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The Impact of Cross-functional Teams on Aircraft Carrier Construction

by

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ABSTRACT

This thesis describes research conducted at Newport News Shipbuilding to better understand the impact of cross-functional teams on aircraft carrier construction. Ship construction is a lengthy and labor intensive process that requires up to seven years and millions of man hours to complete. Each ship is unique and construction techniques evolve continually. Cross-functional teams play a significant role in developing new and more effective construction techniques and improving efficiency.

This thesis examines two distinct types of teams within an organizational learning framework. These teams represent two types of learning commonly referred to as single-loop and double-loop learning. The first team, known as a design-build team, is voluntary, transient, and informal. It brings together members of engineering, production planning, construction management, and the skilled trades. The design-build team focuses on individual projects and is successful in implementing design changes that originate at the production level. The second team, known as a Process Innovation team, is formal and highly structured. This team is one of seven formed as part of a company-wide re-engineering strategy. It brings together members associated with a particular function and focuses on broad processes. It too achieves success in implementing procedural changes within one of the company's manufacturing units.

An analysis of the two teams, their methods, and effectiveness is provided. Additionally, this paper presents a preliminary analysis of the firm's culture and how it affects the teams' performance. Recommendations suggesting opportunities for improvement in each type of team are also presented. These include more emphasis on developing a learning organization and the importance of leadership within the teams. More important, suggestions for achieving greater cooperation between the two types of teams to leverage their strengths are included.

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1. Introduction and overview

1.0 Introduction

Aircraft carrier construction is a lengthy and labor intensive process. While carrier design remains basically the same within a class of ship, customer mandated modifications make each unit different. Additionally, the construction process itself evolves over time because of technological advances and external influences. The need for continuous innovation and improvement has increased dramatically as competition in the shipbuilding industry has steadily intensified. One tool Newport News Shipbuilding (NNS) uses as it attempts to update its aircraft carrier construction process is cross-functional teams. These teams bring together personnel from engineering, project management, and skilled trades. The success of these teams depends on the knowledge and motivation of their members. However, success or failure may also depend on the company's organizational culture.

In his book Organizational Culture and Leadership, Schein defines culture as "the accumulated shared learning of a given group, covering behavioral, emotional, and cognitive elements of the group members' total psychological functioning."[1] This definition implies that shared learning results from shared experiences and that shared experiences require a stable group membership. NNS is a company with a long history in one industry and an often familial workforce. It has, accordingly, developed a strong culture. This could either benefit or hinder NNS as it works to improve and innovate.

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[1] Edgar H. Schein, Organizational Culture and Leadership (San Francisco: Jossey-Bass Inc., 1992), 10.

Should a firm like NNS decide to change its manufacturing processes it must first understand the cultural constraints within which it operates. Second, it must determine if the desired process changes can be accomplished within the culture as it exists, or if the culture must be changed. If it must be changed, leaders must establish a vision for effecting the necessary modifications.

1.1 Thesis outline

This thesis describes research conducted at NNS to understand the impact of cross-functional teams and the role organizational culture plays in the teams' success. To understand and evaluate the effectiveness of cross-functional teams in aircraft carrier construction, one should seek first to understand the corporate culture in which the teams operate. Then, an analysis of the teams' culture, methods, and results will help reveal their strengths and areas for improvement. The first four chapters of this thesis provide background on research topics and establish a research methodology. Chapter 1 provides background information on the organizational structure of Newport News Shipbuilding and recent developments in its product line. Additionally, a brief description of design-build teams within the aircraft carrier program is provided. Chapter 2 provides a more in-depth description of the carrier construction process and includes a process flow diagram. A brief history of the modular construction method and its impact on construction time and cost is presented. Chapter 3 reviews some of the current literature on organizational behavior, culture, leadership and team building. Based on this research, I provide some analysis of the current NNS culture and the challenges it poses for the process innovation efforts. Additionally, I examine how the culture appears to be evolving. Chapter 4 provides background on the design-build teams and discusses some of their projects. This section draws heavily on the documentation of the teams' efforts and on my interviews with team members. I also analyze the impact and approach of the Process Innovation organization. Likewise, my research comes from documentation and personal interviews. This chapter makes an initial comparison between the design-build teams and the Process Innovation teams.

