

DEVELOPMENT AND IMPLEMENTATION OF ZONE LOGIC CONCEPTS ON  
SHIPBUILDING MODERNIZATION

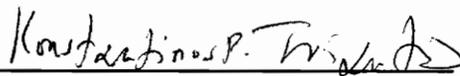
by

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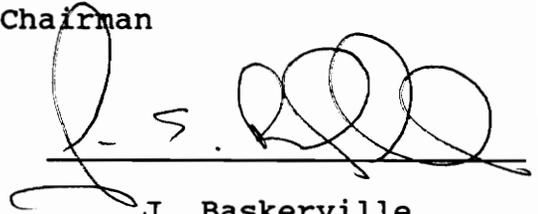
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DEVELOPMENT AND IMPLEMENTATION OF ZONE LOGIC CONCEPTS ON  
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Industrial Engineering

(ABSTRACT)

Shipbuilding is very complex and politically motivated, labor intensive industry. It is essential for the economic future of the country and a requirement for the United States Navy and the country's National Security. The whole shipbuilding concept is a system oriented structure that is dependent on the auspices of the military designers for new technology and a solid way to combat the worldwide threats. This paper will deal with the repair and modernization part of the ship system operation and utilization phase of the system life cycle. The system operation phase is by far the most expensive phase of the life cycle of the ship, comprising approximately 60 percent of the total life cycle cost of the ship. The cost of maintenance, repair and modernization of the ship represents a good portion (approximately 35 percent) of the system operation costs during its life cycle. In order for this paper to facilitate

the position for the use of Zone Logic as an alternative to the traditional system-by-system modernization of the existing U.S. Navy ships, a historical perspective as well as a description of the alternative shipbuilding concepts and modernization techniques are included. Finally the qualitative benefits are shown and an analysis of a recent test for Zone Logic on a LPH - 2 class ship are performed to show that Zone Logic is a valid concept for the use in ship modernization. The data used in the analysis portion of this paper were final return costs that were provided by the contractor to the Naval Sea Systems Command.

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## CHAPTER 1. INTRODUCTION

Shipbuilding is very complex and politically motivated, labor intensive industry. It produces products such as ships, offshore structure's, etc., for the customer (private owners, companies, governments, etc.) and is essential for the economic welfare of the country and a requirement for the United States Navy and the country's National Security. In most cases the product is built to order and customized to the specific requirements of the purchaser. The purchaser that this paper will focus on is the United States Navy.

The Military shipbuilding process generally involves the following stages:

- \*Development of the Navy's requirements
- \*Preliminary/concept design
- \*Contract design
- \*Bidding/contracting
- \*Detail design and planning
- \*Construction
- \*Operation and maintenance

"Systems engineering is a process that has recently been recognized to be essential in the orderly evolution of man-made systems"[1]. Naval ships are very complex systems with multiple subsystems, and its evolution is through a need to combat some threat, be it the recent Persian Gulf War or Soviet warfare. All U.S. Navy ships perform a mission to combat their designed threat. The Naval shipbuilding process involves the application of efforts necessary to transform the operational need or threat into a description of system performance parameters and a preferred system configuration through the use of an iterative process of functional analysis, synthesis, optimization, design, definition, test and evaluation. Naval shipbuilding also involves the integration of related technical parameters to assure compatibility of all physical, functional, and program interfaces to optimize the total system definition. Finally military shipbuilding integrates all of the needed characteristics, such as performance, producibility, reliability, maintainability, supportability, human factors, and other peculiar specialties into a total engineering effort. The above description for Naval shipbuilding is a description or definition of systems engineering, i.e. Naval shipbuilding is a systems concept.[1]

Similar to all systems engineering concepts, ships have

a system life cycle. The definition of the threat commences the ship's system life cycle. It is followed by conceptual development and the definition of the system requirements. With the threat definition and the systems requirements on hand the design process commences with preliminary design, detail design and production of the first ship. This is followed by ship system test and evaluation, large scale production, and operational utilization of the ships. Ships differ from other systems in that prototype development during the detail design and development stage is not feasible due to the high costs involved in building a ship. Therefore test and evaluation is performed on the first ship of the class.

Shipbuilding is centuries old, paralleling the history of man. Shipbuilding techniques have changed in response to changes in vessel design, materials, markets, and construction methods. The organization of shipbuilding companies have also emerged and responded to the changes of techniques. The latest changes in shipbuilding techniques have been generated by group technology or Zone Logic, which has revolutionized the shipbuilding process in Japan and the rest of the developed countries.

This paper will focus on the maintenance and repair of

the ship system operation and utilization phase of the system life cycle. The system operation phase is by far the most expensive phase of the life cycle of the ship, comprising approximately 60 percent of the total life cycle cost of the ship. The cost of maintenance, repair and modernization of the ship represents a small portion (approximately 35 percent) of the system operation costs during its life cycle. In order for this paper to facilitate the position for the use of Zone Logic as an alternative to the traditional system-by-system modernization of the existing U.S. Navy ships a historical perspective as well as a description of the alternative shipbuilding concepts and modernization techniques are included. Finally the qualitative benefits are shown and an analysis of a recent test for Zone Logic on a LPH - 2 class ship are performed to show that Zone Logic is a valid concept for ship modernization. Appendix A comprises of the data and analysis used in this study and the graphs derived from the analysis.

The research accomplished by this paper recognizes the need of a more efficient technique in the repair and maintenance of U.S. Navy ships to increase productivity and reduce the Life Cycle costs involved in the maintenance and repair of the Ship's Operation and Utilization phase of the systems life cycle.

## CHAPTER 2 HISTORICAL PERSPECTIVE

Throughout its early history, shipbuilding, like most other industries, was craft oriented. Thus it was mostly dependent on the skills of the craftsmen doing the work. Little planning was involved prior to the beginning of construction. As the owner's became more specific on the desired characteristics of a new ship, shipbuilder's were required to do more planning. However, prior to the use of iron and steel, shipbuilders built the ship's with little more than a scale model or a simple drawing.

As industrial processes became more complex and efficient shipbuilders kept pace with changing technology. Shipbuilding began to be subdivided into specialties such as hull construction, machinery outfitting, and painting. The specialization of labor did very little for the improvement of the total shipbuilding process. Specialization became a detrimental force for the whole process because labor was only concerned with their own specialized part of the total system, thus increase in rework was eminent. Fortunately the advent of Group Technology and subsequently Zone Logic (Group Technology as applied to shipbuilding) showed that

labor should be more concerned with the total ship system than the specialized work to be accomplished.

## **THE WAR YEARS**

The history of modern shipbuilding has much of its roots in the United States during World War II. When Hitler met with his Admirals in September of 1942 to assess the damage that German submarine warfare had inflicted upon the allied fleets, he confidently asserted that American shipyards could not build merchant ships faster than they were being sunk. By mid-1943 American shipyards were producing ships faster than they were being sunk. The vital lifeline to the United Kingdom had been sustained and Hitler hadn't thought that a man named Henry Kaiser, the industrialist, could tackle the impossible and succeed.[2]

Until the Industrial mobilization which accompanied the outbreak of war in Europe the Kaiser Organization had never build a ship. Kaiser was more well known for large scale construction projects such as the Grand Coulee, the Hoover and the Bonneville Dams and the San Francisco Bridge. Then suddenly, utilizing industrial engineering principles, the Kaiser organization outproduced established shipbuilders. The record shattering performance was mainly

due to the introduction of Group technology which organizes the work by the problems inherent in manufacture. Through Group Technology, Kaiser's yards were achieving high productivity normally associated with production lines, building subassemblies in varying quantities as required for the building of ships.[2]

During the World War years experienced workers existed mainly in the shipyards preempted for building ships. Kaiser's shipyards had to train thousands, including many women, without factory experience. The normal time for training a welder takes anywhere from two to three months, Kaiser's people were able to train welders in ten days, because they were taught downhand welding, that is welding below the waist so as the weld flows through gravity. To make an overhand weld takes experience, therefore Kaiser's yard minimized overhead welding and Kaiser proved that virtually anyone could weld down hand with minimal training. Since time was of the essence the Kaiser yards build ship bows sideways, deckhouses upside down and the sides of the ships on the ground so as to facilitate downhand welding. The Kaiser principle was to organize work to fit the worker instead of finding the worker to fit the work. Government records show that through liberty ships alone, the Kaiser yards saved the United States \$226 million in WWII money.

The most important factor at that time was that the Kaiser yards were producing ships one third faster than his competitors.[2]

During four war years the United States shipyards build over 7000 ocean going vessels, about 5700 for the maritime commission and the rest for the Navy.[3] When the war ended, the yards which continued operations were competitive internationally, in part because foreign yards were damaged or destroyed, and in part because they could build ships faster and less costly than their international competitors. Kaiser left shipbuilding as the wartime emergency yards shut down.

#### **JAPANESE SHIPBUILDING INNOVATIONS**

Elmer Hahn, the former general superintendent at Kaiser's Swan Island Shipyard in Oregon, found employment with National Bulk Carriers(NBC) of New York, which at that time operated Welding Shipyard at Norfolk, Virginia. NBC wanted to build large carriers for the iron-ore trade between Venezuela and the United States. As the facility in Norfolk was too small, Elmer Hahn was given the task to find a facility where such big ships could be built. Due to the budget set forth by NBC Mr. Hahn inevitably stumbled upon

the Kure Shipyards in Japan and set forth the advent of Zone Logic.[2]

A misconception that many believe today is that the Japanese Shipyards were reduced to rubble, much like the German Shipyards. However before the end of WWII the Japanese Navy was completely destroyed by the Allies, and their merchant marine was reduced to one fifth of its prewar size, and the U.S. submarines had effectively stopped flows of raw materials. Therefore the Shipyards were not bombed. Another myth that the Japanese shipyards were resurrected and modernized through U.S. funds is unfounded since the Marshall Plan did not apply to Japan.

Mr. Hahn taught the Japanese organization of work in accordance with the basic principles of Group Technology, emphasis on welding without distortion to control costs, and the importance of college educated middle managers trained in the entire shipbuilding system.

As the teacher, Elmer Hahn recognizes Dr. Hisanhi Shinto as the "pupil who outdid the master". Dr. Shinto found post war employment with National Bulk Carriers (NBC) as Chief Engineer, reporting to Elmer Hahn. With other American inputs Dr. Shinto developed the shipbuilding system

continuously even after the lease NBC carried expired. He build the Shipyard at Kure into Ishikawajima-Harima Heavy Industries Co. Ltd. (IHI). His study of Boeing's B-29 drawings disclosed how composed drawings are used to designate assemblies and subassemblies, each furnished with a material list. He observed the construction of skyscrapers which provided the necessary materials in accordance with the building strategy. These ideas together with uniquely Japanese material control and statistical methods, the processes at IHI became a self-improving shipbuilding system with Zone Logic intact.

Another very important asset the Japanese obtained were the services of Dr. W. Edward Deming , Professor of statistics, New York University. Toward the end of 1945 in Japan, manufacture of civilian goods was began sporadically and industrial production recovered slowly from 1946 through 1947. However products were poor in quality. The Union of Japanese Scientists and Engineers determined that dissemination of statistical control methods could significantly improve quality and productivity. Dr. Deming gave 35 lectures in the summer of 1950 to Japanese top management and engineers. By the spring of 1981, Dr. Deming had made 19 trips to Japan. Statistical Control methods had began to permeate Japanese industry. With the application of

Statistical Control and Zone Logic, the Japanese Shipbuilding Industry was producing 40 percent of the world's total shipbuilding tonnage. Both Elmer Hahn and Dr. Deming were honored with awards from the emperor of Japan.[1]

### **U.S. SHIPBUILDING EFFORTS**

The National Shipbuilding Research Program(NSRP) was a development of the Merchant Marine Act of 1970. The program is a consortium which is cost shared and managed by a number of shipbuilders on behalf of the entire industry and is supervised in behalf of the government by the Maritime Administration's Office of Advanced Ship Development. The NSRP focused on short-term goals in the beginning and in the most part were hardware oriented. The NSRP was joined by research program managers and academics who toured shipyards in Europe and Japan looking for ways to improve productivity. Many were impressed by the new grand scale facilities that were building Ultra-Large crude oil carriers. There were five such shipyards in Japan before the Arab oil embargo in 1973, yet they were not the backbone of the Japanese Shipbuilding Industry. Today those shipyards are either closed or they are not as effective as the older shipyards.[2]

Although the Grand facilities were impressive, they were not pertinent to the Productivity that the Japanese Shipbuilding Industry was enjoying. During 1976, after visits to Europe and Japan the consortium concluded that the operations at IHI was the most developed in the world and was even regarded as such by other shipbuilders in Japan. On a trial basis, a research project was initiated to disclose how outfitting is managed. In 1979 the NSRP published a very illustrative booklet, Outfit Planning, which convinced American shipbuilders that there were more to Japan's Shipbuilding gains than cheap labor and government subsidies.[2]

In 1979 A&P Appledore Limited carried out a comparison of the productivity of a small number of U.S. Shipyards building primarily commercial ships with four roughly comparable foreign yards. Appledore used statistics on ship completion and employment for the period 1976 to 1979 and applied compensated gross registered tonnage coefficients to adjust for ship complexity; it was further aided by a technology survey of the yards completed in 1978. They concluded that productivity in the best Japanese and Scandinavian yard is of the order of 100 percent better than in a good U.S. shipyard.[4]

The principal productivity problem being faced in all of manufacturing is to organize work to be done in a way which permits the maximum use of the players such as the workers and equipment available, while minimizing the waste of material. Ideally there shouldn't be an unnecessary task that the worker must perform, equipment shouldn't be used superfluously and material shouldn't be thrown away and the most important factor of all is that the work should flow continuously in order to work more effectively.[4]

Innovation and automation are two concepts which are often introduced to explain major gains in productivity. Innovation to improve productivity involves the reorganization of the production process to facilitate better management control, to permit increased specialization of workers and machines and to make the flow of work more continuous. Automation involves using machines to perform certain tasks in the production process in place of people. Industries that are labor intensive tend to find ways to automate their processes. Since shipbuilding is the most labor intensive industry in this country, automation will have to play a big role on increasing the productivity of the U.S. shipyards.[4]

Figure 1 illustrates the evolution of shipbuilding methods by relating some of the more salient of these innovations to four stages in the improvement of shipbuilding methods, tracing in parallel the evolution of both hull construction and outfitting.

