equal or exceed 75 percent in fiscal year 1988, 85 percent in fiscal year 1989 and 90 percent in fiscal year 1990. Both the DMI and UDM accounts must have inventory accuracies of at least 90 percent in fiscal year 1988, 95 percent in fiscal year 1989 and 98 percent in fiscal year 1990. All inventory accounts must have location accuracies of at least 97 percent. Specific performance toward the accomplishment of these goals must be reported semi-annually, in writing, the the Shipyard Commander, Comptroller,

Supply Officer, Production Officer and Planning Officer. Physical inventories are required as indicated in Chapter II.

Specific policy changes for the management of Direct Material Inventory, Shop Stores Inventory and Unassigned Direct Material Inventory are addressed in the following sections.

B. DIRECT MATERIAL INVENTORY

As discussed in Chapter II, the Direct Material Inventory account consists of all material obtained to support specific customer overhaul or repair work. This material is frequently placed on order 12 to 18 months prior to the start of overhaul, and is often received and placed in inventory as early as two years prior to the time that the material is actually required. This system was designed to eliminate overhaul and repair delays caused by lack of material. The GAO discovered, however, that this system usually resulted in the ordering of large amounts of excess material, primarily because historical usage data was not routinely considered when determining material requirements [Ref. 12: p. 9]. Schedule delays are actually avoided by the shifting of smaller jobs within the overall work structure, combined with the expediting of material and the use of overtime labor.

The costs of these alternatives are potentially high depending on the extent to which they are used.

Revised NAVSEA policy requires that material "...be ordered to be on-hand in sufficient time to support the industrial process...." [Ref. 17: p. 11] While this policy eliminates the requirement to have all required material on-hand prior to the start of shipyard availabilities, it does not prevent material from being ordered and received well in advance of the date actually required. To minimize the investment in inventory, and in the absence of further guidance from NAVSEA, individual shipyards should develop procedures which will ensure that material is not received far in advance of the date that the material is actually required. Because material delivery times cannot be controlled absolutely, and because individual jobs must often be shifted to prevent overall schedule delays (due to the non-availability of material), orders should arrive no earlier than 30 days prior to the time actually required.

Current policies also require that excess material remain in the DMI account, assigned to specific ships, until the end of maintenance periods. However, at the completion of individual job orders, material is identified as "DMI Category Four" indicating that the material is no longer required for production support.

Such action makes material available for other current or future DMI requirements and permits the cancellation of outstanding orders for identical material. This material is also available to other activities as needed. The DMI account remains inflated, however, because material that is no longer required remains in the account. This material should be returned to system stock or transferred to the UDM account in order to increase its visibility as excess.

To further reduce the investment in Direct Material Inventory, historical usage data must be considered prior to the preparation of material requests. This action is now being performed at individual shipyards for those items for which historical usage data is available. DMI has continued to increase primarily because material is purchased well in advance of scheduled start of overhaul dates and is retained in the DMI account until overhaul completion. This trend could be reversed by ordering material based on individual job order start dates when historical procurement leadtimes are known, and by fully releasing material at the completion of individual job orders. In those instances where historical procurement leadtimes are not available, Navy stock point average turnaround times (for specific classes of material) could be obtained and utilized as estimated shipyard

procurement leadtimes. Material should be ordered for direct delivery to requiring shops whenever possible to reduce both handling and storage costs.

In order to evaluate material planning, ordering and usage, NAVSEA now requires that the amount of unused DMI material be evaluated at the end of each shipyard availability. A goal to remain at less than ten percent unused DMI material has been established, and is calculated to include all material on-hand or due-in to support the availability. Results must be reported to the Shipyard Commander, Supply Officer, Production Officer and Planning Officer. Corrective action is required in order that improvement be experienced during future availabilities. While this is an excellent start for monitoring inventory management performance, additional performance goals should be established for the percentage of high-priority requisitions submitted due to improper requirements determination. Managers should be evaluated, in part, based on the ability to achieve these goals. Penalties should be imposed when these goals are not consistently met.

C. SHOP STORES INVENTORY

The Shop Stores Inventory consists of commonly used material that is stocked based on previous demand, safety stock requirements and expected production

and/or planning department requirements. This account consists mostly of standard-stock government material. Non-standard material is stocked only when standard-stock material does not exist or fails to meet shipyard industrial requirements. Fast-moving, low-value items are pre-expended subject to locally established dollar value ceilings.

Safety stock (including insurance items) is limited to the minimum quantity required to prevent work stoppages and to support emergency situations. Reorder points and order quantities for insurance items are determined based on experienced judgment and are set to achieve economic order quantity replenishment, one-for-one replenishment or zero-balance replenishment [Ref. 17: p. 2].

Individual items are established as demand-based when at least two demands have been experienced in a 12 month period, and are maintained as demand-based if at least one demand has been experienced in the previous 36 months. Reorder points and order quantities are computed automatically every month based on economic order quantity models. [Ref. 17: p. 1] High dollar value and high quantity limits are established locally to ensure the review of selected orders prior to final document submission.

Although the Shop Stores Inventory account has increased 12.05 percent over the past five years, the majority of this growth occurred during 1983 and 1984 as shipyards experienced a change in the type of work performed. This growth has stabilized primarily as the result of increased upper-management effort toward reducing the size of this inventory account. Requirements have been re-evaluated in recent years and material excess to requirements has been transferred or disposed of. The value of this account will remain excessively high, however, as a result of the requirement to retain material in the Shop Stores account, as demand-based, when only one demand in 36 months is experienced. A criterion such as one demand within the previous 12 months would reduce the items retained as demand-based and would significantly reduce the value of the Shop Stores Inventory account.