The fifth and sixth chapters describe in-depth two cross-functional teams at Newport News Shipbuilding. Chapter 5 examines a proposal to modify the build strategy of one part of a carrier. A design-build team was established to explore the proposal and consider the construction process from design to material procurement and final outfitting. Chapter 6 describes my observations of one of the Process Innovation teams. This team developed and began implementing a demand-based manufacturing system within the Steel Production Facility (SPF). Chapter 7 presents conclusions and recommendations based on the research.

1.2 Organizational structure of NNS

The organizational structure of NNS has changed several times in its history and is still evolving . Five years ago the company was organized by project. Each major product line, such as submarines, aircraft carriers, and commercial ships, had divisions ranging from design and engineering to project management. In 1994 the company was reorganized along functional lines. **Figure 1-1** is an abridged organization chart. The aircraft carrier division functions as a project manager. It manages some of the resources of the engineering and trades departments to build aircraft carriers. However, the carrier program does not "own" these resources. The result is a matrix organization where tradesmen at the general foreman level and below report to superiors in the trades department, but work to support the project management division. **Figure 1-2** illustrates a simplified matrix within the aircraft carrier new construction program.

Figure 1-1 NNS Organizational Chart

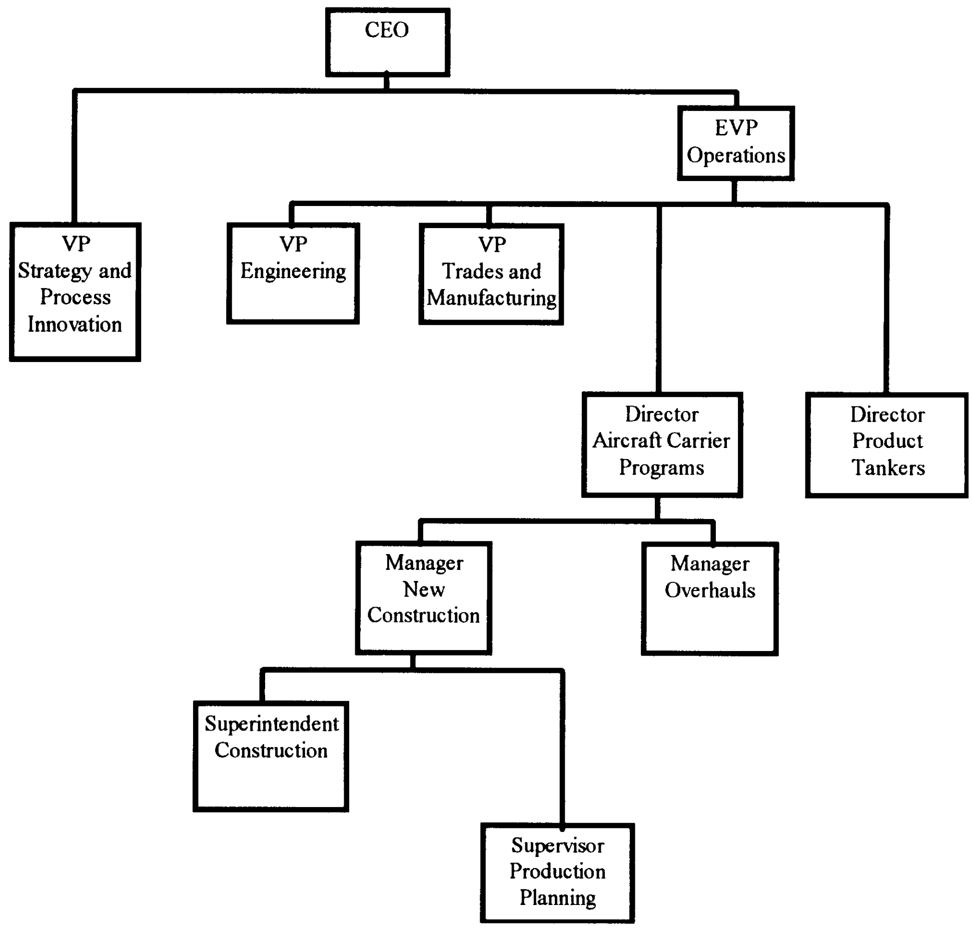

Figure 1-2 Matrix organization of Aircraft Carrier Division

<table>
<tr><td></td><td></td><td colspan="6">Carrier Program</td></tr>
<tr><td></td><td></td><td colspan="6">Director</td></tr>
<tr><td></td><td></td><td colspan="3">Manager</td><td colspan="3">Manager</td></tr>
<tr><td></td><td></td><td colspan="3">Superintendent</td><td colspan="3">Superintendent</td></tr>
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</table>

NNS's type of functional organization may increase efficiency by consolidating resources and allowing manpower to shift between programs to meet demand. However, inefficiencies occur when members of supporting departments feel powerless to meet the demands of multiple projects requiring the same resources. Perhaps a more significant effect of this type of organization is the creation of functional barriers. If a particular group identifies more with its department than with the project on which it works, there may be little incentive to contribute to process improvement. Similarly, if process improvement in a product line depends on inputs from several departments, a project manager may be unable to garner enough support to effect a change. These functional barriers can have more serious downstream side-effects such as inhibiting continuous process improvement through cooperation and prohibiting the establishment of a knowledge base within a product line.