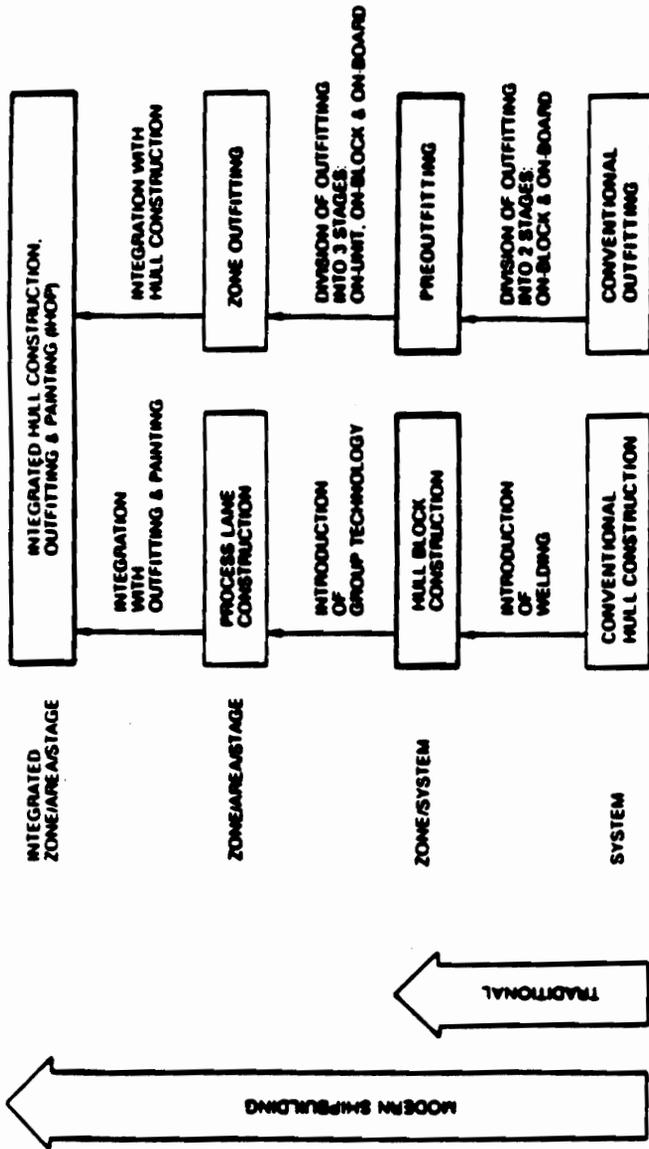


Fig. 1 History of basic improvements in shipbuilding methods [Reference 2]

## CHAPTER 3 SHIPBUILDING TECHNIQUES

### 3.1 TRADITIONAL SHIPBUILDING

The traditional way of constructing a ship dates back to the wooden ships, where a ship was constructed in place, working on each functional system of the ship in turn. The keel was laid out first, then the frames were erected and everything else followed. When the hull was complete outfitting began. Outfitting was planned and carried out by system, as ventilation, piping, electrical, and machinery systems were installed.

The management of the construction of a large ship, which requires hundreds of employees, became a very difficult task. Except for the launching when the hull was nearly complete, there were very few milestones in the process by which progress was measured. The failure of one group of employees (work crew) to finish their work that is needed by another usually resulted in overtime for one crew and idleness for the other. Worker specialization was difficult because of the sequence of different activities, such as the difference of hull erection vice outfitting. Consequently workers specialized by skill rather than by

master outfitter, or master hull builder.

Outfitting the ship after erection of the hull has many misgivings. The cramped quarters inside the ship severely limit the number of workers who could work in a space at a particular time. The size of the hull openings made moving machinery and equipment awkward and time consuming. The provisions for temporary services such as welding cables, staging, and compressed air were made difficult, costly and often times dangerous. Moreover workers often compromised access to their work performing overhead welding and were exposed to the weather.[4]

Engineering design drawings reflected very little of detail, since craftsman were expected to use their training and experience to develop details on the job. This created disorientation and an organizational gap between the shops because they would work in isolation from each other. Productivity depended almost exclusively on the effort and the ability of the production craftsmen.

In many shipyard engineering departments, the installation of hull outfit systems and equipment is considered a craft much like cabinet-making. The machinery drawings are used by the shipbuilder as a definition of

equipment arrangement so that other engineering disciplines can prepare the detail design, such as piping, foundations, floor plates, etc.. Piping drawings are prepared for the particular system and they may or may not show pipe breaks, hangers, and some production information. The same is true for electrical and Heating Ventilation and Air Conditioning (HVAC). [5][6]

Interference control is the design process that reduces obstructions in shipbuilding design. In traditional shipbuilding interference control is usually provided by space composites. This approach created many problems because the electrical crafts go ahead and perform their "hot-work" before many of the other detailed systems and composites are completed. The work is usually performed in the easiest location possible without checking it or even feeding back to the engineering department to locate it to the composites. Apparent great production work progress is achieved early in the process until realization sets that extensive rework is needed. [6]

As welding replaced riveting in hull construction, the whole concept of shipbuilding began to change. Hull construction began being a process of making block-like weldments of hull and decking and assembling these blocks

together to erect the hull. Hull building began a new phase by moving much of the work away from the shipways since the welding could be done more safely and conveniently adjacent to the ship or in separate shops. To facilitate work flow in the shops, a typical block might weight 40 to 50 tons. Better accuracy was required in cutting and fitting parts, which provided the need to develop better lofting and steel processing.[4]

The construction of a ship in blocks permitted a change in outfitting practice. Outfitting could either be done on-board the ship after the hull had been completed or on the blocks before the assembly of the hull. On-block outfitting was clearly preferred for the items which could not be installed on-board due to size limitations or compartment access. This transformation of the production process along with the depressed shipbuilding market of the 1970's led to the need for many shipbuilders to consolidate their facilities and to improve their production process.[4]

### 3.2 ZONE LOGIC

Zone Logic is a shipbuilding technique where the construction of the structure, and the installation of the distributive systems, outfit and equipment, are integrated and occur when the ship is in a modular or partially erected stage. The normal breakdown into system disciplines, such as structure, piping, HVAC, electrical, and painting, tends to disappear and all items become interim products. To accomplish this a ship is divided into Zones. The division can be sequential, divided by compartments in sequence, or hierarchical, divided by major system such as Hull, Machinery, Electrical etc., or any combination of these extremes.

Zone Logic redefines the approach to shipbuilding and encompasses the planning of the construction at the same time as the drawings are being prepared, thus influencing the design to suit the intended building plan. This can be done without significant changes to the facilities and construction equipment. Shipyards using Zone Logic are identifiable by constructing ships in modules and incorporating extensive advanced outfitting.[5]

The optimum engineering information format for Zone Logic is a drawing or sketch and a part list for each work station (including zones on-board the ship). This information is not only for the structure but for all other systems. A work station drawing shows all the work that is going to occur in the particular location, such as a platen, shop, machine, module, or zone. It can be one sheet showing the completed product at the end of all the work to be completed at the given station with written sequence(process) instructions, or it can be a series of sequential construction sketches showing the build-up of the product from the received parts to its completed status for the work station.

Zone Logic requires significant overlap of design, material procurement, and production for reducing the overall construction period, but overlap reduces the time needed to organize the information developed by the designers. Thus from the outset, design information must be formatted to anticipate the needs relating to material and production.

The design process is divided into:

- \*Basic design and
- \*Product engineering

Basic design covers all design throughout the system from conceptual to functional design. The process is divided into concept, preliminary, contract and functional design. All except the last must be performed before the award of the construction contract. Functional design is the phase where the contract design is expanded to contain all design decisions. Product Engineering covers all tasks required to transmit construction information to Production, and other shipyard departments. It contains two phases, transitional design and zone information. Transitional design is the task of integrating all design information into complete zone detailed arrangements. Zone information is the task of providing all drawings, sketches, part lists, process instructions, production aids required for production and other service departments to construct the ship.

Zone Logic concepts are proven to be effective in the shipbuilding world especially in new ship construction, however as a concept Zone Logic has a number of disadvantages:

1. United States Shipyards are 90% Unionized and trade unions are established by craft which in turn are in a philosophical conflict with the Zone Logic Principles. Zone Construction requires that workers be

formed into flexible teams that must perform different types of work.

2. Capital Investment - The shift to Hull Block Construction and Pre-outfitting requires investment in large cranes with heavy lift capabilities to move the blocks around.

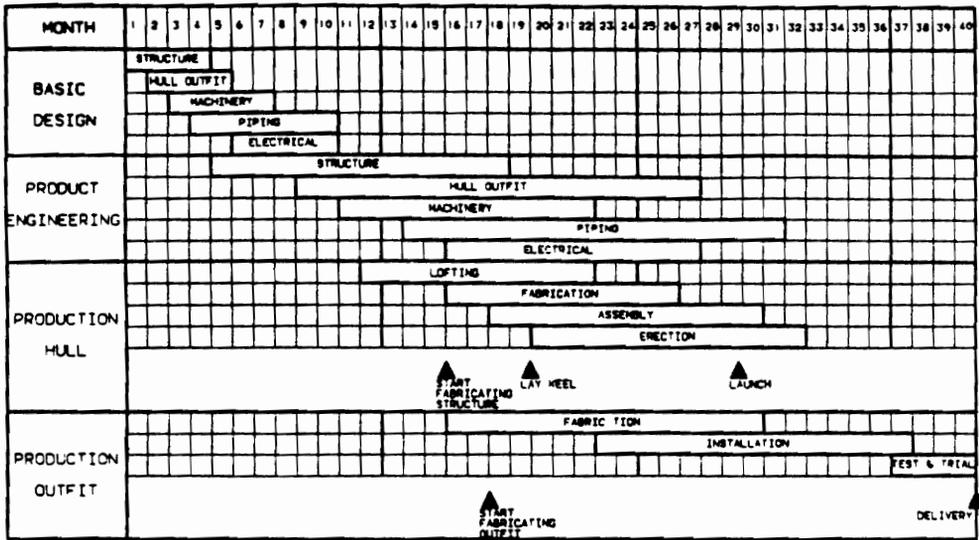
3. The Product Work Breakdown Structure (PWBS) that is required for Zone Logic is in conflict with the Extended Ship Work breakdown Structure (ESWBS) currently used by the United States Navy and its contractors.

Table 1 summarizes the major differences between Zone Logic and Traditional Shipbuilding construction along with the benefits of Zone Logic. Figure 2 shows examples of the ship system design and construction schedule using the traditional shipbuilding approach and the Zone Logic approach respectively. Obviously, the Zone Logic approach to engineering will require additional man-hours. The engineering portion of shipbuilding will take over the planning sketches and the loft sketches as were accomplished by traditional methods. Lofting, the hull construction drawings, and production manhours will be reduced and as

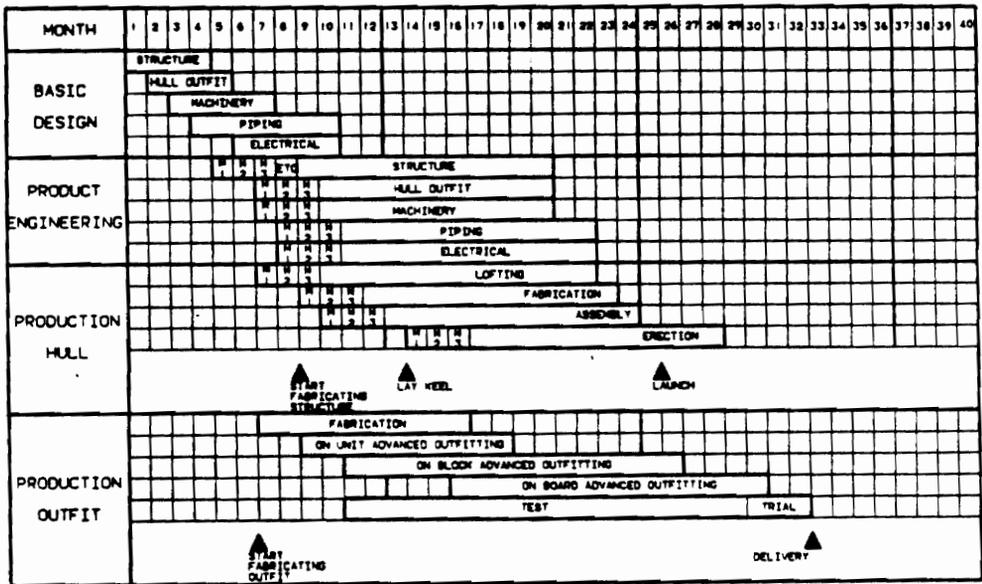
shown in Fig. 3, the overall result of Zone Logic will be a reduction in total man-hours to design, engineer and construct a ship.[6]

Table 1 Comparison of Traditional and Zone Engineering [Ref: 4]