Shop Stores material is classified as excess based on several criteria, depending on the sub-category of the material. Demand-based items are considered excess when the on-hand quantity exceeds the shipyard requisitioning objective plus 24 months demand. Items are considered inactive when no demand has been experienced within the previous 36 months. Insurance items are reviewed every two years to evaluate the future need for the material, and processed as excess

material if it is determined that the material is no longer required. Excesses are disposed of, transferred to the UDM account or retained in the Shop Stores account at the discretion of shipyard management. Shop Stores excess and inactive items must be made available to other activities, but not necessarily transferred to the UDM account. [Ref. 17: p. 7] All Shop Stores excess should be transferred to the UDM account, however, in order to reduce the value of the Shop Stores Inventory account as well as increase the visibility of this excess material.

The revised NAVSEA policies have established both stock turn and service level goals for material in the Shop Stores account. Non-NIF material, material not-ready-for-issue and insurance items are not included in the stock turn calculations. Goals for stock turn have been established as 1.0 times for fiscal year 1988 and 1.5 times for fiscal year 1989. Stock turn calculations are reported to the Supply Officer quarterly. [Ref. 17: p. 8] Such goals will ensure that managers devote effort toward the identification and transfer of excess Shop Stores material.

Service level is defined as the percentage of stocked requirements that are satisfied upon initial request, and are determined by computing the percentage of zero-balance items versus the total number of items

in the Shop Stores account. Items ordered for the first time that have zero balances are included in the calculation. Existing goals are to equal or exceed 97 percent when new items are excluded from the computation, and to equal or exceed 95 percent when new items are included. The revised policies also require that high-demand, zero-balance items be reviewed for possible expediting action. Shop Stores service levels are computed monthly. [Ref. 17: p. 9]

Because most items carried in the Shop Stores Inventory account are stock numbered, and because seven of the eight naval shipyards are located near Naval Supply Centers, shipyards should place increased reliance on the supply system for backup stocks. Safety stocks could therefore be decreased, reducing the overall investment in the Shop Stores account. Established service goals could still be met through the existence of cycle stocks maintained on the basis of demand and properly computed reorder quantities. Such a philosophy should not be used at Portsmouth Naval Shipyard, however, due to its distance from a supply center.

D. UNASSIGNED DIRECT MATERIAL INVENTORY

The Unassigned Direct Material Inventory account consists of unused material previously assigned to the DMI account, Shop Stores material evaluated as excess

to requirements and unused material returned from production shops. Material is transferred to the UDM account from DMI at the completion of shipyard availabilities and is retained for a maximum of 24 months based on expected future requirements for that material. At the end of this period, material is returned to system stock or otherwise disposed of unless expected future requirements exist for the material. Material may also be retained for extended periods based on direction from NAVSEA or when management considers it unwise to transfer the material (i.e., the item is high-cost or unique to shipyard industrial use). Material for particular ship-types is transferred to other shipyards when the holding shipyard no longer has use for the material and the receiving shipyard has responsibility for work which requires that material. Material is transferred to the DMI or Shop Stores accounts when a need is identified in either of those inventory accounts.

In 1983, the Unassigned Direct Material (UDM) account was valued at $50.4 million and was 9.72 percent of total shipyard inventories. By the end of 1987, this inventory account had increased to $104 million and was 16.94 percent of total shipyard inventories. The dramatic growth is this inventory account is an obvious indication that a policy did not

exist to ensure the timely transfer or disposal of material from this account.

NAVSEA's revised inventory management policies require that individual shipyards establish goals for the percentage of UDM utilized. This quarterly ratio is determined by dividing the value of transfers (excluding disposal actions and returns to the supply system) by the average monthly value of the UDM account for the quarter. Monthly reports are also required that indicate the current UDM balance as well as trends in growth or reduction. [Ref. 17: p. 20] Although this action brings upper-management attention to the management of the UDM account, specific goals are required which are realistic yet provide the incentive for the overall reduction of this account.

To increase the visibility of UDM assets, as well as to minimize overall shipyard material costs, a centralized data bank is being created at Navy Ships Parts Control Center (SPCC) which will permit all shipyards to source other shipyard UDM accounts prior to the initiation of requisition or purchase requests. This system will also provide visibility for shipyard material assets throughout the Navy supply system.

A prototype system is currently being tested between Pearl Harbor Naval Shipyard and SPCC in order to evaluate the system and correct system deficiencies.

This system, to be known as the Shipyard Material Visibility System, will be implemented at the remaining shipyards at the completion of system testing, and will be updated monthly based on current on-hand UDM balances at each shipyard. Material identification data will exist both for standard and non-standard material items. Initially, data inquiries will be performed manually for long-leadtime procurement requests, but will be converted to automated screening of all not-carried requests (above an established dollar value) once system reliability is verified.

Before transfers of material take place, individual shipyards must weigh the cost to transfer material between shipyards against the costs to obtain material through purchase actions. Material should be transferred to requiring shipyards in all instances where the transfer cost is less than the purchase cost of new material. Purchase cost includes the dollar cost of the material as well as the costs associated with preparing and processing material orders. When the transfer price of the material is the same as the new material purchase price, the decision to transfer the material is based on a comparision of transfer costs and ordering costs. As a result, individual shipyards may decide to purchase material when assets exist at other shipyards. To reduce the overall

investment in inventory, NAVSEA should establish policies to ensure that existing assets (valued above a specified dollar value) are utilized before additional purchases are made. The costs of potential delays due to the non-availability of material must also be considered in the decision to either transfer or purchase material.

When evaluating the decision to dispose of material that is excess to expected future shipyard needs, the cost to move that material should be compared to the cost of maintaining that material. In all instances where the cost to move is less than the cost to maintain (except as noted below), the material should be returned to system stock or disposed of, as appropriate. When the cost to move is greater than the cost to maintain, the material should be retained. The operating costs of maintaining material in inventory should include the following components:

1. Cost of taking physical inventories.
2. Cost of inventory records, including duplicate locator systems.
3. Cost of duplicate bin locations.
4. Costs due to loss of space consolidation.
5. Costs due to loss of freight consolidation.
6. Cost of shelf-life surveys.
7. The differential in estimated second destination transportation costs, if any.