1.3 Re-entering the commercial market

Throughout its history, NNS has been active in the commercial shipbuilding industry. However, during the 1970s first Japan and then Korea developed a competitive shipbuilding base. From 1974 to 1993 the U.S. commercial ship output fell from 97 units to only 1 unit.[2] Similarly, commercial ship construction as a percentage of revenue fell. In 1979 NNS delivered its last new-construction commercial ship. While NNS remains active in the commercial repair and overhaul market, this segment makes up less than 5% of the company's total revenues.

In 1994 NNS signed a contract with Eletson, a Greek shipping company, for five Double Eagle class product tankers. This marked the end of a 17 year drought in new commercial ship construction at NNS and was the first commercial ship built in the U.S. for a foreign country since 1957. The new Double Eagle construction program is additionally significant because it marked the establishment of NNS's Process Innovation organization. This department has seven cross-functional teams ranging from design to construction. These teams were chartered to improve the Double Eagle development and construction processes.

1.4 Design-build teams

In addition to establishing cross functional teams for the Double Eagle project, NNS has similar teams within the aircraft carrier program. These design-build teams, as they are called, differ from the Process Innovation teams in that they are voluntary, informal and transient. They combine members from various functions to propose,

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[2] IMA Associates, Inc., Five year outlook for U.S. Shipbuilding (Washington, 1994), I-3.

analyze and implement construction improvements. Although these teams usually have no official charter, they can be very effective. Unfortunately, because of their unstructured nature, their use is not widely recognized and successes are seldom shared with other departments.

NNS would like to expand the scope and effectiveness of design-build teams in aircraft carrier construction. Additionally, the company hopes to establish greater cooperation between the more informal design-build teams and the Process Innovation teams. The design-build teams played a significant role in my research and this thesis. Their composition, history and current status are described in the fourth and fifth chapters.

1.5 Summary

Newport News Shipbuilding uses cross-functional teams in a variety of settings. These teams have demonstrated varying degrees of effectiveness. Their success depends largely to the culture of company and the teams themselves. A thorough study of the teams and the corporate culture can offer insights into improvement of team performance. The remainder of this thesis explores the teams' culture and offers recommendations on improving their effectiveness.