Traditional	Zone	Benefit
Structural drawings prepared on item basis from bow to stern, for example —shell drawing —deck drawing —bulkhead drawing —tank top drawing —framing drawing	Structural drawings prepared on a construction sequence basis for subassemblies, assemblies and blocks, for example —web frame subassembly —transverse bulkhead assembly —double-bottom block —wing tank block	<ol style="list-style-type: none"> <li>1. With traditional approach, construction cannot be started until a number of item drawings are complete. For example, one block required 13 drawings to show necessary data. With zone approach, construction can commence when the first block drawing is complete.</li> <li>2. With traditional approach, it is necessary for someone (production planning) to prepare block parts lists and sequence assembly sketches. With zone approach, production can use engineering-prepared drawings directly, thus saving additional effort and time.</li> </ol>
Machinery arrangements laid out for individual equipment and piping installation.	Machinery arrangements laid out for "on unit" advanced outfitting packages and piping and grating package assemblies.	"On unit" advanced outfitting has been demonstrated to be the greatest productivity improver. Also allows work to be performed on unit and the ship to be completed earlier.
System diagrammatics prepared for design use only in preparation of A&D drawings with no particular accuracy in equipment location or pipe routing.	System diagrammatics prepared accurately as possible, including scheming for pipe routing with other systems and showing all information required for material procurement and planning.	<ol style="list-style-type: none"> <li>1. By integrating all system diagrammatics in a given space, the grouping for piping of various systems can be considered.</li> <li>2. Also, knowing that the diagrammatics are more accurate allows material to be ordered with greater confidence, which reduces the need for margins.</li> <li>3. More complete diagrammatics are acceptable for complete owner and classification approval; that is, it is not necessary to send A&amp;D drawings for approval.</li> </ol>
A&D system drawings prepared for complete ship or areas of ship without regard to block breakdown or "on unit" advance outfitting. Usually prepared as independent drawings for each system, thus making integration and grouping of piping and supports together for installation difficult, if not impossible.	System working drawings consist of final instructions to the production worker, such as spool sheets, installation sketches and material lists suitable for direct incorporation in work packages.	<ol style="list-style-type: none"> <li>1. Elimination of traditional A&amp;D system drawings.</li> <li>2. Earlier availability of construction information for piping.</li> <li>3. Prepared on a zone basis, earlier installation of piping.</li> <li>4. Eliminates current additional step which can introduce human error which can mushroom due to unexpected interferences and/or rework.</li> </ol>
Engineering drawings, data, etc., that are unsuitable for direct issue to production, must be further processed by production planning.	Engineering prepares all production-required drawings and data, such as structural subassembly, assembly and block sequencing sketches, pipe spool sketches, advanced outfitting drawings and lists.	<ol style="list-style-type: none"> <li>1. Increase in mutual engineering/production knowledge and cooperation.</li> <li>2. More problems solved on paper rather than on hardware.</li> </ol>
No input for advanced outfitting.	Prepares advanced outfitting drawings and parts lists.	<ol style="list-style-type: none"> <li>1. Engineering designs ship to facilitate advanced outfitting.</li> <li>2. Forces material definition to support advanced outfitting.</li> <li>3. Results in a more integrated ship.</li> </ol>
Lofting is prepared from and therefore after detailed structural drawing is completed.	Lofting is an integrated part of structural development. Usual detailed drawings eliminated.	<ol style="list-style-type: none"> <li>1. Shortened time from contract award to cutting steel.</li> <li>2. Increased productivity of combined engineering and lofting.</li> </ol>
Independent planning and scheduling keyed to a master event schedule.	Integrated planning and scheduling for engineering, material procurement, and production for individual work packages.	<ol style="list-style-type: none"> <li>1. Compatibility of all detailed schedules.</li> <li>2. Effect of change on one department automatically apparent to other departments.</li> <li>3. Schedule items identifiable to simplest production package.</li> </ol>



Traditional shipbuilding and isolated engineering



Advanced shipbuilding and integrated engineering

Figure 2: Traditional versus Zone Engineering [Ref:5]

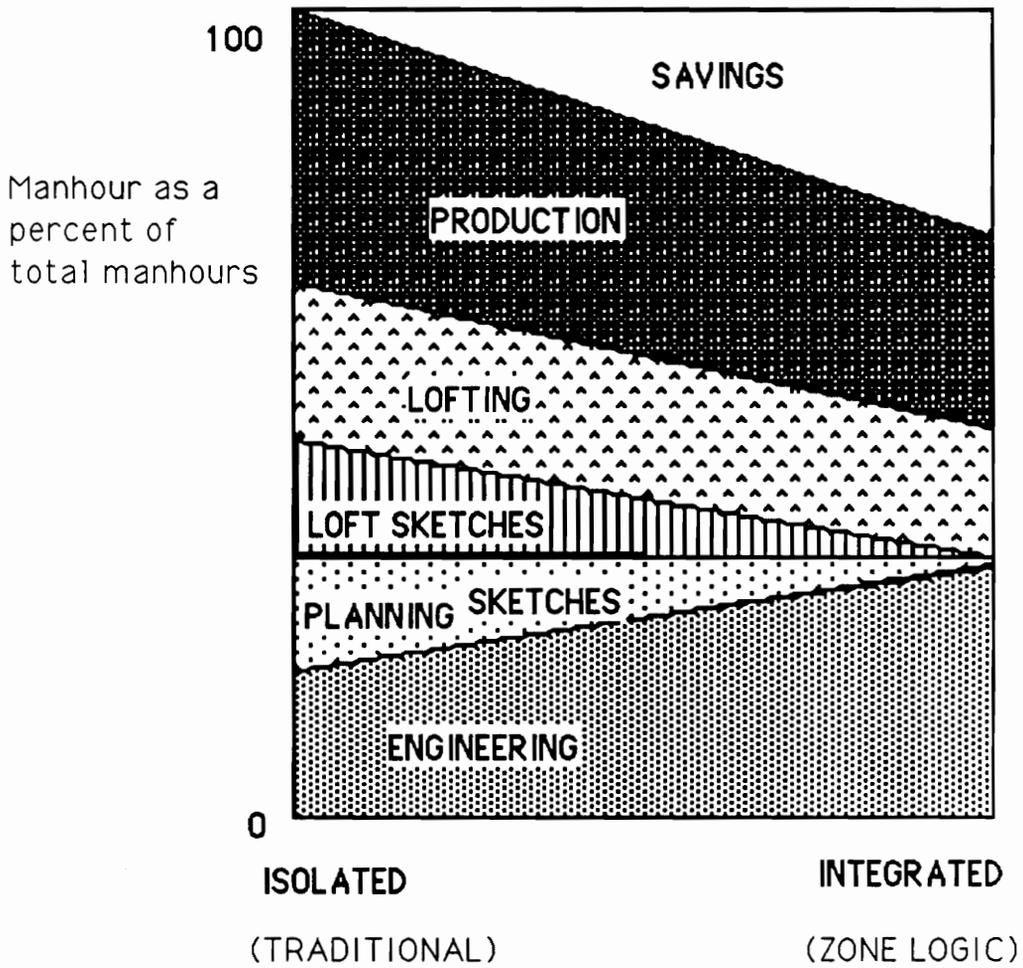


Figure 3: Manhour reduction due to Zone Logic

## CHAPTER 4 SHIP CONVERSION, OVERHAUL, AND REPAIR

Ship conversion, the process of modernizing an existing ship with new systems, overhaul, the process of replacing or repairing major ship systems, and repair, the process of fixing parts of major systems that have deteriorated, represents a very important part of the U.S shipyard market in terms of volume, profitability, and market stability. Repair and conversion in private yards employs approximately 25 percent of the ship work labor force. In terms of dollar value, this work represented nearly 26 percent of all ship work in 1975 and approximately 40 percent in 1980. The U.S. Navy accounts for approximately 75 percent of the ship repair and overhaul market.[7]

Conversion, overhaul and repair is divided between commercial and public work. The private yards are allocated between 33 - 39 percent of the Navy overhaul and repair work. A congressional mandate directs that the private sector share not to fall below 30 percent of the market. The Navy has historically awarded less complex ship overhauls to private yards, to the extent possible. However, as the complexity of the ships increases the Navy is allocating

more complex work to the private shipyards. In FY 1983 the ship maintenance and overhaul budget was \$4.994 billion with a steady increase to \$5.279 billion in 1985 and \$6.37 billion in 1986.[8]

Conversion and repair is generally more profitable than ship construction, since the work is usually performed on existing ships and the overhead required is much smaller than that required for new ship construction. However, the stabilizing effect of the industry is also a primary reason for many shipyards to be in it. This part of the shipbuilding industry is more stable and predictable than ship construction. It is also more skill intensive and provides a base for retaining highly skilled shipyard workers in times of low demand for ship construction. Shipyards have come under Navy criticism for allocating workers back and forth between new construction and overhauls, however, this criticism does not have any merit since the work has flourished instead of being diminished.[7]

There are a number of similarities and differences between new construction and conversion, overhaul, and repair. The similarities include application of essentially the same manufacturing and construction processes, although

the mix is different. The major difference is the addition of a rip-out, the removal work stage, and the requirement to work with existing products, such as an existing machinery room, rather than beginning with essentially a clean slate. For a better understanding of the differences between ship construction and conversion, overhaul, and repair is to examine the differences that exist in worker skills and planning.[7]

The difference in worker skills is the need to respond to on-site information and to evaluate and solve problems that may not be apparent until the work is underway. The result is the need for more skilled craftsmen in repair work and a greater number needed than in new construction. This is a result from the difficulty in organizing the work to permit enough similar jobs to exist so that simpler, specialized approaches can be employed. The time frame of modernization is generally much shorter than new construction, which implies for greater understanding of the work and rapid solutions to problems that come up on the waterfront.

The differences in planning are also driven by the greater uncertainty in modernization work. The uncertainty in the scope of work often results in the growth of the job,

based on what actually is found when work commences. Following rip-out, the exact nature of the required repair becomes evident for the first time. Often this produces more work than was originally anticipated.

Preplanning can be a way of solving this problem. The most promising approach to preplanning is to have repair specialists visit the ship prior to its arrival at the shipyard. These specialists can then attempt to further define the requirements of the job, both by inspection and discussion with the ship's crew. In addition to determining the scope of the work, preplanning can facilitate rip-out, improve work flow, and reduce worker congestion on-board the ship.

#### **4.1 SYSTEMS-ORIENTED MODERNIZATION**

Ship repair is a classic example of the job shop form of production organization. It is highly labor intensive with limited potential for automation. Most of the work is accomplished aboard the ship, and consists of rip-out and refitting steel, pipe, machinery, or wiring to existing systems.

Historically, all outfitting work in naval shipyards has been planned, scheduled, executed, and tested on a system-by-system basis. This method was developed for several valid reasons, including:

- \*cost estimating and accounting
- \*material estimating
- \*ship operation and identification of problem areas
- \*system testing

Repair work is usually accomplished on a system-by-system basis, such as, repairing a major weapon system, beginning with planning, and including scheduling, executing and testing. The reasons for this basis have to do with the process and institutional considerations. Planning begins with the ship operators identifying the repair requirements in terms of systems capability and material condition. Cost and material are naturally suited for a systems approach. Finally tests are accomplished by system.

Planning, cost and material estimating, and testing are valid reasons to start modernization through a system-by-system approach, however, holding on to this approach is purely institutional. Work is planned and scheduled, for the most part, by trade and because of this,

no one person may have the overall picture of the work to be accomplished and the time to be accomplished. Usually the general foreman resolves conflicting work requirements for personnel, space and material.[7]

Since the overall plan is understood by few individuals, supervisors of all levels are put in the position of being responsible without having the necessary knowledge and authority. When work orders and procedures are written on a system-by-system basis, further breakdown usually identifies the job to a lead code or cognizant trade. However, the documentation does not usually identify similar work taking place on the same ship, or adjacent/interface work. This results in the real Production Department decisions, such as which tasks to perform together and when to perform the tasks, being made by individual trade.[9]

Through the application of system oriented logic to actual work accomplishment, there is no allowance for an objective, analytical examination for the best possible way to perform the work, nor a method of feedback provided to increase the corporate knowledge of the shipyard. With the various systems being considered separately, trades often occupy space and compete for access simultaneously, which

minimizes the effect of production scheduling and control. Figure 4 is a simple example of a network based on a system basis and shows the various phases of modernization.

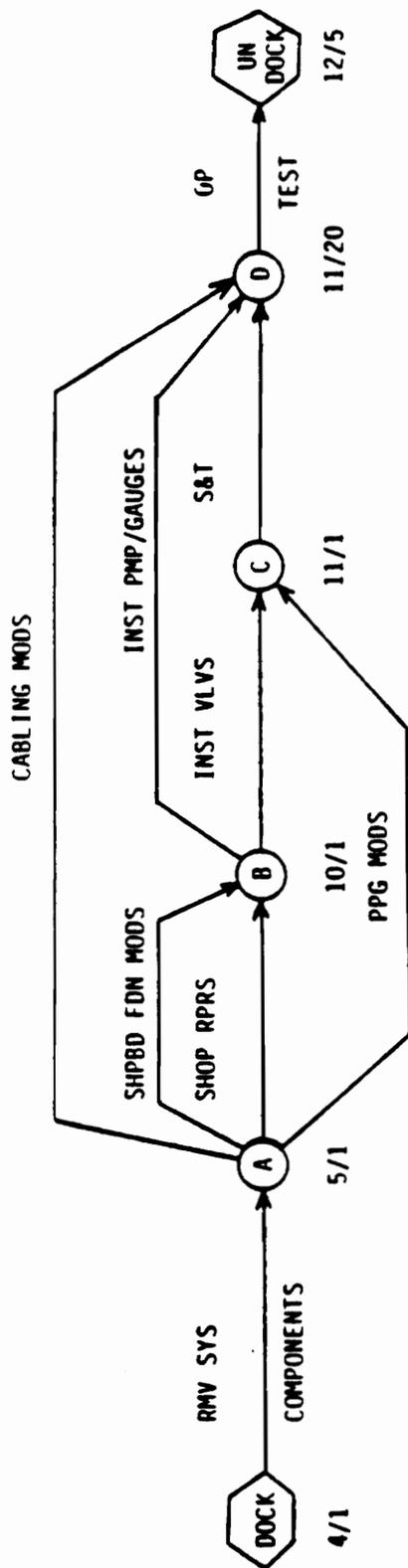


Fig. 4. Systems-oriented planning network for repair. [Ref: 7]

## 4.2 ZONE ORIENTED MODERNIZATION

By looking at how outfitting work actually occurs, it is found that products are produced by procuring and/or manufacturing parts and joining them together to create subassemblies. These subassemblies are then put together to form a completed operational product. It is clear that the best way to modernize a ship is to subdivide ship repair and overhaul work in zones so as to focus on the needed parts, or interim products, that preoccupy the worker. Zone Logic provides a method for this.[10]

Outfit planning addresses all outfitting components within a defined three dimensional space, and frees outfitting as much as possible from hull dependence and ship systems control. Zone Logic provides a basis for grouping work into classes or problems so that the common solutions can be applied regardless of product configuration or location, and for planning installations in a logical sequence. This scheme allows outfitting to be performed earlier, and away from the ship, where it is safer, cleaner, and where resources can be delivered to the work site economically. Overhaul durations can be reduced because of simultaneous accomplishment and coordination of outfitting

and hull work, minimizing total shipboard construction time.[9]

A zone is any subdivision of the planned work which best serves for organizing information needed to support outfitting at a particular stage of the overhaul. A zone might be a compartment or a portion of a compartment; it could include an entire superstructure or a component subassembly. The principal aspect of a zone is that it represents a means of dividing the ship's overhaul package into manageable, trackable blocks.