8. The differential between costs of commercial storage sites or commercial versus government-owned storage sites, if applicable.

9. Other additional costs, if any. [Ref. 18: p. 3]

Because of the long-term impact of these factors, it is assumed that all obsolete material will be either returned to system stock or disposed of. Special consideration should be given to the inventory items described below before a decision is made to transfer the material.

1. Items managed with a high degree of intensity (i.e., high-cost, special manufacture or long leadtime items).

2. Shelf-life or deteriorative items.

3. Bulky items or items requiring special handling or transportation.

4. Items for which tactical, strategic, or national emergency dictates overriding considerations.

5. High-demand items where the activity is the sole or principal demand source. [Ref. 18: pp. 3-4]

This material should be retained or transferred based on the experienced judgment of the responsible manager, or on the basis of specific decision rules issued by Naval Sea Systems Command. Specific decision rules (such as individual dollar limits) do not currently exist, but should be developed at the earliest opportunity.

E. OPTIMAL INVENTORY LEVELS

Given the magnitude of naval shipyard inventories, managers are concerned with the overall investment in inventories and total inventory performance. However, most theories addressing inventory management issues are concerned with the behavior of individual items. Although there are currently no funding constraints regarding maximum inventory levels at naval shipyards, federal budget limitations and increased attention concerning Department of Defense and shipyard inventory growth make such constraints inevitable in the future. As a result, shipyards must be prepared to adopt inventory models and practices which will optimize customer service through the minimization of the cost of material shortages, subject to investment as well as workload constraints.

Such a model was recently developed by Everett S. Gardner for use at Navy retail stock points [Ref. 19]. The purpose of this model is to provide managers with trade-off curves which consider the aggregate relationships among the number of inventory shortages per unit time, a fixed lump-sum investment in inventory and stock replenishment workload. The basic premise of this model involves the reallocation of funds from safety stocks to cycle stocks while keeping total investment constant. Such a model could be adapted for

shipyard use and is especially suited for use in managing the Shop Stores Inventory account.

The first step in applying this model to naval shipyards is to establish a budget constraint based on the average number of months of stock required to sustain shipyard operations. This constraint, although fixed in total dollar amount, becomes flexible through the variation of safety and cycle stocks. Next, a customer service goal must be established relative to the number of material requests that are filled immediately at the time of initial customer demand. The aim is to satisfy each request completely at the time of initial receipt regardless of the number of units demanded. A customer service goal from which 85-90 percent of demands are filled at the time of initial request would be reasonable given budget constraints and the availability of back-up stocks within the Navy supply system. The problem then becomes one of identifying the exchange curve between customer service and reordering workload at a given fixed investment. [Ref. 19: pp. 2-3]

Gardner found that using existing inventory models for this type of analysis was tedious and subject to a large number of trial-and-error calculations with respect to ordering, holding and shortage costs. Such problems exist because existing Navy models seek to

optimize costs for single items. To overcome this deficiency, a Lagrangian optimization was formulated which would minimize the number of requisitions for which material was not available subject to investment as well as workload constraints. The Lagrangian multipliers corresponding to these constraints are actually imputed marginal cost estimates that, when used in existing models, yield the same results. Exchange curves are developed by solving the model for a range of workload constraints at a fixed investment constraint. The appropriate investment in safety stock is found at the point where the customer service goal is achieved at the minimum number of orders. [Ref. 19: pp. 3-4]

Once the appropriate safety stock level is determined, the Lagrangian multipliers are used to determine new cost variables yielding the appropriate safety stock in the existing inventory model. During the first year after this model was implemented at the eight Naval Supply Centers, an overall reduction of 20.24 percent in material reorders (from 840,000 to 670,000 orders per year) was experienced, at a cost savings of about $2 million. Customer service and inventory investment remained constant. [Ref. 19: p. 5] This model should be evaluated by qualified

personnel for use at naval shipyards in the determination of Shop Stores inventory levels.

The most obvious action for the optimization of Direct Material Inventory (DMI) is the use of historical usage data, whenever possible, in the determination of material requirements. Such action minimizes the amount of material that is ordered and placed in inventory but never used. Since the material ordered and placed in the DMI account is requisitioned based on relatively unique requirements, inventory models such as previously discussed do not apply. Several alternatives do exist, however, which will reduce the overall investment in the DMI account.

Once work packages are written and the actual material requirements are determined based on available historical usage data, material should be sourced to existing shipyard assets in the Shop Stores or Unassigned Direct Material accounts. For the most part, this action is already being effectively performed. Shipyards have also begun to source potential excess from the DMI account. Material which cannot be sourced to existing assets should then be segregated into standard stock (National Stock Numbered) and non-standard stock categories. Utilizing average turnaround times available in the Material Management application of the shipyard management

information system, standard stock requirements should be matched against job order start dates and requisitioned such that the material will arrive just prior to the start of work. This practice has been extremely successful throughout industry in recent years under the name of "just-in-time" inventory management. It should be noted, however, that historical turnaround times do not exist for all shipyard material requirements because not all standard stock requisitions are repetitive procurement actions. As a result, "just-in-time" procurement is not possible for these items. If possible, average procurement leadtimes for each item in this category should be obtained from Navy stock points and utilized to determine best estimates of procurement leadtimes for shipyard requirements. This would permit the most accurate application of "just-in-time" procurement for non-repetitive standard stock requirements.

The requisitioning of non-standard material presents several complications which, in effect, require that this material be requisitioned far in advance of the time that the material is actually required. This material normally must be procured under purchase contracts which often require up to six months of administrative leadtime, followed by a variable amount of production leadtime, before the

material is ultimately shipped to the requistioner. Therefore, long-leadtime material must be procured far in advance of other categories of material because of potential shipyard production delays resulting from the non-availability of this material. The need to start the procurement process well in advance of the actual material need date must be weighed against the cost of holding the material for extended periods in the event that material is received far in advance of the date actually required. Estimates of administrative leadtimes for procurement of identical or similar items should be considered as much as possible in determining the timing for the submission of procurement requests in order to minimize the length of time that material will be held prior to use.