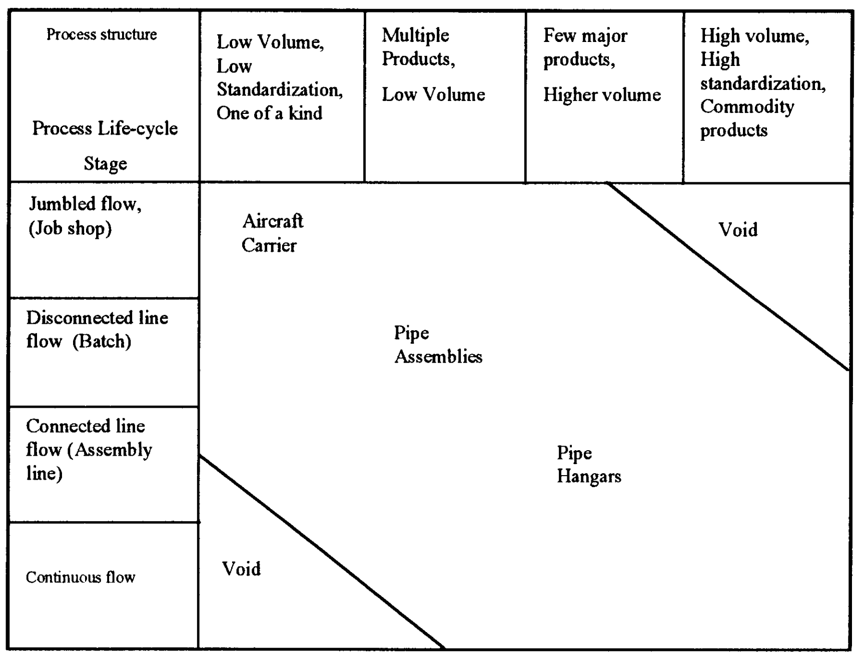
2. Aircraft carrier construction process

2.0 Overview

Aircraft carrier construction is a lengthy and complex process with numerous phases. Cycle time for a single carrier is approximately seven years. This includes approximately eighteen months of steel fabrication prior to keel laying, thirty months of construction in dry dock, and twenty-four months of construction and finishing work performed at a pier. Additionally, pre-construction planning and design may begin two years prior to construction. The long cycle time of each unit requires that many phases such as planning, design, and manufacturing be performed simultaneously and on a rolling basis. For example, engineering drawings continue to be generated after construction has begun and are issued as needed. Additionally, some phases may be repeated with increasing accuracy. For example, a concept design and an “order of magnitude” cost estimate may be developed for an initial proposal. The detailed design and final cost estimate will be refined one or more times prior to contract signing. The design will be further refined before being issued to the manufacturing department. In fact, detail design work will continue almost until project completion.

Carrier construction involves a variety of manufacturing types. While the carrier itself is custom built, many components are mass produced. **Figure 2-1** illustrates a product-process matrix and three of the types of manufacturing that take place during carrier construction. The ship is clearly a one-of-a-kind unit that is typical of a job shop operation. Pipe is cut and shaped according to size and then joined to form assemblies that are installed as completed modules. These assemblies represent batch manufacturing. Pipe hangars, supports for the miles of piping running throughout the ship, are mass produced. This thesis focuses on the company's efforts to optimize a job shop type of operation.

Figure 2-1 Product-Process Matrix[3]



The remainder of this chapter describes the construction process from concept to ship delivery. Emphasis is placed on the assembly and erection of major components on the ship. **Figure 2-2** illustrates a simplified process flow diagram for aircraft carrier construction.