Zone Logic features three basic stages of construction, these include, on-unit, on-block, and on-board, coordinated with the master of erection sequence.

### On-unit

On-unit outfitting is the assembly of an interim product consisting of manufactured and purchased equipment(components). It includes all but final painting. A unit is composed exclusively of outfitting materials (pumps, motors, mechanical, and electrical interfaces, and a common foundation including false floor ribbing). The on-unit production is separate from the main hull structure. Units

can be categorized in three separate ways, functional, geographical, and combination.[10]

*Functional* units consist mainly of components necessary for the operation of a part of the ship, for example, a heat exchanger assembly. Functional units are usually associated with one ship system, i.e. the Refrigeration plant of the ship. *Geographical* units provide passage for the systems. Such units are assembled together to insure that they will fit inboard the ship. For example an accommodation unit must fit inboard the ship and must be assembled together. *Combination* units include more than one system built together and lifted to be installed (pipe/HVAC/wireway/machinery/ and associated equipment).

On-unit outfitting is by far the best of the three processes because assembly is performed in the shop with ideal conditions such as climate, lighting and access. Shop work increases safety and productivity.

### On-block

On-block outfitting is the installation of outfit components onto a hull structural assembly or "block" prior to its erection. It requires coordination between hull,

mechanical, ventilation, and electrical systems supported by material (supply), planning and estimating, and scheduling. A sequential road map is needed for the systems to be installed. Such a map is the "master bill of erection sequence" which is developed by the engineering, production, and planning departments and is controlled by scheduling. On-block outfitting also includes all the painting except for the final coat. On-block outfitting is the next best alternative to On-unit outfitting.[10]

#### On-board

On-board outfitting includes and should be limited to the connection of all the units and/or outfitted blocks, final painting, tests and trials. This method includes some necessary installation of systems or components on board the ship, which otherwise could not be installed using the On-unit or the On-block methods.[10]

A method that could be used to organize the information needed to support Zone Logic is the Work Package concept. This is a conceptual approach that allows the information that is filtering down from design, material, and production to integrate in order for the various shipyard departments to have a common understanding

of how the ship will be overhauled. The work package represents a definite increment of work with allocated resources needed to produce a defined interim product. This concept is particularly important for staging material for delivery on the worksite.[9]

Zone Logic has significantly contributed to productivity gains achieved by the worlds most competitive shipbuilders. It minimizes the low efficiency of on-board work, simplifies management control, avoids interface problems in the construction/overhaul process, and maximizes the high efficient shop work in order to reduce the overall time required to overhaul a ship. Figure 5 shows the Zone-oriented conversion, overhaul, and repair manufacturing levels.

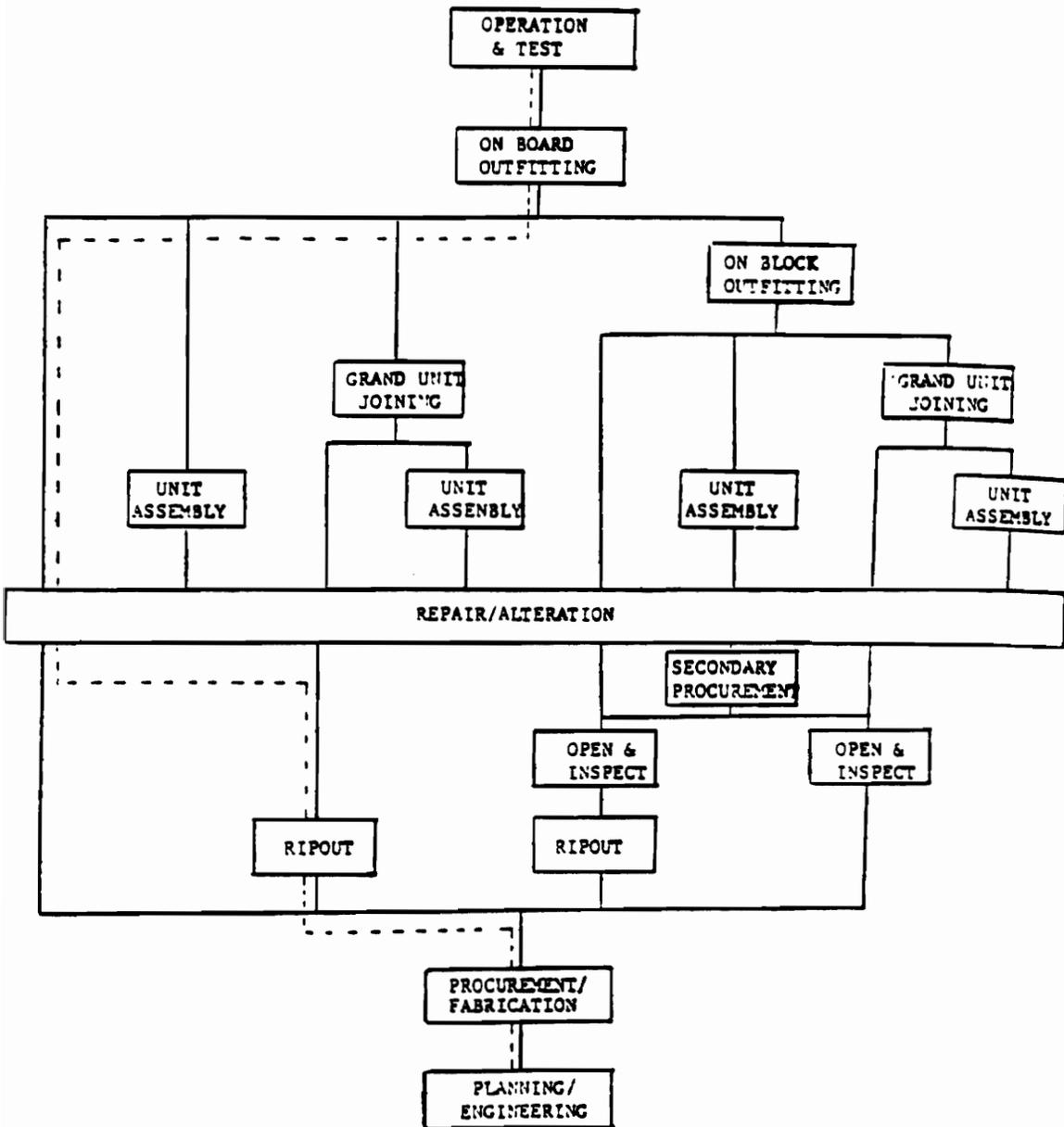


Fig. 5 Zone-oriented conversion, overhaul, and repair manufacturing levels. [Ref: 7]

## DESIGN, MATERIAL PROCUREMENT, AND PRODUCTION

Significant overlap among design, material procurement, and production is essential for reducing the overall construction period, however, it also reduces the time needed to organize information developed by the designers. Therefore design information must be formatted to fully anticipate the needs associated with material and production.

Zone Logic design is divided into the following successive stages:

- \*Basic Design - e.g., specification which establish performance requirements.

- \*Functional Design - e.g., systems diagrammatics developed from basic design. It includes simultaneous preparation of a material list, divided into unique material ordering zones, for each system diagrammatic. Functional design also includes preparation of other key drawings such as general machinery and block arrangements, the overall drawing of the block for installation on the ship.

\*Detail Design - e.g., conversions from functional design to working drawings. This process yields composite drawings upon which zones are delineated. It also includes the start of lists that associate specific materials with specific work zones. The composites are sufficiently comprehensive so that the details needed for manufacturing certain items could be derived. Detail design also includes preparation of material detail design drawings, including their material lists, for items that must be custom fabricated such as pipe pieces.

\*Work Instruction Design - e.g., light-line contract prints, made from the composite drawings, on which only the components to be installed during a specific stage of construction are delineated by darkened lines. Therefore, there can be more than one work instruction drawing per zone. These drawings are annotated with assembly instructions and each is accompanied by a specific material list per work zone per work stage. These drawings are more commonly referred as a work package. [10]

The information developed by designers provides the

framework upon which other shipyard workers build necessary data to procure material for and produce a ship. The development of this framework inescapably involves planning decisions such as definition of materials, construction details for fabrication and assembly, identification of zone boundaries and designation of work stages. The concept that design and material definition are aspects of planning is most important because certain design groups are in the best position to contribute significantly. They are primarily the groups concerned with functional, detail and work instruction design.

In order to achieve a greater overlap of design, material and production, it is necessary to organize material requirements so that purchase and manufacturing orders can be placed as early as possible. The designers have the opportunity to:

- \*Create Lists as early as possible of all needed components and bulk raw material. Such lists are called MLS (Material List by System)

- \*List the raw material needed for outfit items which will be custom manufactured, e.g., pipe pieces, ladders, small tank assemblies, etc.. They may require

material detail design effort, such as details to produce pipe pieces. Such lists are called MLP (Material List for Pipe) and MLC (Material List for Components).

\*List material per work package for assembly of a specific interim product. Such lists are called MLF (Material List for Fitting).[10]

The various Material Lists by System (MLS) are produced quickly not only to accelerate procurement, but also to check for major mistakes in the material estimate used to establish the contract price. MLS are system oriented, which benefits estimators, and are simultaneously zone oriented in a way that facilitates early material procurement. In contrast Material Lists for Pipe (MLP), Material Lists for Components (MLC), and Material Lists for Fitting (MLF) are product oriented, i.e., they are structure bills of material for use as planning documents for specific interim products.

Another method for improving the timeliness and accuracy of design information is through the use of standards, i.e. standardizing the design and repair of the machinery room of a ship. Decisions made in forecasting, planning, scheduling and production are controlled by

information from previous work and from feedback from subsequent work. Standards provide an opportunity for common understanding and improved communications among shipyard departments. Standards benefit the estimating, scheduling, and accounting functions by providing simplified quality information that facilitates prediction, implementation and evaluation.[10]

Shipbuilder's that have successfully standardized elementary components have extended their use to modules of arrangements of various components. These design modules are intentionally general in nature so they may be reapplied in different ship sizes and types.They also anticipate different customer needs and therefore allow some flexibility in application.

The production department is the ultimate user of the information furnished by the design and material departments. In order to use their services effectively certain production functions may be regrouped to optimize resource utilization. By organizing the work in terms of common processes, improvement in productivity can be achieved.[10]

This approach groups interim products regardless of

their appearances or where they will be located on the ship. Instead interim products are grouped by similarities in production problems in order to match each group to a single set of solutions. For example, different structural panels, regardless of their location on the ship should have then same classification and resources allocated in accordance with common parameters.

Separation of the production functions by common processes permits their planning to proceed separately until they reach a level where they must interlock. This simplifies scheduling and performance of work.[10]

## CHAPTER 5 QUALITATIVE BENEFITS OF ZONE LOGIC

### 5.1 PUGET SOUND NAVAL SHIPYARD

Puget Sound Naval Shipyard began experimenting with the concept of Zone Logic, by sponsoring two day seminars to all shipyard upper management and mid-level managers in May 1982 and January 1983. These seminars provided the necessary background to gain the shipyard-wide support needed to successfully carry out test cases for outfit planning. In February 1983, while understanding that the Zone Logic concept applied more to new construction, the shipyard production and planning officers called for Zone Logic Outfit Planning to be applied to the type of repair and overhaul work being accomplished at Puget Sound.

Since this was an exploratory project, and because of its potential far-reaching impact on the methods and procedures used within the shipyard, it was determined that an Outfit Planning Group with representatives from all shipyard departments was necessary to ensure total evaluation. This type of approach gave shipyard workers the best opportunity to assure familiarity with all problems and solutions and got all departments involved in the planning

documents through completed installation testing.[9]

USS RANGER (CV-61)

The complex overhaul of the aircraft carrier USS Ranger (CV-61) provided the first opportunity for Puget Sound Naval Shipyard to determine how Zone Logic concepts could be adopted. Two Ship Alteration packages were targeted for analysis. The first task involved the construction and installation of a new deckhouse which closely resembled a new construction process, while the second task accomplished complete reoutfitting of an existing space which represents typical overhaul work. In order to concentrate on the Zone Logic concept, the Outfit Planning Group limited the focus to the specific compartments involved, and did not attempt to sequence work once a system exited the defined zone.

**ZONE 1; CLOSE IN WEAPON SYSTEM DECKHOUSE**

This project consisted of fabricating, outfitting, and attaching a new 24 by 26 by 8 foot 26 ton deckhouse to the outboard side of the existing superstructure. It required the coordination and sequencing of 14 various systems, and the integration of these systems with the production process.

Through the use of the composite drawing, the hull block/ outfitting interface areas were identified and incorporated into the structural construction phase of the deck house to support future outfitting installations. All system penetrations and under deck foundation stiffening in the new structure were detailed in the structural prefabrication drawing so that they could be included during the initial construction of the deckhouse. This process allowed for accomplishing common work procedures regardless of the particular system and independent of when the system was going to be installed.[9]

The deckhouse was 50 percent complete prior to the ship's arrival for the Complex Overhaul. This illustrates the impact that Zone Logic Outfit Planning has on the duration of the overhaul. One major factor that precludes complete outfitting is the allowance for attachment to the existing superstructure. Forty-four days after arrival of the ship the new structure with 80 percent of the outfitting was attached to the ship.

ZONE 2 ELECTRICAL SHOP UPGRADE

This project involved the complete reoutfitting of the existing electric shop with updated equipment to improve shipboard electrical repair capability. The shop is located on the third deck at centerline and represented the more typical type of overhaul work encountered by a repair facility. It required the sequencing of nine different systems to be modified, and coordination to the effect of these systems to existing systems.