The application of "just-in-time" inventory methods assumes that extensive control over suppliers exists such that material delivery dates are assured. Such guarantees are not always possible under existing Navy procurement methods, and as a result "just-in-time" methods are seldom applied to non-standard procurements. Where possible, shipyards should establish long-term relationships with vendors for "just-in-time" delivery of purchased material. Material could be delivered in the minimum quantities required to support production just prior to the times

actually needed, even though the purchase contract specifies a larger quantity over an extended period of time. The additional costs of receipt processing experienced under this philosophy should be compared to the expected savings from decreased inventory carrying costs before such agreements are made. Competitive purchasing could still occur by dividing business among several firms based on each firm's performance in meeting "just-in-time" requirements.

The administrative leadtimes required to procure material have increased in recent years primarily as a result of congressional initiatives to increase competition and support small or minority-owned businesses. Although this policy is good for the economy as a whole, longer leadtimes result in larger inventory investments to support maintenance during the longer procurement leadtime. This situation will remain somewhat troublesome for purchasing activities as well as for shipyards until circumstances permit the relaxation of existing purchasing requirements. Because it is in the public interest to use competitive procurements as well as to support small and minority-owned businesses, this situation is not expected to change in the foreseeable future.

Goldratt and Fox [Ref. 20] have shown that a high correlation exists between short leadtimes and high

quality material. Shorter leadtimes are associated with the production of smaller, more frequent batches of material which are quality inspected earlier and more often than are single, large batches. The ability to inspect material more frequently permits the early discovery and correction of production errors and contributes to enhanced product quality over time. [Ref. 20: p. 65] Because product quality improves, shipyards and purchasing activities should purchase large total quantities of material to be delivered in smaller lot-sizes at periodic intervals. Such action will also reduce inventory carrying costs. The ability to satisfy required leadtimes at reasonable product cost should be a major criterion for vendor selection. The importance of shorter leadtimes in the optimal scheduling of purchase orders is discussed in more detail by Ronen and Trietsch [Ref. 21].

Existing government procurement regulations and procedures present several other difficulties which impair the procurement of non-standard material. Material descriptions for shipyard purchases are normally limited to general performance specifications, and cannot specify features that are unique to a particular brand of material. Sole-source procurements are prohibited unless it can be demonstrated that the recommended source is the only firm capable of

producing the required end-item. In addition, competitive bidding must be used for all purchases exceeding an extended value of $25,000. These actions are intended to enhance competition as well as ensure that the maximum number of firms are being awarded government contracts. However, these regulations frequently result in the receipt of material which requires rework or alteration prior to use.

To ensure the receipt of the proper material as well as to minimize the amount of rework required prior to installation, procurement regulations should be revised to permit the specification of form, fit and function and, if available, the manufacturer's make, model and part number. Sole-source procurement should also be permitted for critical or highly technical repair parts, when experience reveals that a single firm is the only source capable of providing the required material and when a single supplier has demonstrated superior leadtime performance.

Purchase requests, particularly those which contain extensive descriptions or instructions, are often delayed because of the time required to process such requests. Procurement personnel are evaluated based on the number of procurement requests processed, and individuals frequently set aside difficult, time-consuming procurements in order to meet established

performance quotas. Material requests containing detailed descriptions are often processed only after they are brought to the attention of management, resulting in lost management time, longer procurement leadtimes, higher material costs and late material arrival. Performance measures should be revised to include allowances for the longer times required to process complex purchase requests.

The cost of purchase actions can be reduced through the delay of purchases for small quantities of an item until such time that a larger quantity can be procured. This assumes that sufficient stock exists to meet customer demand during the procurement period and applies to joint purchases among shipyards as well as purchases of DMI material (for several ships) within single shipyards. Manufacturers and suppliers frequently grant price breaks for larger quantities due to the ability to minimize costs during larger production runs. The grouping of requirements is best performed at the material planning level, where the ability exists to control document flow and determine when entire quantities have been identified.

An alternative for the application of this philosophy is to analyze historical usage data for single line items on one or more ships, and then generate bulk orders for future shipyard requirements.

Material would then be allocated to various requirements upon receipt.

The delay of purchases to achieve cost savings must be weighed against the potential negative impact on mission accomplishment, and procurement actions prioritized in order to minimize mission degredation. Cost savings resulting from quantity discount buys must also be weighed against such costs as increased investment costs, additional storage requirements, increased manual procurement workloads, increased administrative leadtimes, potential contract termination costs, potential excess or long supply inventory and shelf-life considerations.

Consideration should also be given to consolidating purchase actions among several shipyards in order to achieve purchase cost savings for high-cost, commonly used items. Consolidated purchases should be made for all orders exceeding an established dollar value, for example all non-standard procurements exceeding $5,000.

Major candidates for joint procurement include quantities of plate steel, bar stock and special categories of material such as smoke-free electrical cabling or other material subjected to unique quality assurance requirements. Large lot-size purchases of quality assurance material are particularly well suited for this type of procurement, and additional cost

savings could be realized during the receipt inspection and testing of large groups of items.

The consolidation of purchases such that a single purchase is made for all shipyards would possibly result in even higher distribution costs, however, and should not be attempted unless the savings are certain to exceed the cost of material shipment. Consolidation of purchases among shipyards should therefore be limited to shipyards located in close proximity to other shipyards (i.e., Puget Sound, Mare Island and Long Beach Naval Shipyards on the west coast and Portsmouth, Philadelphia, Norfolk and Charleston Naval Shipyards on the east coast).

Pearl Harbor Naval Shipyard should be included in west coast shipyard procurements only when material for that shipyard is typically obtained from outside Hawaii, or when the savings gained exceed the transportation costs required for delivery to Hawaii.