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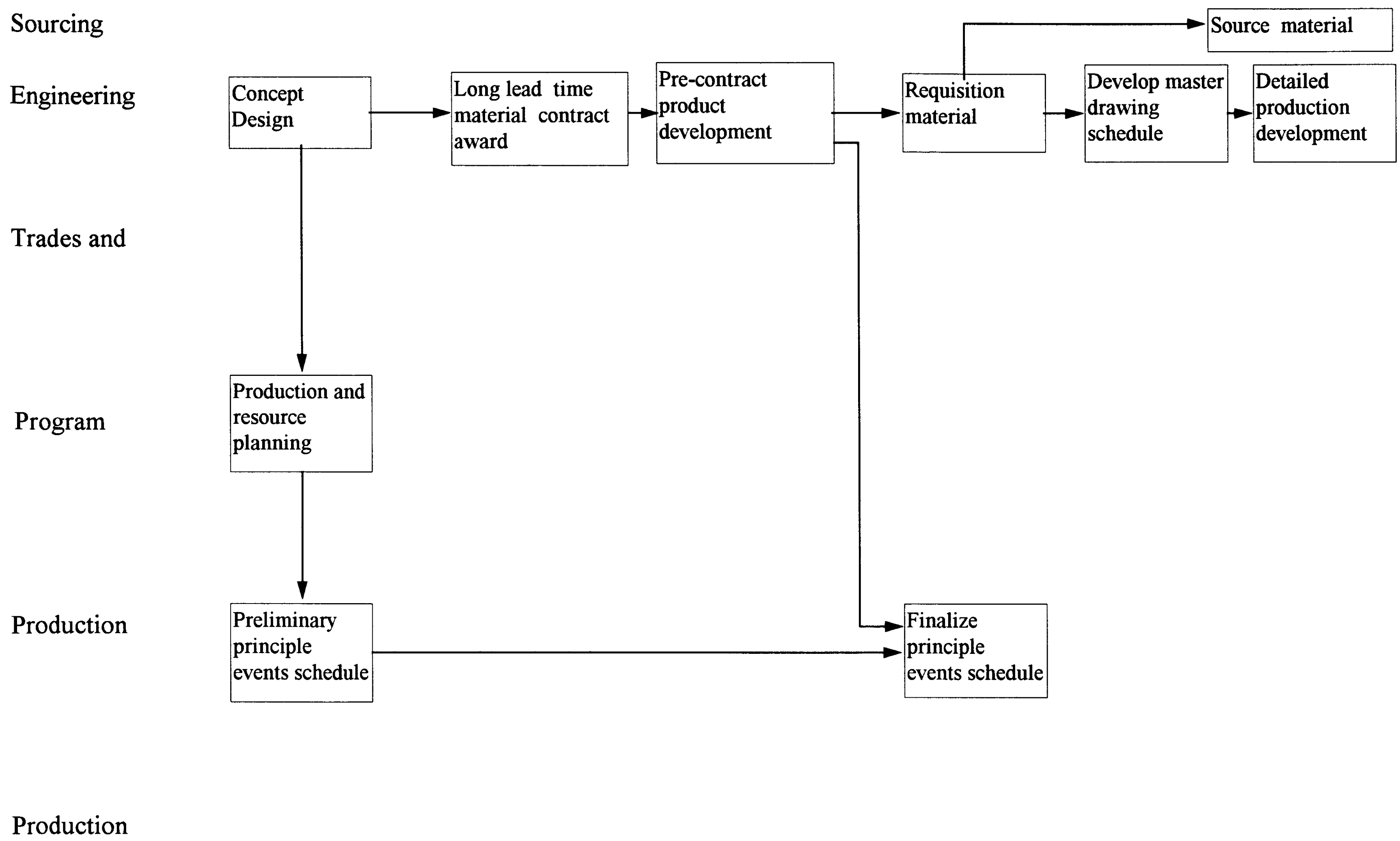