The Electric Shop task concentrated on the on-unit and on-board concepts of Zone Logic and emphasized the trade coordination necessary to support the planned sequence of removal and installation. This task proved successful even though it encountered material problems, the shipyard was in a much better position to identify the impact and to coordinate solutions because of the planned approach for the production effort.[9]

#### SUMMARY

Even though the USS RANGER Complex Overhaul was just one of the experiments that Puget Sound Naval Shipyard run, it is indicative of the productivity gains they encountered. Adoption of Zone Logic concepts into the naval ship overhaul/repair arena is continuously proving its benefits.

Perhaps the most significant benefits Puget Sound realized were the involvement of the production department during the planning stage, and the development of the work package instruction.

## **5.2 PHILADELPHIA NAVAL SHIPYARD**

Philadelphia Naval Shipyard started its implementation of Zone Logic in the late fall of 1986, targeting the Service Life Extension Program (SLEP) of the aircraft carrier USS Kitty Hawk (CV-63). The technical services of Ishikawajima-Harima Heavy Industries Co. LTD.(IHI), Japan, were contracted to assist in the transition. This implementation of Zone Logic on the Kitty Hawk would involve approximately one-third of the production mandays and half of the compartments on the ship.

The intent of the SLEP is to add 15 years to the ship's life cycle after approximately 30 years of service. This requires not only repairs and overhaul of equipment but also ship alterations and modernization to keep the aircraft carrier in top fighting shape for the extended life. The SLEP is also a massive package of modernization with approximately 1.2 million mandays of production work over 37 months.[9]

Initially the hull extension project was to serve as the impetus for Zone Logic. This project was estimated approximately 350,000 mandays and was to impact approximately 30 percent of the SLEP package. Therefore all of the impacted work must also be done using Zone Logic principles. Once the work started using the new principles there was no turning back to traditional methods, because it would cost millions to revert back. Thus when the hull extension project was canceled, the other work that proceeded had to remain in the new concept.[9]

#### AREAS FOR ZONE LOGIC

The ship was arranged in 10 zones four of these were for the application of Zone Logic. The areas are as follows:

Zone 1: Tanks and voids, underwater hull, rudders, anchors and anchor chains.

Zone 2: Four machinery rooms, compartments on fourth deck above the machinery rooms, shaft alleys, uptakes, propellers and shafts.

Zone 3: Two Auxiliary Machinery rooms, compartment

fourth deck above these machinery rooms.

Zone 4: Magazines and weapon elevators.

Zone 5: Seven pump rooms, three emergency generator rooms, two steering gear rooms, two steering motor rooms, air conditioning machinery rooms, refrigeration chambers and various other storerooms below third deck.

Zone 6: Habitability on second and third decks.

Zone 7: Hanger Bay and the offices and storerooms related to the hangar bay, aircraft elevators and the related machinery rooms.

Zone 8: Habitability, offices and electronic rooms from the main deck to the flight deck, excluding compartments in zones 2, 4 and 7.

Zone 9: Flight deck, catapults and the related machinery rooms, catapult troughs with wing voids, arresting gears and related machinery rooms and jet blast deflectors and the related machinery rooms.

Zone 10: Island and other structures above the flight

deck.

After close investigation, Zones 1, 5, 6, and 8 were the zones selected for Zone Logic application. The production work in these zones amounts to approximately 400,000 mandays about one-third of the total production mandays of the SLEP.

A project of this magnitude would have been assigned to the executing yard 3 to 4 years ahead of the scheduled start date. A project team was established with key members from all the shipyard's major departments; planning, production, supply and design. The shipyard existing estimating and planning branches made adjustments to support Zone Logic. Similarly, the design branch established a zone logic design team whereby all efforts for Zone Logic Design were coordinated. Also an additional work packaging group called the Outfit Planning team was established. The primary mission of the Outfit Planning team is to package work by zone, product and problem category as well as to schedule this work.[11]

Figure 6 shows the initial organizational breakdown of the Zone Logic Project Team.

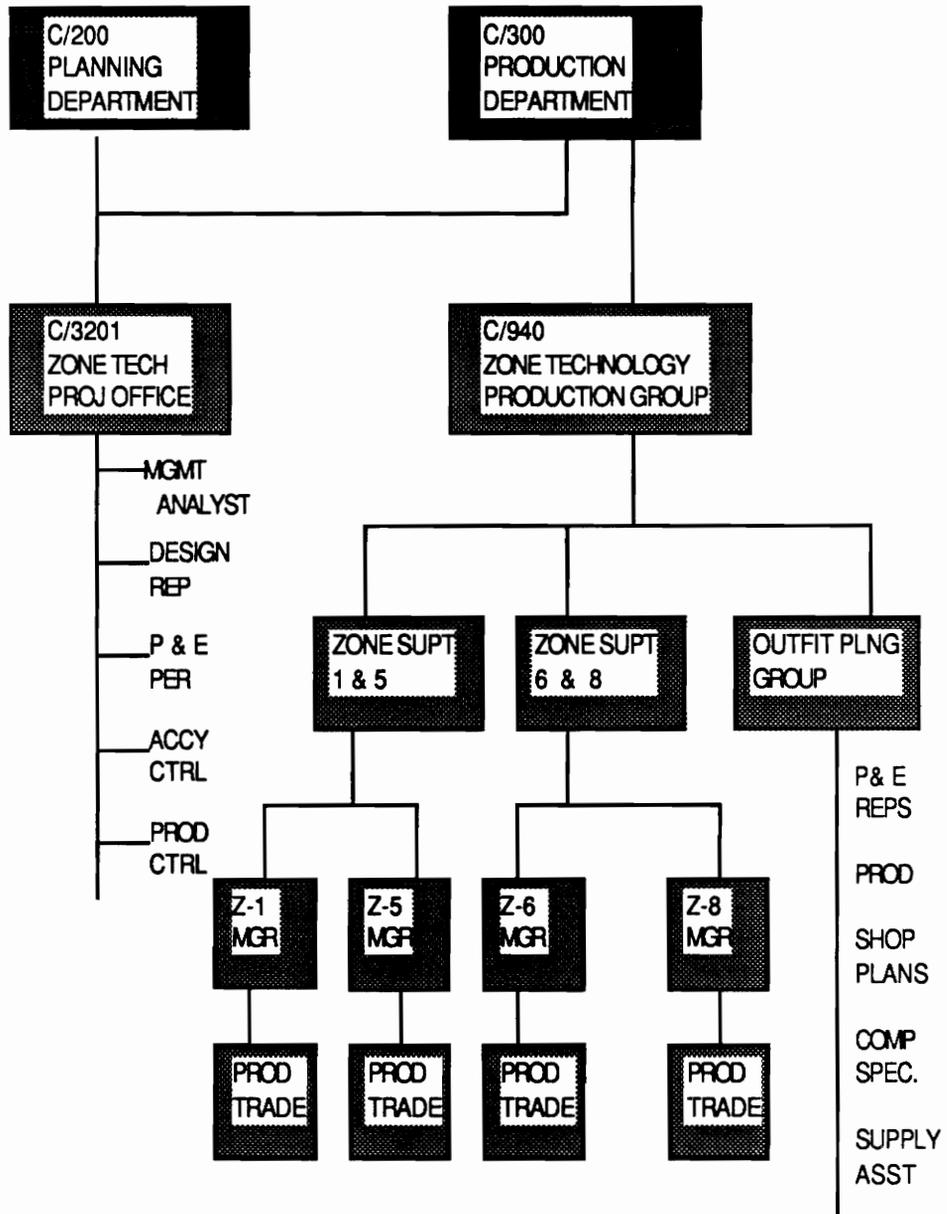


Figure 6: Zone Logic Project Team

ZONE LOGIC WORK BREAKDOWN STRUCTURE

The historical work definition method at Philadelphia Naval Shipyard used a Job Organization for Production Control (JOPC) and work center system. JOPC's define work on a system-by-system level; key or lead production shop are defined along with assist shops to accomplish needed work. Zone Logic work would use the existing JOPC's and system drawings to develop work instructions for Zone Logic production. Since the current work proportionment method did not efficiently support Zone Logic, a new work issuing and identification system was required. This new breakdown structure is called the "Unit Work". Each Unit Work describes three components of the work:

- \*Where the work is located (Zone)
- \*What category or type of work it is (Phase)
- \*Who will do the work (Product trade)

A hierarchical structure was used to break the ship down into Zones, Intermediate Zones and Sub-zones. The four zones selected for Zone Logic Implementation were tanks and voids, pump room and miscellaneous auxiliary machinery spaces, and the upper and lower habitability spaces. These selected zones were then broken down into intermediate

zones, primarily for scheduling and planning. The sub-zones were the most detailed level and used to define the "Unit Work".[11]

For the USS Kitty Hawk, zone logic work was broken down into:

4-----Major Zones  
117-----Intermediate Zones  
388-----Sub-zones

With the majority of the planning complete the USS Kitty Hawk was drydocked on November 25, 1987, though January 28, 1988 was the planned start of the SLEP. Currently Philadelphia Naval Shipyard is nearly half way through the project. Of the projected 1.2 million mandays to be completed during the SLEP the actual physical progress is at 47%. Of the approximate 400,000 mandays to be performed under Zone Logic over 230,000 have been completed by June 2, 1989.

Over the first 8-10 months of the project a cost savings of nearly \$1.8 million was realized in the tank package alone. Although these preliminary results were encouraging, other developments took place and were impacting the overall potential for success. One alarming

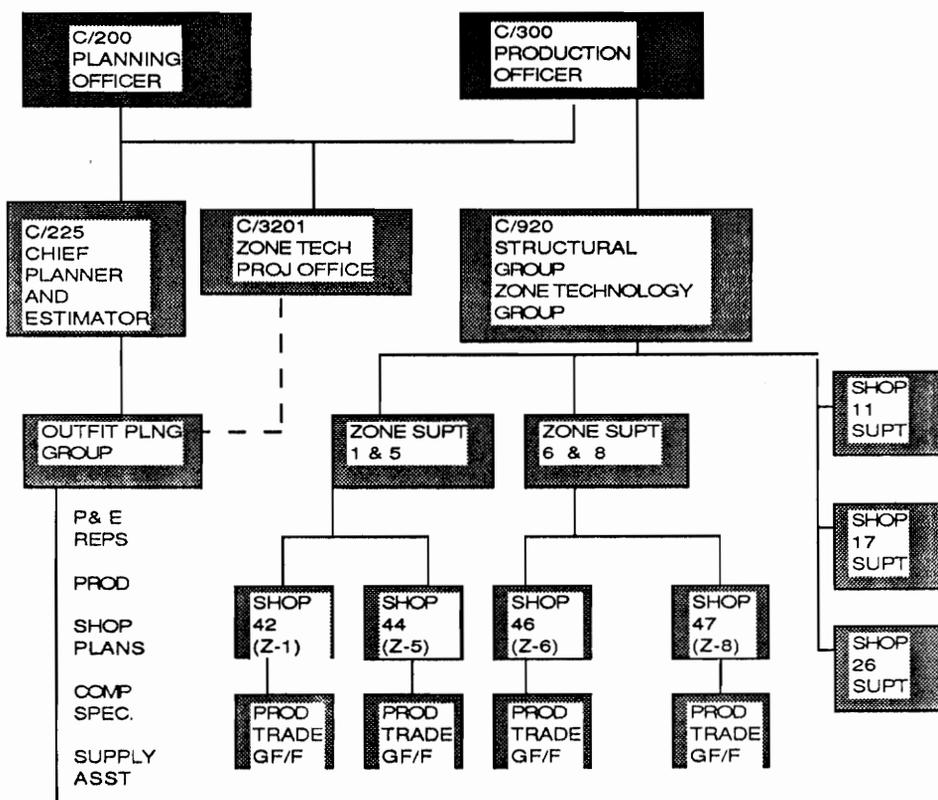


Figure 7: Current Zone Logic Project Team

affect was the disharmonious relationship between the Zone Logic Production Group and the Non-Zone Production groups, giving signals of the "Two shipyard syndrome". Consequently the Zone Logic organization was changed to reflect this as shown in figure 7.[11]

LESSONS LEARNED

1. The Zone Logic package was not initially networked into the overall ships scheduled network. As a result, shipyard management governing the availability had to refer to two sources of information to review the projects disposition
  
2. The Zone Logic work package was set up to work in four month windows. Only the work scheduled for those four months was issued. This was not a popular decision and not the ideal situation, but was a compromise, since there was not enough work available for issue to justify anything longer.
  
3. The Unions representing the trades must be actively involved in the process.
  
4. The cultural issues, i.e. the difficulty of labor to confront new processes, involving the personnel were/are/will be a great factor of concern for all involved.[11]

RESULTS

The major merits in the implementation of Zone Logic at Philadelphia Naval Shipyard are the following:

\*Total efficiency is enhanced by having the same people do similar work at the same time at the same location.

\*Work sequencing problems are solved by organizing the workers into product trades and scheduling each Unit Work.

\*Work efficiency is enhanced by following a realistic schedule prepared by allocating the Unit Work.

\*Overall schedule adherence is achievable through Zone Logic.

\*Manhour reduction is achievable.

\*Rework is reduced.

## CHAPTER 6 ZONE LOGIC IMPLEMENTATION ON LPH CLASS SHIPS

The Naval Sea Systems Command (NAVSEA) decided to test the Zone Logic concepts due to the successful implementation of the concept to new construction. This came about through discussions for the improvement of the Fleet Modernization Program (FMP) during the Chief Engineers conference in October 1987. NAVSEA decided to let Philadelphia Naval Shipyard as the lead yard, for the implementation of the concept, during the USS Kitty Hawk (CV 63) Ship Life Extension Program (SLEP). The USS Kitty Hawk implementation of Zone Logic has been shown in chapter 5 of this report.