Initially, historical purchase data from each shipyard could be obtained from the MM system and consolidated at centralized procurement agencies on each coast. The savings generated through increased quantity discounts should also exceed the cost of holding the larger quantities of material.

As previously addressed, the cost of holding material is estimated to be 23 percent of the total

value of inventory held. In order to minimize this cost, as well as the dollar investment in inventory, excess material should be kept to a minimum. In this regard, material in the Unassigned Direct Material (UDM) account should be limited to material for which a future need can reasonably be determined. The decision to transfer material from this account should be evaluated considering the cost to hold and order material as well as the potential costs incurred by not having the material when needed. Material should be returned to system stock to afford its use for other purposes, or transferred to the Defense Property Disposal Office (DPDO) in order that the government can recoup at least a portion of the material value through periodic sales.

It should be noted that, on average, shipyards typically receive credit for only 23 percent of the value of material items returned to system stock. This occurs because excess assets (on-hand plus on-order) often exist in the Navy supply system, and current Naval Supply Systems Command policy awards credit only for those assets turned-in which are in short supply. This policy is currently being evaluated at NAVSUP, and future action is expected which will result in increased credit for assets turned-in.

Currently, all stock returns in excess of $2,500 per line item are being reviewed, and credit given when unawarded procurement contracts exist for those line items. As a result of this situation, it is often advantageous from the shipyards' standpoint to retain material in the UDM account even though there is only a slight possibility that the material will be used in the future. NAVSUP should ensure that material returns are consistently reviewed, and provide sufficient incentives for shipyards to return excess material. Such incentives could include the distribution of shipyard excesses to non-Navy stock points. NAVSUP should also periodically screen the Shipyard Material Visibility System to identify shipyard excesses which could be utilized by the supply system.

To coordinate the total material management effort, shipyards should establish an organization to manage the material planning and ordering functions under the control of a single responsible individual. This organization would be responsible for the overall investment in inventory and would monitor the planning of material requirements based on overall work schedules. Comprehensive knowledge of material requirements based on overall work schedules would permit the reallocation of material from existing assets to support current job orders, preventing the

need to requisition and expedite the delivery of material which exists in stock but is designated for other jobs. Additional material, when required, would then be requisitioned on a routine basis to arrive prior to job order start dates for follow-on availabilities. By using existing assets, material inventories would be reduced through the minimization of additional investments for material items that currently exist in stock. Additional cost savings would also be realized through fewer expediting actions and smaller numbers of high-priority requisitions.

Such an organization was recommended by Coopers & Lybrand to contain specific branches and sections with specific functions, as listed below:

1. Master Scheduling. Long range ship availability scheduling and workload forecasting.

2. Detailed Scheduling. Preparation of the Detailed Production Schedule which serves as the basis for establishing action dates for plan issue, long leadtime material ordering, regular material ordering and job order issue....

3. Availability Planning Branch. Ship availability work package formulation and control....

4. Specification Section. The preparation of job order specification and craft manhour allowances.

5. Material Ordering Section. The identification and ordering of all required material from the documents prepared by the Specification Section....

6. Material Division. All productive work material support functions of the Supply Department within the shipyard, i.e., material procurement,

expediting, receipt control, inventory control, warehousing and distribution. [Ref. 16: p. MM-8]

Coopers & Lybrand recommended that this organization be consolidated under the shipyard Planning Officer, similar to existing organizations at the Type Commander level which combine engineering and supply under a single Assistant Chief of Staff. However, this consolidation could also occur under the shipyard Supply Officer, as was implemented at Pearl Harbor Naval Shipyard in late 1985 [Ref. 22: p. 48]. The Pearl Harbor organization, called the Logistic Support Center, serves as the data base manager for Job Material Lists and centrally manages advance material planning and ordering. Its functions include obtaining and maintaining current material planning data, determining material requirements for authorized work and providing complete and accurate data for requisitioning material. The following specific functions are assigned to the Logistic Support Center:

1. Updating the automated Job Material List system.
2. Determining and ordering advance material requirements for authorized work and new work for ships already in availability.
3. Making recommendations for "make-or-buy" decisions.
4. Ensuring the timely ordering of material in accordance with published plans and ordering schedules.

5. Researching and providing complete and accurate data for sourcing against locally available assets, requisitioning of standard stock material and non-standard procurement actions.

6. Reviewing and resolving non-engineering type technical issues including cost on referrals from local purchase actions. [Ref. 22: p. 48]

Production department personnel should also have a greater role in shipyard inventory management. As the primary user of shipyard material, the production department can identify potential support problems and enhance material management efforts through the timely return of unused material. Production shops should routinely monitor material status to ensure that required material is received prior to the date actually required. When problems are identified, the supply department should be notified that expediting action is necessary. This early notification will serve to minimize the number of high-priority requisitions or special material shipments required to ensure timely material delivery.

Ensuring that all required material is on-hand prior to job order start would also minimize the number of schedule delays or adjustments needed due to lack of material. Production shops should also ensure that all material issued to job orders, but unused, is returned to stock as soon as possible after job order completion. Excess material should not remain in

production shops more than 30 days after job order closure. Supervisors should be held responsible to ensure that unused material is returned to stock in a timely manner. Periodic spot checks of material in production shops should be performed by an independent party (i.e., Internal Review Office) to ensure that all material is identified to a current job order.

G. SUMMARY

Although naval shipyard inventories have continued to grow over the past five years, this growth is less severe than experienced prior to that time. This change is largely the result of increased management attention regarding inventory management issues. Historical usage data is utilized, where available, for the determination of material requirements, and material is being procured based on available historical turnaround times. A major element in the stabilization of inventory growth has been the successful sourcing of material requirements to excess material, which restricts additional investments in inventory. Inventories have continued to grow primarily as the result of policies which restricted the transfer of material from the Unassigned Direct Material account, combined with policies which prevent the transfer of excess material from the DMI account at the time of job order closure. Shipyards are able to

source requirements to potential excess material in the DMI account only on an exception basis.