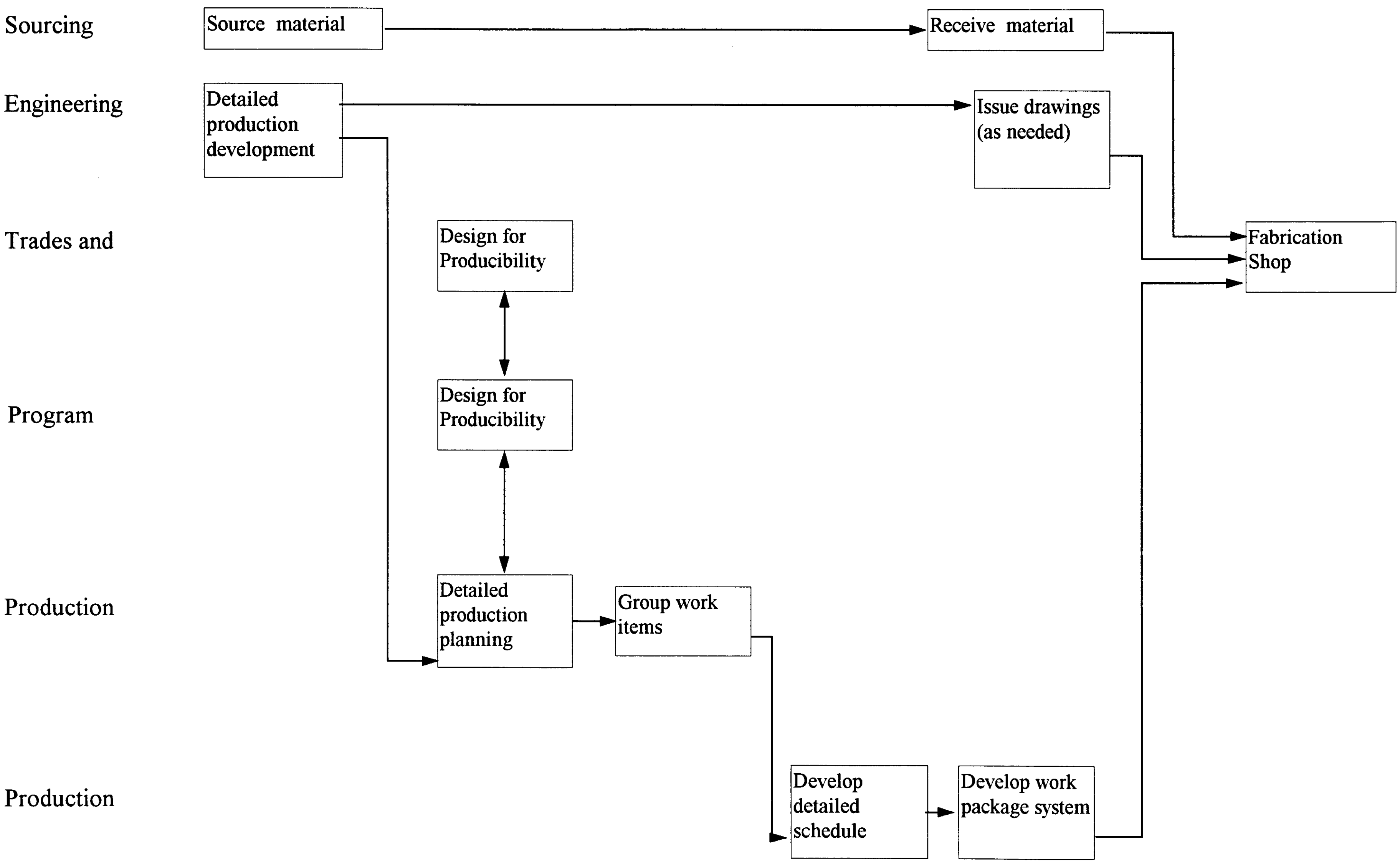
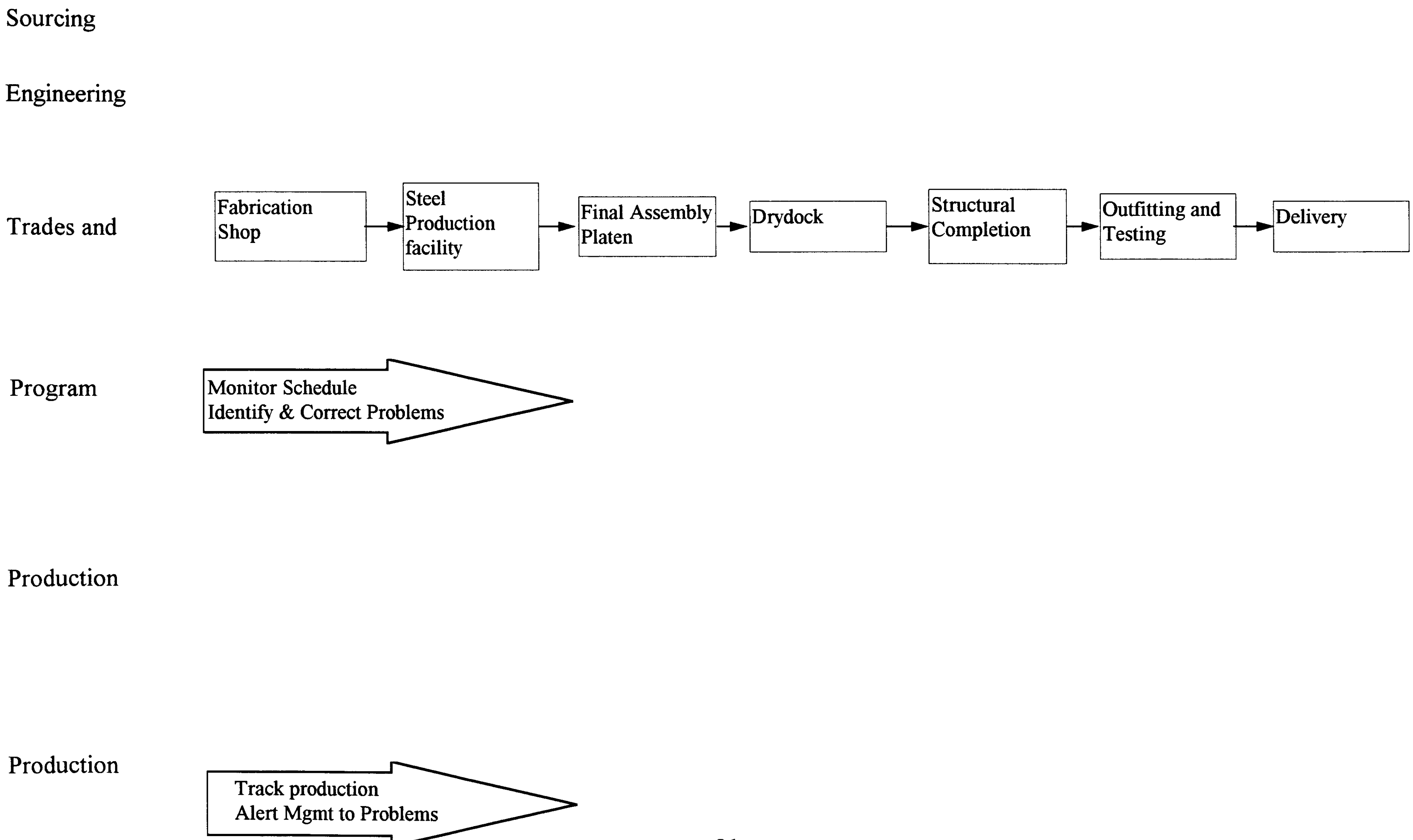
[3] Steven Nahmias, Production and Operations Analysis (Boston: Richard D. Irwin, Inc., 1993), 11.