In January 1988, NAVSEA code PMS 331 selected USS Guam (LPH 9) FY 89 Dry-Docking Phased Maintenance Availability (DPMA) as the test implementation of Zone Logic. In April 1988, NAVSEA PMS 331 chaired a Philadelphia Naval Shipyard (PNSY) briefing to the Supervisor of Shipbuilding, Portsmouth, VA (SPORT), the LPH-2 class overhauling activity for the Atlantic Fleet based Ships, and the Overhaul contractor, Metro Machine Corporation (METRO). During this meeting it was agreed that all Ship Alteration Installation Drawings (SIDs) will be developed by Zones and by Ship Alterations (by System). METRO was receptive to the Zone

Logic concept, but proceeded cautiously. It was also agreed that the contractor's implementation would be voluntary and the risk for unforeseen problems would be reduced. The Zone Logic top level meeting was followed by a working level meeting in late April 1988 where details of the program was discussed with all involved in the project.

#### **6.1 LPH-2 CLASS PHASED MAINTENANCE PROGRAM**

The LPH-2 Class ships are Amphibious Assault Ships with a mission to transport through aircraft, Marine Corps personnel to an enemy shore. They also serve as Flag ships for Amphibious operations. They carry a complement of approximately 2500 personnel and are equipped with helicopters and high tech combat systems and radar. The ships were built between 1963 and 1970.

The Operating profile for the LPH-2 Class Phased Maintenance Program (PMP) consists of two Phased Maintenance Availabilities (PMAs) and one Drydocking Phased Maintenance Availability (DPMA) during a fifty-four (54) month cycle. The Phased Maintenance Program for the LPH-2 Class began by the "LPH PMP Plan of action" in July 1983. The basic focus of the PMP was to improve ship readiness by spending less amount of time in the Shipyards for Regular Overhauls

(ROHs). Typically ROHs took approximately eight to ten months and a vast amount of manhours, putting the ship out of commission for a long time, requiring re-training for ships force, and reducing readiness of the ship.

The Phased Maintenance Program was also conceived as a better way for the Navy to run its contracting to the private yards. Therefore the notion was conceived that the ships would be better served by a multi-ship, multi-year, cost-plus award fee, type of contract, where one contractor would be responsible for all depot maintenance of the ship class for a period of time (usually 5 years). Another aspect of the decision for a Phased Maintenance Program was that the contractor will have a learning curve for the ships that he is contracted to service. For the LPH-2 class in the Atlantic Fleet, METRO was the Phased Maintenance Program contractor with a multi-ship, multi-year contract beginning with the FY 86 USS Guadalcanal (LPH 7) PMA. The contract ensures the contractor that all the costs conceived will be paid and the government reduces the risk of a "bad" contractor by exercising yearly options to the contract for up to five years.

## 6.2 PARTICIPATING ACTIVITIES

### PHILADELPHIA NAVAL SHIPYARD

Philadelphia Naval Shipyard (PNSY) is the LPH-2 class Planning Yard. PNSY develops Ship Alteration Records (SHIPALTS) for the Type Commander (TYCOM D-Alts) and the Naval Sea Systems Command (NAVSEA) (K-Alts) through NAVSEA cognizance, develops Ship Alteration Installation Drawings (SIDs), and provides On-Site-Representation (OSR) and technical support to the contractor through Liaison Action Records (LARs).

Ship Alteration Records are installation documents for implementing the Navy's new technology on existing ships (i.e. installing new radar technology, installing new firefighting systems, installing new combat systems, etc.). They also serve as a solution for existing problems aboard the ships (i.e. piping modifications, underway replenishment modifications, etc.). Ship Alterations are the primary document to install any system that will modernize the ships to serve its mission. They usually replace an obsolete system onboard the ships.

SUPERVISOR OF SHIPBUILDING, PORTSMOUTH VA

The Supervisor of Shipbuilding, Portsmouth (SPORT) is the overhauling activity responsible for the advance planning, fund management and execution of the Phased Maintenance Availability (PMA). SPORT's responsibilities include identification and procurement of the Government Furnished Equipment and Materials (GFM), specification development, PMA execution contract evaluation, awards and management, and liaison between the PMA contractor and all related Navy activities.

METRO MACHINE CORPORATION

Metro Machine Corporation (METRO) is a private shipyard located in Norfolk Virginia. They are responsible for the accomplishment of the Phased Maintenance Availability work package of the LPH 2 class for the Commander, Naval Surface Force, U.S. Atlantic Fleet.

COMMANDER, NAVAL SURFACE FORCE, U.S. ATLANTIC FLEET

The Commander Naval Surface Force, U.S. Atlantic Fleet (SURFLANT) is the Type Commander for all Surface Ships stationed in the Atlantic Fleet. They are responsible for

the scheduling of the Phased Maintenance Availabilities and programming of the repair package as well as the Type Commander funded ship alterations (D-Alts) for accomplishment during the scheduled PMA.

#### COMMANDER, NAVAL SEA SYSTEMS COMMAND

The Commander, Naval Sea Systems Command (NAVSEA) is primarily responsible for the procurement and modernization of all Naval Ships. NAVSEA code PMS 331 is the intricate agent for the modernization of the Navy's Auxiliary, Amphibious, Mine warfare, and Military Sealift ships. PMS 331 is responsible for the programming of Ship Alterations (K-Alts) through the concurrence of the Chief of Naval Operations (CNO). PMS 331 is also responsible for the advance planning for these SHIPALTS and material procurement as well as fund distribution to the various activities involved for the implementation of the Phased Maintenance Availability.

#### **6.3 ZONE LOGIC ON THE USS GUAM FY 89 DPMA**

Philadelphia Naval Shipyard (PNSY) as the LPH-2 Class planning yard and the sole design agent to the Naval Sea Systems Command developed the Ship Alteration Installation

Drawings (SIDs) for the programmed Ship Alterations. The drawings were developed by Ship Alteration (i.e. by system) and by Zone. Philadelphia Naval Shipyard specified 8 zones for the Drydocking Phased Maintenance Availability (DPMA). However, each drawing within the Ship Alteration Installation Drawing (SID) package covered only one zone. Therefore, the SID package could easily be sorted by Ship Alteration or by zone as required. This was done in order to reduce risk for the contractor and the government and to allow the contractor to provide cost reports by Ship Alteration and to track his material distribution and manpower sequencing by zone. This also allowed the government to track cost control by Ship Alteration.

The Ship Alteration that METRO voluntarily agreed to implement for Zone Logic were the following:

LPH 2 - 397K OILY WASTE TRANSFER PUMPS  
LPH 2 - 684K INSTALL OIL/WATER SEPARATOR  
LPH 2 - 888K INSTALL JP-5 FUEL STATIONS

These are relatively large SHIPALTS and require extensive work in several areas of the ship. They were selected for that nature and were attractive for the implementation of Zone Logic. Only three Ship Alterations were selected to reduce the risk for both the contractor and the government.

It also allowed for a manageable package which will provide sufficient data for a realistic evaluation of Zone Logic.

#### ZONE LOGIC SHIP ALTERATIONS

LPH 2 - 397K, "OILY WASTE TRANSFER PUMPS", installs two 90 Gallons Per Minute (GPM), 110 Pounds per Square Inch (PSI), 10 Horse Power, sliding shoe pumps which will provide bilge discharge service and transfer oily waste water to and from the oily waste tanks and discharge oily waste via the deck discharge connections. This Ship Alteration along with LPH 2 - 684K are mandated by the Chief of Naval Operations and provide water pollution solutions to the ships about their waste removal.

LPH 2 - 684K, "INSTALL OIL/WATER SEPARATOR", installs a Oil/Water separator to provide the ships the ability to separate oil from bilge fluid and other oily waste water in order for the water to be discharged overboard without causing water pollution and the waste oil can be stored the off-load at a shore point. This separator will be installed in the LPH 9 machinery room (6-85-0-E).

LPH 2 - 888K, "INSTALL JP-5 FUEL STATIONS", installs JP-5 fueling stations on the starboard deck edge walkway A1

at frames 25 and 129. Each JP-5 station consists of: one 50 Gallon Per Minute (GPM)/15 Pound per Square Inch (PSI) positive displacement defueling pump driven by a spray tight electric motor; one 300 Gallon Per Minute (GPM) filter-separator with automatic drain and fuel shut-off controls; two hand operated hose reels; two 2 1/2 Inch No. 302m automatic fuel-defuel valves; one flushing connection and a sampling connection to permit flushing of the fueling hose prior to refueling the aircraft. This Ship Alteration was developed to accommodate the AV-8 (HARRIER) type of aircraft procured the U.S. Marine Corps.

The other SHIPALTS programmed for the USS GUAM FY 89 Drydocking Phased Maintenance Availability, but were not accomplished by Zone Logic, were the following:

LPH 2 - 280K WEIGHT AND MOMENT COMPENSATION  
LPH 2 - 413K INSTALL SPN-43 AIR SEARCH RADAR  
LPH 2 - 667K INSTALL SPS-67 SURFACE SEARCH RADAR  
LPH 2 - 892K INSTALL DEMINERALIZED WATER FOR AV-8s  
LPH 2 - 986K WEAPON STAGING AREA

LPH 9 ZONE BREAKDOWN

The following zones were conceived by PNSY in their design of the SHIPALT package for the LPH 9 FY 89 DPMA:

ZONE 1-----TANKS AND VOIDS

ZONE 2-----MACHINERY SPACES

ZONE 3-----AUXILIARY MACHINERY SPACES

ZONE 4-----MAGAZINES

ZONE 5-----AUXILIARY SPACES

ZONE 6-----HABITABILITY BELOW THE SECOND DECK

ZONE 7-----AVIATION HANGERS

ZONE 8-----HABITABILITY AND ELECTRICAL ABOVE THE  
MAIN DECK

**6.4 QUANTITATIVE EVALUATION OF ZONE LOGIC**

The quantitative evaluation of Zone Logic onboard the USS Guam's (LPH 9) FY 89 Drydocking Phased Maintenance Availability involves a productivity analysis, a variance analysis and a cost analysis. The productivity analysis will be derived from cost reports received from the contractor (METRO) and will be based on the contractor's estimated manhours and costs versus actual manhours and costs. The variance analysis will evaluate the variance of the

estimated manhours and costs versus the actual manhours and costs as a ratio of the actual costs and actual manhours. The cost analysis will compare the costs incurred by the Ship Alterations accomplished through Zone Logic with the same Ship Alterations accomplished in other availabilities. These analyses will be based on the final cost reports that METRO submits to Naval Sea Systems Command for the LPH 9 FY 89 Drydocking Phased Maintenance Availability, LPH 12 FY 88 Phased Maintenance Availability, and LPH 9 FY 87 Phased Maintenance Availability.

#### 6.4.1 PRODUCTIVITY ANALYSIS

Productivity is simply the relationship of the amount produced by a given system during a given period of time, and the quantity of resources consumed to create and produce the outputs over the same time period.

Productivity measurement is the selection of physical, temporal, and/or perceptual measures for both the input variables and the output variables and the development of a ratio of output measures to input measures. For the productivity analysis, a variation of the Multifactor Productivity Measurement Model (MFPMM) was used to determine the productivity improvement of the Zone Logic concept.[12]

The MFPMM can be used to measure productivity change in labor, materials, energy, and capital. It can also be used to measure the effects of these changes separately as well as in corresponding change in profitability. Since all the necessary data that were required to form a total model were not at the author's disposal, a variation consisting of only the cost reports that METRO submits to the Naval Sea Systems Command (NAVSEA) were used to define the model. The data from these reports were further defined for only the Naval Sea Systems Command costs incurred during the Phased Maintenance Availabilities's.

For this project the output consisted of the actual manhours and costs conceived to perform the job, and the input consisted of the estimated manhours and costs that were used by the contractor to do the availability. The ratio estimated manhours versus actual manhours represented the ability of the contractor to estimate the manpower necessary to do the job. The ratio of estimated costs versus actual costs showed the ability of the contractor to estimate the costs required for the job.

The ratios mentioned above were developed for the USS Guam FY 89 (LPH 9) Drydocking Phased Maintenance

Availability and the corresponding Zone Logic Ship Alterations. The Zone Logic ratios were separated from the final cost reports of the USS Guam's FY 89 availability and were treated as an entity. The Zone Logic ratios were compared to the rest of USS Guam's ship alterations, the USS Inchon (LPH 12) FY 88 Phased Maintenance Availability and to the USS Guam FY 87 Phased Maintenance Availability. These availabilities are compatible because they were performed by the same contractor (METRO), Type Commander, Overhauling Activity, and the same Planning Yard. Table 2 will provide the summary of the Phased Maintenance Availabilities for estimated manhours, actual manhours, estimated costs and actual costs. Table 3 provides the summary of the ratios of estimated manhours versus actual manhours, estimated costs versus actual cost, cost variance, and manhour variance.

#### ASSUMPTIONS

1. The estimated manhours and costs are assumed to be accurate.

2. The Productivity of a Phased Maintenance Availability (PMA) increases as the manhour ratio and the cost ratio approach one (1), i.e. as the estimated and the actual values approach equivalency.

To form a comparative interrelationship between the Phased

Maintenance Availabilities the following ratio was formulated:

$$\frac{\text{Ratio of period 1}}{\text{Ratio of period i}}$$

Ratio of period i

The ratio of period 1 represents the Phased Maintenance Availability ratios that will be compared with the rest of the availabilities. For example the manhour ratio of period 1 is 0.85 then we compare it with the manhour ratio of period 3 which is 0.83. Using the above ratio period 1 is  $0.85/0.83=1.024$  times better than period 3, or period 1 experienced a 2.4 percent increase in productivity. Table 4 shows the productivity interrelationship between the Phased Maintenance Availabilities that this project is based on.

The rows of table 2 represents each Phased Maintenance Availability that were compared in the productivity analysis. The first column of table 2 shows the periods of the evaluation. Column 2 provides METRO estimated manhours for the period. Column 3 shows the actual manhours used for the project. Column 4 shows the estimated costs as were perceived by METRO's estimators. Column 5 provides the actual costs incurred at METRO. Table 3 provides the ratios of estimated manhours versus actual manhours(column 2), and the ratio of estimated costs versus actual costs(column 3).

The cost distribution, manhour distribution, variance, etc., of each PMA is shown in appendix A. The data formulated in tables 2 and 3 were based on the final cost reports that the contractor (METRO MACHINE) provided to the Naval Sea Systems Command. The analysis of each Phased Maintenance Availability (PMA) considered in this project were derived through the final cost reports.