NAVSEA has recently issued a policy statement in an effort to correct inventory management deficiencies previously identified by GAO and Coopers & Lybrand. These revised policies establish performance goals for the percentage of DMI ordered but not used, service level and stock turn goals for the Shop Stores Inventory and goals for the percentage of UDM utilized. The requirement to have 100 percent of the material required to support production prior to the start of availabilities was eliminated. Each shipyard is required to develop specific goals and procedures for the management of the inventory accounts with the overall goal being to improve inventory management. Strengths and weaknesses of these policies were addressed and recommendations for improvement were provided.

Numerous alternatives remain which would serve to reduce the investment in inventories below current levels without affecting customer service or production schedules. Safety stocks could be reduced, particularly in the Shop Stores account, given the availablity of material at nearby Navy stock points. Direct Material could be purchased based on job order start dates utilizing historical procurement leadtimes

or stock point procurement leadtimes when historical data is not available. Existing purchase regulations could be altered such that shipyards could specify form, fit and function when writing purchase requests. The cost of purchase actions could be reduced through large quantity discount buys at individual activities or through the consolidation of purchase actions among several shipyards. The consolidation of the material planning and ordering functions would provide centralized management of the investment in inventory and would streamline the process of material reallocation among job orders. In addition, production department personnel should assume a greater role in the material management effort by ensuring that material required delivery dates will be met, and by returning unused material to the supply department in a timely manner.

VI. SUMMARY AND RECOMMENDATIONS

A. SUMMARY

The purpose of this thesis was to identify the causes of inventory growth at naval shipyards and identify possible material procurement and inventory management alternatives which would serve to reduce the future investment in shipyard inventories. Four basic research questions were considered to achieve this purpose:

1. What are the contributory elements of shipyard inventory growth in terms of physical quantities as well as cost, and what is the financial and managerial impact of this growth?
2. What is the effectiveness of the current data base and management controls over acquisition, requisition and disposition of inventory?
3. What changes in inventory management policies could be implemented at naval shipyards to reduce the size of inventories without affecting overhaul schedules and support?
4. Is it cost effective to permit schedule changes due to late material arrival?

These questions were answered on the basis of data obtained from related background literature, detailed analysis of prior studies of shipyard inventory management problems, analysis of current shipyard inventory management data and personal (telephone)

interviews with individuals responsible for inventory management decisions.

Material inventories at naval shipyards have increased 18.37 percent, from $518.7 million to $614 million, over the past five years. This increase in inventory value is the result of many factors, including increases in the complexity and costs of repair parts, the inability to transfer excess materials due to restrictive policies and the requirement to obtain and hold 100 percent of the material required for an availability prior to the start of the availability. Contributing to this growth are poorly defined technical data and purchasing requirements which prevent requisitioners from specifying required procurement sources. Both of these latter factors frequently result in the receipt of material which is not functional and requires substantial rework prior to use.

A major contributor to this problem is the lack of coordination between the materials planning and ordering functions which are performed by separate departments within the shipyard command structure. This lack of coordination results in unnecessary investments in inventory when identical material already exists but is restricted to other uses. These problems become more severe as inventory levels

continue to increase subject to fiscal limitations which are necessary in a climate of federal budget deficits and mandatory budget reductions at the activity level.

Inventory growth is not necessarily a problem because the complexity and value of ships undergoing overhaul and repair increase over time. In fact, some inventory growth is to be expected due to the increased complexity of repair parts (such as electronic modules) as well as inflationary factors which cause the cost of material to rise. However, the failure to use accurate planning data, including historical material usage factors, enhances the investment in inventory. Inventory management in any organization the size and scope of naval shipyards will never be perfect, and some material shortages and surpluses will always exist due to unforeseen maintenance requirements and the cancellation of previously scheduled work.

Revised inventory management policies were issued by the Commander, Naval Sea Systems Command in February 1988 in an effort to correct numerous inventory management deficiencies identified by the U.S. General Accounting Office and the accounting firm Coopers & Lybrand. These policies require that shipyards develop material handling procedures and methods to reduce inventory inaccuracies, and establish internal controls

for the documentation of material from the time of receipt to the time of issue.

Shipyards must also establish programs to improve, as well as maintain, inventory accuracy. Specific inventory accuracy goals for each inventory account were established to be achieved over the next three years. Reporting requirements for inventory management performance were also provided. Although the revised policies are a positive first-step toward reducing the investment in shipyard inventories, they are deficient in several respects.

For example, shipyards were not provided sufficient guidance regarding the extent to which new methods or procedures should be developed, nor were timeframes provided for required implementation. In addition, shipyards were directed to establish goals for the utilization of material in the UDM account, but were not provided specific goals concerning the extent to which this inventory account should be reduced under normal conditions (such as 15 percent reduction per year through 1992). Specific strengths and weaknesses for these revised policies were addressed and recommendations for improvement were provided.

Many additional changes could be made to existing inventory management policies which would reduce the size of inventories without adversely affecting

overhaul schedules and support. As discussed in this thesis, overhaul schedules have been met through the shifting of individual job orders within the overall schedule in order to meet specific key events for overhaul completion. Because these recommendations are expected to increase material availability through more accurate requirements determination, the need to reschedule individual job order completion dates should decrease. However, the potential to shift job orders due to lack of material would always exist, and conditions for overhaul completion would be no worse than under existing policies. The ability to delay overhaul schedules due to lack of material is considered cost prohibitive due to the impact on future overhaul and repair work, given limited shipyard facilities and the need to have fixed numbers of ships deployed or in a deployable status at all times.

B. RECOMMENDATIONS

Numerous recommendations for improving inventory management within naval shipyards have been proposed by the General Accounting Office and Coopers & Lybrand as the result of their individual studies. The recommendations of those studies, as well as those proposed below, are consistent in the identification of actions that should be taken at naval shipyards to improve inventory management. Additional

recommendations are provided and emphasized based on information that has become available since the conclusion of the GAO and Coopers & Lybrand studies. The benefits derived from the implementation of any or all of these recommendations are expected to exceed any dollar cost incurred, and will contribute to smaller investments in material inventories.