Table 2: Summary of the availabilities

**NAVSEA COSTS INCURRED AT METRO MACHINE CORP.**

	<u>BUDMHRS</u>	<u>ACTUALMHRS</u>	<u>BUDCOSTS</u>	<u>ACTUALCOST</u>
ZONELOGIC	22727	21370	\$945,910	\$974,924 *
LPH9FY89	13468	17139	\$877,283	\$983,937 **
LPH12FY88	13147	16037	\$608,948	\$743,425 ***
LPH9FY87	53168	66271	\$1,393,541	\$1,769,503 ****.

\* The cost and manhour breakdown and the associated graphs of the analysis is located in Table 7 in appendix A.

\*\*Table 8 in appendix A.

\*\*\*Table 9 in appendix A.

\*\*\*\*Table 10 in appendix A.

Table 3: Productivity ratios for manhours and costs

	MHRRATIO	COSTRATIO
ZONELOGIC	1.064	0.970
LPH9FY89	0.785	0.892
LPH12FY88	0.819	0.819
LPH9FY87	0.802	0.788

Table 3 provides the data necessary for the productivity analysis. The manhour ratio as well as the cost ratio are the productivity ratios of the project. A ratio of 1 shows that the estimators were on target with their estimates. A ratio which is greater than 1 shows that the estimators overestimated the project. A ratio less than 1 shows that the estimators underestimated the project.

Table 4 shows the productivity interrelationship between the Phased Maintenance Availabilities. Each ratio from every availability is compared to the other three availabilities by using the comparison ratio mentioned above, thus producing a productivity relationship between the availabilities.

Table 4: Comparative productivity analysis

AVAIL	LPH9FY89		LPH12FY88		LPH9FY87		ZONE	
	COST	MHR	COST	MHR	COST	MHR	COST	MHR
LPH9FY89			1.09	0.96	1.13	0.98	0.92	0.74
LPH12FY88	0.92	1.04			1.04	1.02	0.84	0.77
LPH9FY87	0.88	1.02	0.96	0.98			0.81	0.75
ZONE	1.09	1.35	1.18	1.30	1.23	1.33		

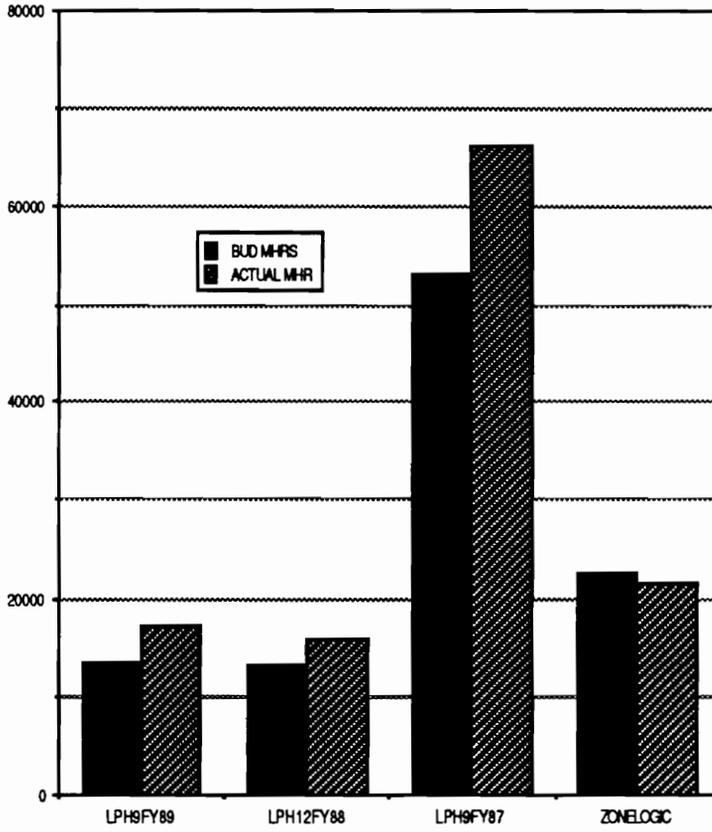


Figure 8: Manhour Distribution

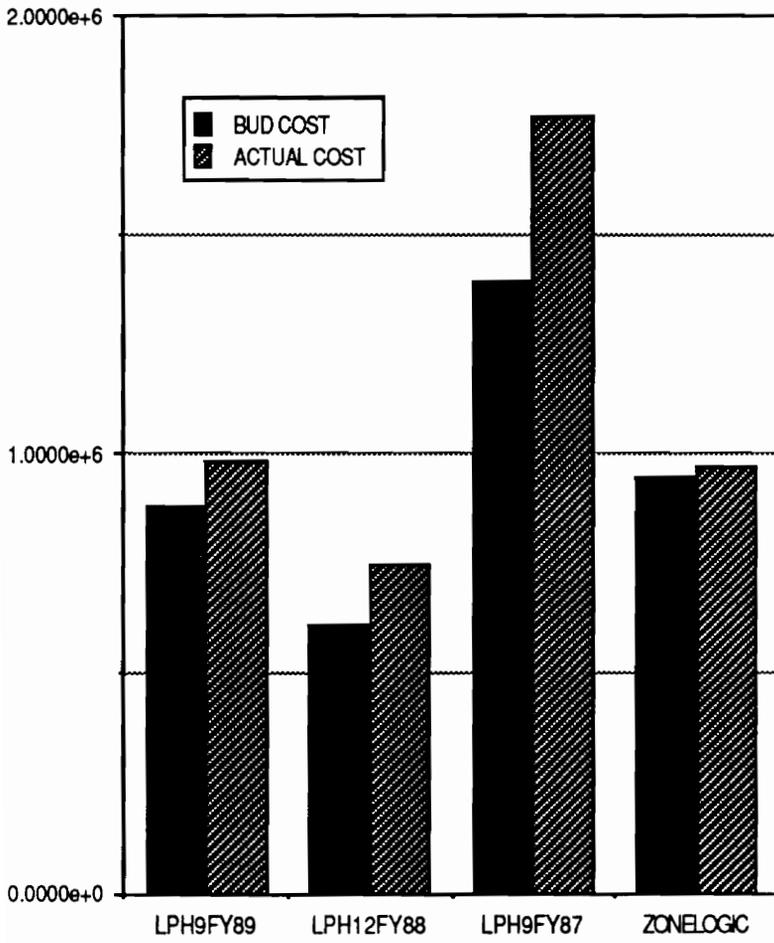


Figure 9: Cost Distribution

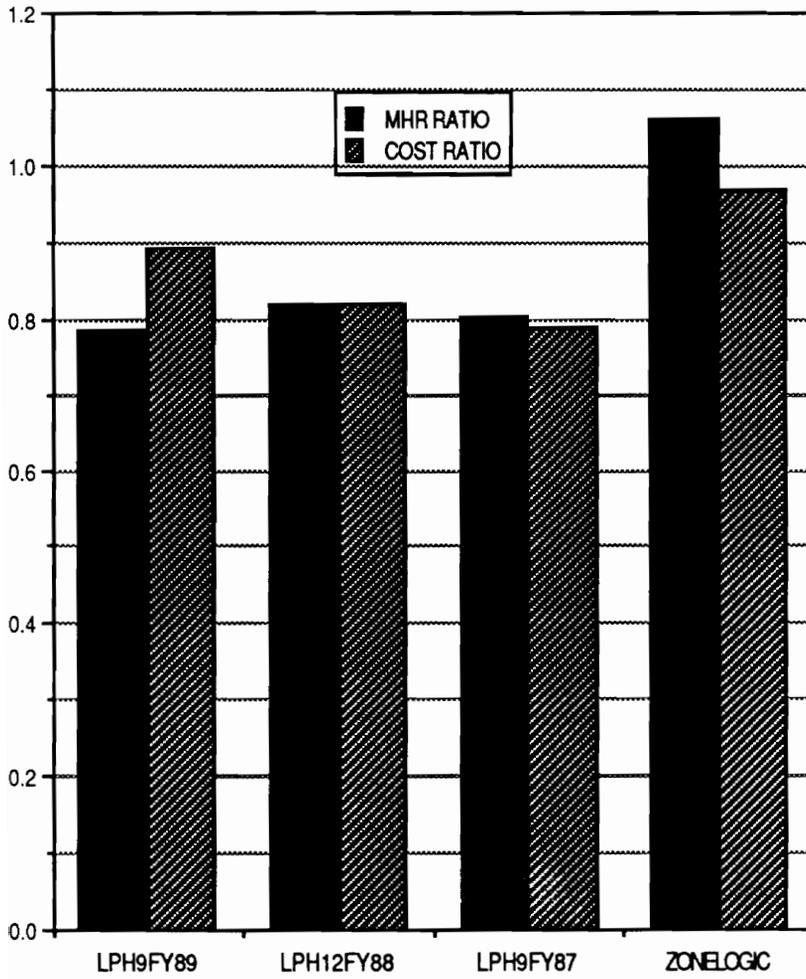


Figure 10: Productivity Ratios

**SUMMARY**

The productivity comparison provided by table 4 shows how the manhour and cost productivity ratios of each availability fared with the others. For example the comparison ratio showed that the Zone Logic productivity ratios for cost and manhours were 1.09 and 1.35 greater than the productivity ratios of the rest of the ship alterations accomplished during the USS Guam's FY 89 availability. Therefore the Zone Logic method incurred a 9 percent and a 35 percent increase in productivity in cost and manhours respectively compared to the rest of USS Guam's Ship Alterations. Table 4 also shows the effect that Zone Logic had when the manhour and cost productivity ratios were compared to the other availabilities. It showed an increase in productivity in all facets of this analysis. Figures 8 through 10 represent the manhour distribution, cost distribution and the productivity ratios of each availability respectively.

It should be noted that the productivity improvements shown in this paper do not account for the Phased Maintenance Contractor's Learning curve and to the inflation of the manhour rate.

#### 6.4.2 VARIANCE ANALYSIS

The variance analysis is based on the variance between the actual costs incurred and estimated costs the contractor provided to the Government. The same analysis was performed between the actual manhours incurred versus the estimated manhours. In order to compare the cost and manhour variance between the availabilities, variance ratios were conceived for the cost variance and the manhour variance. The ratio of the cost variance divided by the actual cost, and the manhour variance divided by the actual manhours incurred, will show a percent of the variance compared to the actual values. For example the cost variance of the Zone Logic ship alterations ( $(\$29,014) = (\text{actual cost} - \text{estimated cost} = \$974,924 - \$945,910)$ ), divided by the actual cost ( $\$974,924$ ) is equal to 0.03 or 3 percent of the actual cost. The cost variance, manhour variance, and their respective variance ratios are provided in table 5 and shown in pictorial fashion in figures 11 through 13. The values provided by table 5 show that the cost variance of the Zone Logic SHIPALTS is 3 percent of the actual cost and the manhour variance is 6 percent less than the actual manhours incurred. If we compare the above values with the USS GUAM FY 89 DPMA, the USS INCHON FY 88 PMA and the USS GUAM FY 87 PMA we will see a tremendous percentage of increase in the variance of costs and manhours.

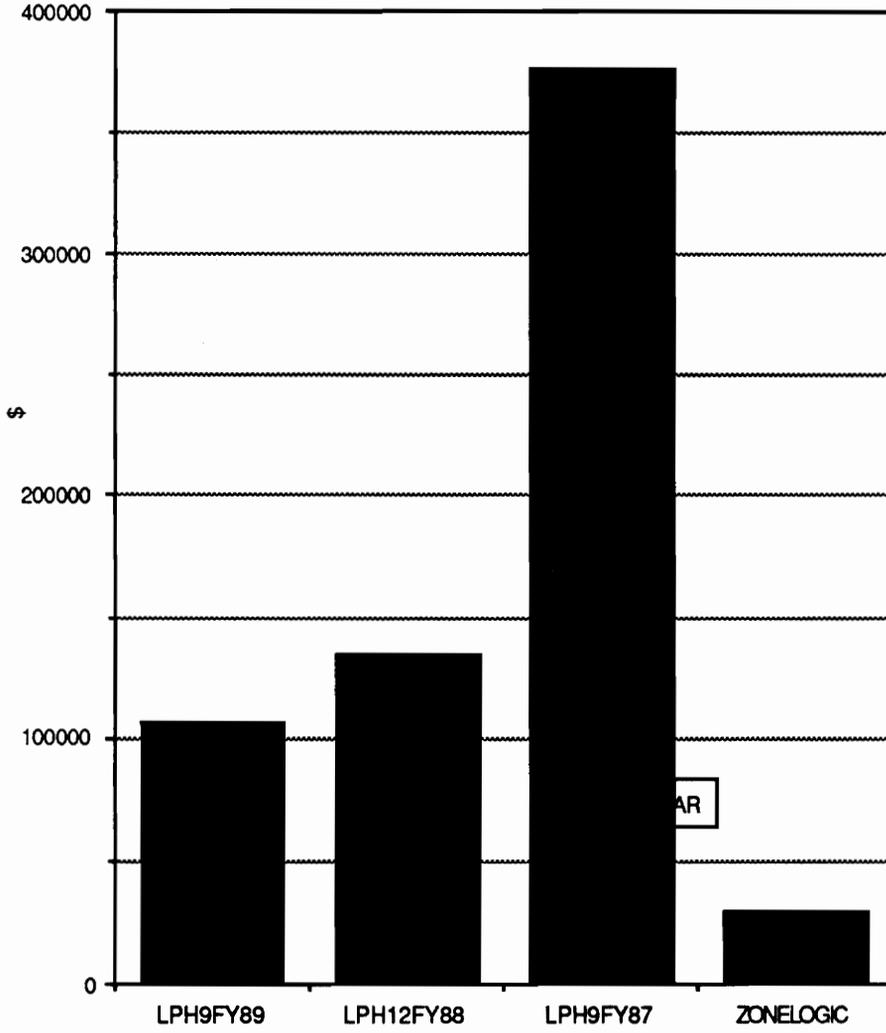
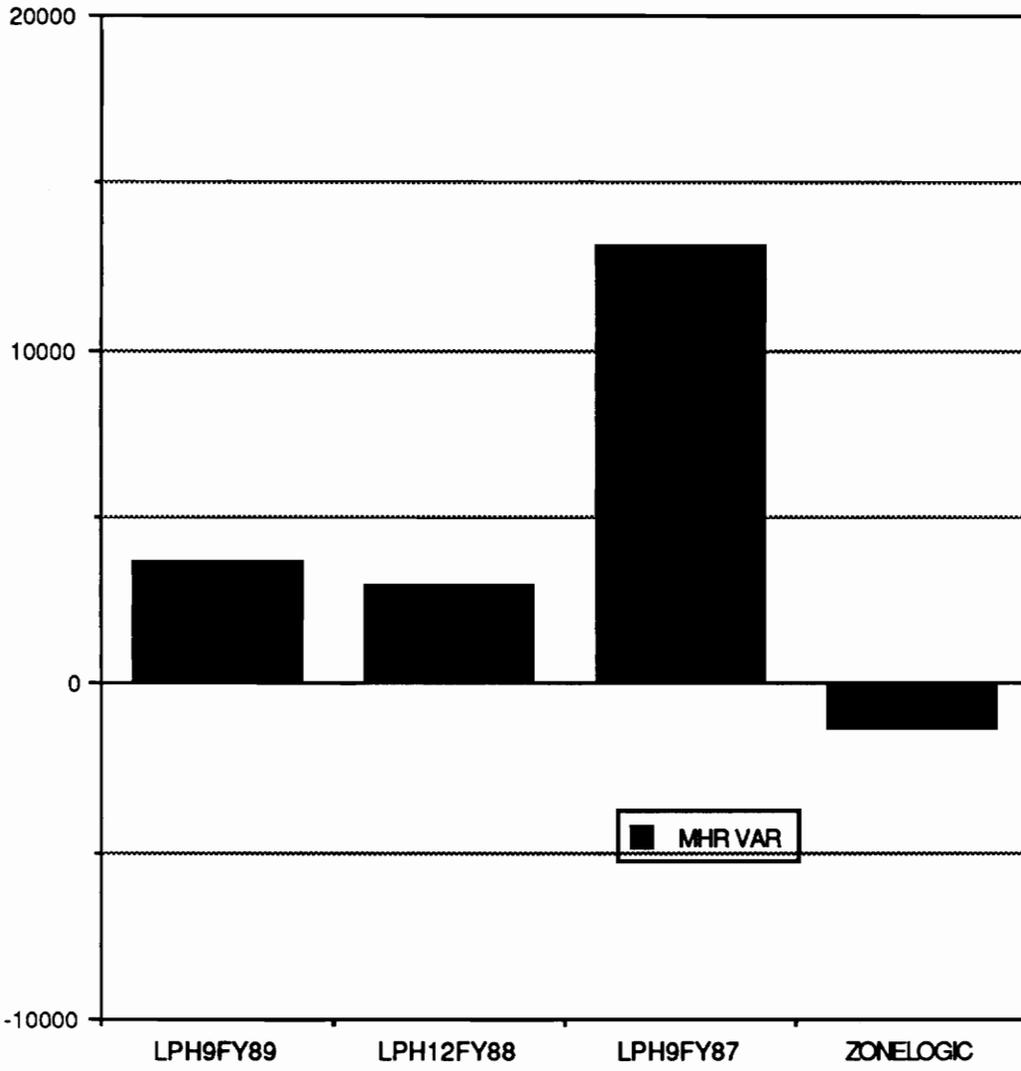


Figure 11: Cost Variance



**Figure 12: Manhour Variance**

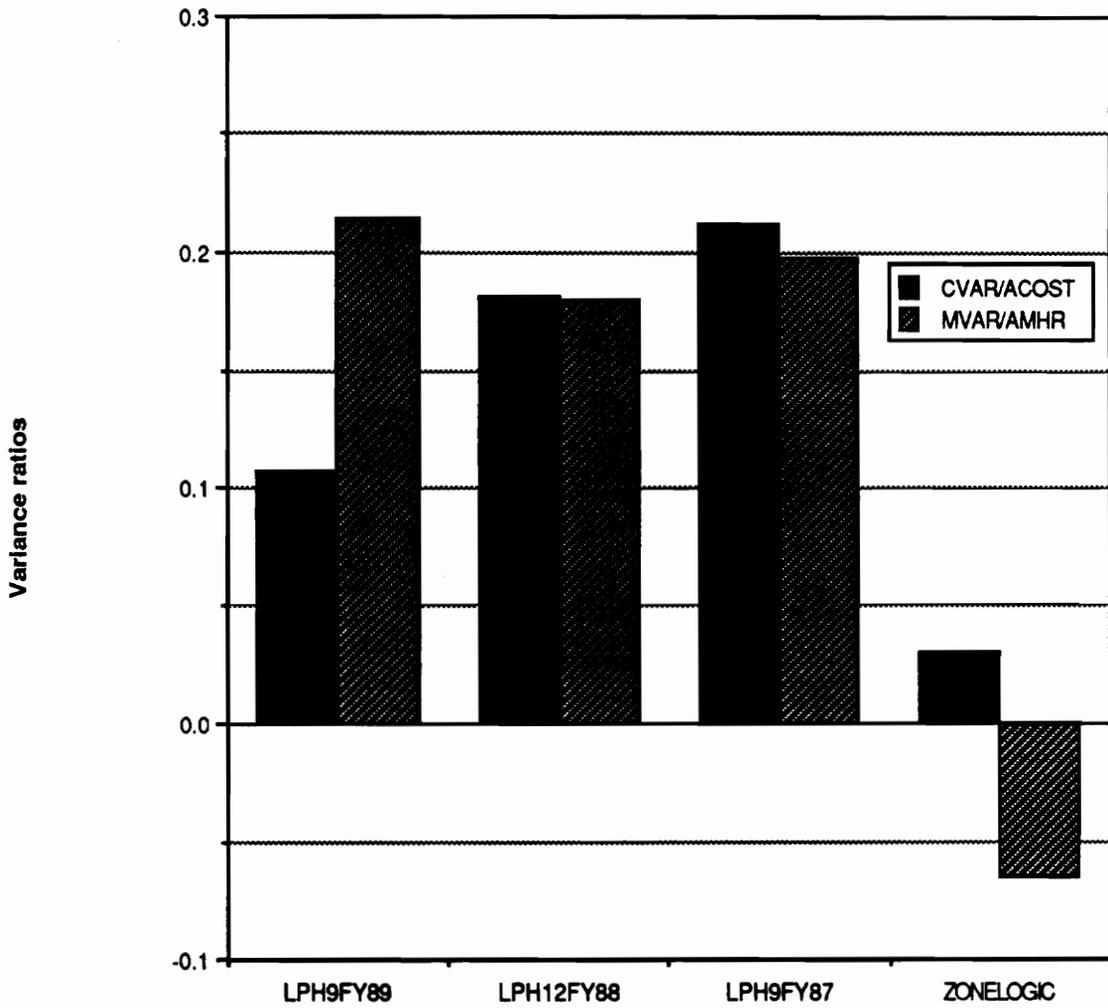


Figure 13: Variance Ratios

Table 5: Variance ratios

## VARIANCE ANALYSIS

	COSTVAR	MHRVAR	CVAR/COST	MVAR/MHRS
ZONELOGIC	\$29,014	-1357	0.030	-0.064
LPH9FY89	\$106,654	3671	0.108	0.214
LPH12FY88	\$134,477	2890	0.181	0.180
LPH9FY87	\$375,962	13103	0.212	0.198

### 6.4.3 COST ANALYSIS

The cost analysis will be oriented toward the benefits achieved by Zone Logic through the increase in productivity and the reduction in variance thus far shown in this study. The cost to convert to Zone Logic were minimal. The only cost involved was to assimilate the drawings for the PMA for Zone Logic. As was shown in the beginning of this chapter the drawings were drawn for both Zone Logic as well as for SHIPALTS and the contractor was never required to use Zone Logic as the preferred method for overhauling the ship. The benefits achieved far out-weight the costs incurred.

The initial cost for the IMPLEMENTATION OF ZONE LOGIC was minimal, due to the greater number of drawings that needed to be sent to the overhauling activity. The savings of Zone Logic will be evaluated by comparing the SHIPALTS with previous costs at METRO and at other contractor's that have performed the job. Table 6 shows the cost comparison of the Zone Logic Shipalsts. By subtracting the cost of the previous installation with the Zone Logic Installation and adding those differences, Zone Logic posts a cost benefit of \$183,817.

Table 6: Cost comparison of Zone Logic Shipalts

## COST ANALYSIS (FY 89 COSTS)

SHIPALT	SHIP	FY	ACTIVITY	MHRS	TOTAL COST
397K	LPH 2	81	NNSY	3880	\$219,546 *
397K	LPH 9	89	METRO	2992	\$148,781 **
684K	LPH 2	85	NORSHIPCO	10344	\$635,349 ***
684K	LPH 9	89	METRO	12700	\$546,801 **
888K	LPH 12	88	METRO	7106	\$303,846 ****
888K	LPH 9	89	METRO	5678	\$279,342 **

\* USS IWO JIMA (LPH 2) FY 81 REGULAR OVERHAUL (NORFOLK NAVAL SHIP YARD)

\*\* USS GUAM (LPH 9) FY 89 PHASED MAINTENANCE AVAILABILITY (PMA)

\*\*\* USS IWO JIMA (LPH 2) FY 85 REGULAR OVERHAUL (FIXED PRICE CONTRACT)-- TOTAL COST INCLUDES SUBCONTRACTOR WORK WHICH WAS NOT INCLUDED IN MANHOURS EXPANDED

\*\*\*\* USS INCHON (LPH 12) FY 88 PHASED MAINTENANCE AVAILABILITY (PMA)

The benefits enjoyed by the Zone Logic implementation are pointed out in this paper. Higher productivity, due to better estimation of the job, lower variance, and \$183,817 cost benefit.

## CHAPTER 7 CONCLUSION

The relationship of between technological change in production processes and productivity has become an issue of major importance throughout the world. Although the United States shipbuilding industry has led the technological evolution of shipbuilding by developing effective methods for all-weld ship construction and for mass in-line production of ships during World War II, which made it the by far the largest and most efficient builder of ships at that time, it has fallen far behind other major shipbuilding nations in productivity and output.

Adoption of Zone Logic concepts, developed for the new construction of ships, into the ship repair and modernization process is continuously proving its benefits. Unlike new construction ship repair and modernization adds the necessity of dealing with existing entities that must be accounted for in the planning of the work. This results in gathering definitive data reflecting existing conditions installed by the system-by-system thinking, and integrating into it the Zone Logic concepts.

This paper provides an in depth view of Zone Logic and the traditional shipbuilding methods. The objective of this paper was to introduce the fact that Zone Logic works and will provide intrinsic benefits in the short and long term future. The United States Shipbuilding Industry needs a boost in order to compete internationally and Zone Logic will provide the necessary tools for a more competitive shipbuilding industry. Throughout this paper justification of the existence of Zone Logic through a productivity analysis, a variance analysis and through the analysis of NAVSEA costs, have been provided. The productivity analysis alone proved that increases in productivity can easily be seen in the near future. The Variance analysis proved that the Zone Logic Shipalts had the lowest variance ratio. Only three percent of the actual cost was the variance of the Zone Logic Shipalts, which is minimal by all standards.

The cost analysis demonstrated that the Zone Logic Shipalts combined with a small learning curve benefit saved the U.S. Government approximately \$183,817 (16%).

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**APPENDIX A**

Table 8: Zone Logic Ship Alteration Summary

Table 9: LPH 9 FY 89 Phased Maintenance Availability

Table 10: LPH 12 FY 88 Phased Maintenance Availability

Table 11: LPH 9 FY 87 Phased Maintenance Availability

Table 7: Zone Logic Ship Alteration Summary

ALTS	BMHR	AMHR	BUDCOSTS	ACTCOSTS	MHRR	COSTR
397K	3550	2992	\$155,685	\$148,781	1.186	1.046
684K	11332	12700	\$494,098	\$546,801	0.892	0.904
888K	7845	5678	\$296,127	\$279,342	1.381	1.060
ZONE	22727	21370	\$945,910	\$974,924	1.063	0.970

Table 8: LPH 9 FY 89 PMA Summary

ALTS	BMHR	AMHR	BUDCOSTS	ACTCOSTS	MHRR	COSTR
280K	2329	4648	\$81,618	154,380	0.501	0.528
667K	134	184	\$70,095	\$74,005	0.728	0.947
413K	5664	7860	\$464,380	\$524,441	0.720	0.885
986K	3864	2591	\$140,994	\$106,270	1.491	1.327
892K	1477	1856	\$120,196	\$124,841	0.795	0.963
TOT	13468	17139	\$877,283	\$983,937	0.785	0.892

Table 9: LPH 12 FY 88 PMA Summary

ALTS	BMHR	AMHR	BUDCOSTS	ACTCOSTS	MHRR	COSTR
383K	972	824	\$29,296	\$22,302	1.179	1.313
624K	1338	528	\$62,519	\$43,748	2.534	1.429
667K	763	385	\$59,141	\$48,797	1.981	1.212
888K	4482	7106	\$224,754	\$297,015	0.630	0.757
806K	1404	1691	\$40,761	\$101,011	0.830	0.404
433K	2283	3381	\$111,393	\$124,821	0.675	0.892
280K	1905	2122	\$81,084	\$105,731	0.897	0.767
TOT	13147	16037	\$608,948	\$743,425	0.819	0.819

Table 10: LPH 9 FY 87 PMA Summary

ALTS	BMHR	AMHR	BUDCOSTS	ACTCOSTS	MHRR	COSTR
880K	160	340	4494	8248	0.470	0.545
753K	160	435	4191	15026	0.367	0.279
941K	2652	2369	64419	55778	1.119	1.155
940K	844	844	19640	17771	1.000	1.105
942K	1608	2074	51647	73806	0.775	0.699
751K	976	1734	35069	54782	0.562	0.640
925K	3966	3167	99761	82215	1.252	1.213
928K	1270	2569	31765	55113	0.494	0.576
933K	26674	31890	676776	866685	0.836	0.780
936K	14858	20849	405779	540079	0.712	0.751
TOT	53168	66271	1393541	1769503	0.802	0.787