The following actions are recommended to improve inventory management at naval shipyards:

1. MATERIAL PROCUREMENT:

   a. Continue to utilize historical usage data, when available, for determining material requirements. Segregate standard stock requirements from non-standard requirements, requisitioning standard stock requirements prior to job order start dates based on historical average requisition turnaround times. Obtain Navy stock point average turnaround times for use in those instances where shipyard data is not available. When possible, order standard stock material for direct delivery to the requiring shop. Order non-standard requirements in advance of job order start dates based on historical or expected procurement leadtimes in those instances where delivery dates are certain.

   b. Revise procurement policies to permit shipyards to specify form, fit and function as well as manufacturer's make, model and part number. This will ensure that only required material is procured as well as minimize the amount of rework required prior to the installation of material and equipment. Requirements for competitive bidding and sole-source procurements should also be revised to permit the direct purchase of critical or highly technical repair parts from the original manufacturer. Sole-source procurement should also be permitted when a single supplier is known to be the only existing manufacturer of the required material and when a single supplier has

demonstrated superior leadtime performance. Because procurement personnel are currently evaluated based strictly on the number of purchase transactions performed, changes should be implemented to ensure that difficult transactions are not indefinitely set aside. Such measures might include criteria for various types of transactions which provide allowances for the longer time required to process complex transactions.

c. Develop a system wherein joint purchases among several shipyards can occur for high-cost material exceeding an established dollar value and for all purchases where price breaks may be obtained for quantity discount buys. The costs of such action should be weighed against the potential benefits, and joint purchases made only in those instances where the benefits exceed the costs.

2. INVENTORY MANAGEMENT:

a. Ensure that periodic physical inventories are performed as required, and that inventory records are updated based on verified physical inventory results.

b. Establish effective procedures to ensure the proper and timely assignment of material to the Unassigned Direct Material account. Assignment of material to UDM should occur at job order closure, and be limited to material which historically has long procurement leadtimes, are high-cost, require special manufacture or for which the shipyard is the sole or principal demand source. Standard stock material should be returned to system stock unless a potential future need can be demonstrated, and then returned to system stock at the end of the required minimum holding period.

c. Establish specific performance goals for requisitioning and inventory management performance and hold managers responsible to meet those goals. Such goals should include the percentage of high-priority requisitions submitted due to improper requirements determination, specific goals for the percentage reduction of the existing UDM inventory and specific goals for the percentage of UDM

utilized. Penalties should be imposed when such goals are not consistently met.

d. Revise the requirement that Shop Stores material be retained as demand-based on the basis of one demand in a 36 month period. A criterion such as one demand in a 12 month period would be more conducive to the reduction of the size and value of the Shop Stores account. Material could be transferred to the UDM account at the end of the 12 month period, held for the permissible 24 months and be available for production support during that period. Unused UDM would then be transferred or otherwise disposed of at the end of the maximum UDM holding period. The long-term impact of this action would be to reduce the Shop Stores inventory as well as return material to system stock earlier than under existing policies.

e. Lower the existing Shop Stores service level goal to 90 percent at all shipyards except Portsmouth Naval Shipyard. The Shop Stores inventory consists mostly of stock-numbered items which are usually available at Navy stock points. By relying on stock points for backup stocks, inventory levels can be reduced with minimal impact on customer support. Portsmouth Naval Shipyard is excluded because it is not located near a major supply activity. If this lower service level goal is achieved with negligible impact on production support, it might be lowered even further in the future. The ability to rely on backup stocks at Navy stock points assumes that the supply system will continue to operate at high service levels.

f. Develop specific decision rules for the transfer or disposal of material from the UDM account. Specific decision rules are required to ensure that shipyard inventory managers make correct, timely decisions for the transfer or disposal of material assigned to this account.

g. Evaluate the Gardner model for use in the determination of Shop Stores inventory levels, and determine if this model might be applicable to other shipyard inventory accounts. If inventory levels and safety stocks can be reduced with negligible impact on mission accomplishment such that the overall benefit derived exceeds the cost of implementation, the model should be

implemented for the management of the Shop Stores or other inventory accounts. Personnel with experience and training in the use and implementation of mathematical inventory models should be relied on throughout evaluation and implementation efforts.

h. Establish an organization responsible for the overall investment in inventory to include the planning and ordering functions. This organization should monitor the planning of material requirements based on overall work schedules as well as reallocate material from existing assets to support current job orders. Other responsibilities would include making recommendations for "make-or-buy" decisions, ensuring the timely ordering of material in accordance with published plans and ordering schedules, as well as researching and providing complete and accurate data for sourcing against locally available assets, requisitioning of standard stock material and non-standard procurement actions.

i. Establish procedures to ensure that material required delivery dates are monitored at the production shop level, and advance follow-up action is performed to ensure material delivery prior to job order start. Such action would serve to minimize current expediting efforts, including special ordering and shipment of material, as well as delays caused by lack of material.

j. Establish procedures and controls to ensure that unused material issued to production shops is returned to stock when it is determined that the material will not be required for production support. Materials actually used in production should be routinely matched to job orders, and shop supervisors held responsible to ensure that unused material is returned to stock within specified timeframes after job completion.

3. EXCESS MATERIAL:

a. Transfer all excess Shop Stores material to the UDM account for greater visibility as part of the Shipyard Material Visibility System. This action would ensure that the material is identified as excess to the holding shipyard's current needs. In addition, the size of the Shop

Stores account would be reduced by the amount of the excess material, making Shop Stores management (including physical inventories) much easier and less costly.

b. Continue the development of a centralized data bank that contains a record of all material assigned to the various shipyard UDM accounts, inactive and excess Shop Stores items and material assigned to DMI Category Four. Shipyards should then utilize this data bank to fill material requirements prior to the initiation of non-standard procurement requests or high-cost standard stock requisitions. In all cases, the cost to transfer the material to the requesting shipyard should be compared to the cost to procure that same material (including the dollar cost of the material purchased) as well as the implied cost of potential delays resulting from the lack of material. Material should be transferred when the transfer cost is less than the costs of procurement and production delays.

c. NAVSUP should adjust its existing material returns policy to ensure that shipyards have sufficient incentive to return excess material to system stock. In addition to reviewing all stock returns in excess of $2,500, NAVSUP should coordinate the return of material, such as material managed by the Defense Logisitics Agency (DLA), to the DLA for distribution to DLA storage sites or to other military services. NAVSUP should also periodically screen the Shipyard Material Visibility System to identify shipyard excesses which could be utilized by the supply system.

C. FURTHER RESEARCH

Further research is required regarding the availability and applicability of new models for the determination of shipyard inventory levels. Such models should consider the availability of backup stocks within the Navy supply system as well as limits for the overall investment in inventory. Models

tailored to shipyard requirements are unavailable, yet necessary, due to the unique procurement relationships between naval shipyards and the various sources, both military and civilian, from which material is obtained. The research required to develop such models is best performed by individuals experienced in the development of mathematical inventory models.

Additional research should also be directed at the material rejection rates that exist for shipyard material. Although rejection rates have decreased in recent years, the (current) rejection of 11.1 percent of all material purchased is higher than material rejection rates experienced by civilian shipyards. The author believes that this situation is a combination of improper material standards, poorly written purchase specifications, improper vendor selection and perhaps improper receipt inspections. A detailed study in this area could lead to corrective action which would reduce the investment in material that is not suitable for use.

Once the recommendations of this and other studies have been implemented, a follow-on study should be conducted to evaluate the effectiveness of these measures. Corrective action and additional alternatives for improvement should be identified and

implemented based on conditions in existence at that time.

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APPENDIX

LIST OF ACRONYMS

COMSUBLANT	Commander Submarine Force U.S. Atlantic Fleet
CNSYD	Charleston Naval Shipyard
DMI	Direct Material Inventory
DLA	Defense Logistics Agency
DOD	Department of Defense
FY	Fiscal Year
GAO	General Accounting Office
JML	Job Material List
LLTM	Long-leadtime material
MIS	Management information system
MM	Material Management subsystem
NAVSEA	Naval Sea Systems Command
NAVSUP	Naval Supply Systems Command
NIF	Navy Industrial Fund
NRFI	Not-ready-for-issue
NSN	National Stock Number
RFI	Ready-for-issue
SPCC	Navy Ships Parts Control Center
SRA	Selected restricted availability
TYCOM	Type Commander
UDM	Unassigned Direct Material Inventory
WIP	Work-in-process

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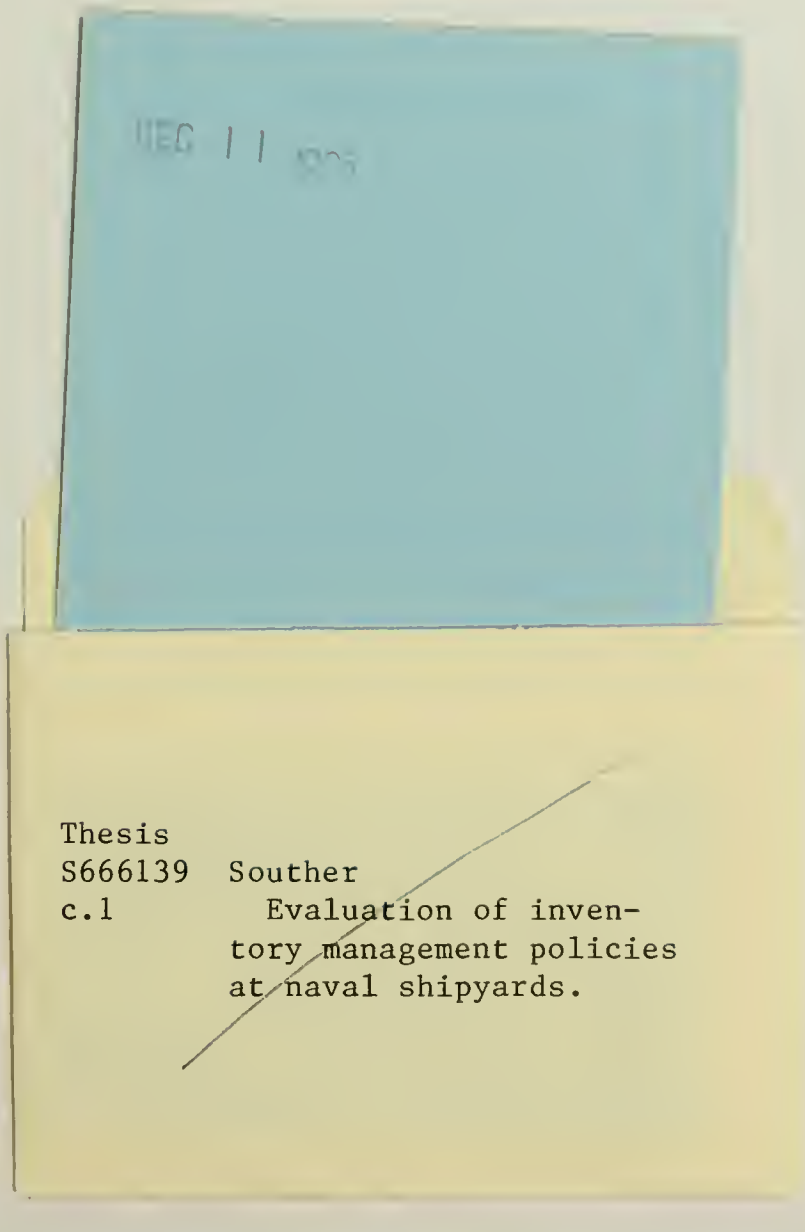
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