Figure 2-2 Simplified Shipbuilding Process Flow




Sourcing
Engineering
Trades and
Program
Production
Production
Source material
Receive material
Detailed production development
Issue drawings (as needed)
Design for Producibility
Design for Producibility
Fabrication Shop
Detailed production planning
Group work items
Develop detailed schedule
Develop work package system


Sourcing
Engineering
Trades and
Fabrication Shop
Steel Production facility
Final Assembly Platen
Drydock
Structural Completion
Outfitting and Testing
Delivery
Program
Monitor Schedule
Identify & Correct Problems
Production
Production
Track production
Alert Mgmt to Problems

2.1 Planning

Work authorized in a final contract is divided into two major categories, planning and execution. In this paper, planning encompasses design, engineering, production planning and sourcing. Execution includes fabrication, assembly, erection and outfitting.

2.1.1 Design and engineering

Design is the first step in the construction process and may begin with a new concept, or a rollover of an existing design. For example, the ninth carrier in the Nimitz class of ships is currently under construction and the Navy plans to procure a tenth and final ship in a few years. Subsequent aircraft carriers will be of an entirely new class and design.

New drawings are created for each ship regardless if it is a new design or a rollover. These drawings incorporate changes required by the customer as well as those implemented by the builder to increase efficiency or cut costs. Detailed drawings are produced continuously, approximately seven weeks prior to their use in construction.

2.1.2 Production planning and material sourcing

Production planners take detailed drawings and generate material requirements and work breakdown. The work breakdown includes line items for fabrication in the shops and erection on the ship. Planners then *group* the work. Grouping is essentially associating material and work to a particular part of the ship and stage of construction.. This phase is critical because final scheduling is accomplished through the Group and Index Scheduling system (GIS). The GIS ultimately drives material sourcing, engineering drawing issue, and manpower planning. Material that is not grouped with a particular unit will not be available for use during that unit's construction time frame. The planners enter material requirements into a master bill of materials database. Purchasing uses this information to solicit bids from vendors for material.

Once work and material requirements are established, a computer system called Artemis generates a schedule by working backward from the desired completion date. This information is used to develop a master schedule for work and material procurement.

2.2 Execution

The execution phase can be broken into two basic types of work, manufacturing and construction. Manufacturing typically involves shop work while construction involves ship work. The line between the two areas is unclear because some work is done on assemblies after they leave the shop and before they reach the ship. For purposes of this analysis the line will be drawn using the company's organizational boundaries. Hence manufacturing ceases when the work item leaves the fabrication facility and is delivered to the project management division at the dockside work area, or *platen*.

2.2.1 Manufacturing

The steel manufacturing shops operate to meet the schedule set forth by the GIS. The process begins in the fabrication (fab) shop where material, typically steel plates, that has been sourced and grouped for a particular unit are taken from inventory and fabricated into sub-assemblies. These are simple three-dimensional structures that may consist of a plate with stiffeners attached. The sub-assemblies are shipped to the steel production facility (SPF) where larger structures called *base units* are assembled. After the base units leave the SPF they are sent to the blast and coat facility where they are primed.

2.2.2 Construction

Once the base groups are moved to the platen they are joined into *superlifts*. A superlift may exceed 120 feet in length and weigh over 500 tons. Non-structural components, like pipes and electric wire, are frequently installed while the superlift is on the platen. This *pre-outfitting* reduces the work required aboard ship. Construction time for a superlift varies from a few days to several months. The cycle time is driven by the required delivery date and the amount of pre-outfitting accomplished. Since 1981, when modular construction commenced, the number of superlifts has decreased while their size has increased. Additionally, the amount of pre-outfitting has also increased. Once a superlift is completed, a large crane suspends it on the ship while it is welded in place.

Superlifts are fabricated and attached to the ship in accordance with a build strategy. The process is similar to stacking building blocks. Each ship's build strategy is different. While this may be due to a variety of reasons, a common cause is the need to accommodate scheduling conflicts within the dry dock. Since the dock can hold more than one ship, it may be necessary to work in only one direction to accommodate work on the other ship. Material availability may force a change in the build strategy during construction.

Outfitting begins once the superlifts are attached to the ship. This involves installation of pipes, machinery, furniture, and electrical wiring and equipment. The outfitting sequence is driven by the GIS. However, certain equipment that must be installed prior to launch takes priority and can disrupt the schedule. Also, material availability frequently prevents work from proceeding.

When an aircraft carrier is christened and launched, it is only about fifty percent complete. After launch the ship is moved along side of a pier to facilitate final outfitting and integration of the various systems within the ship. Testing takes place continuously, with specific systems coming on line sequentially. Once the ship is completed, it is taken on sea trials. After the sea trials, the ship return to the yard for final work and is then delivered to the customer.

2.3 Summary

In the aircraft carrier construction process many steps of the process occur continuously, so it is difficult to delineate the different phases. While this type of manufacturing has drawbacks, there are some advantages. For instance, process improvements can often be implemented in a pilot program and tested during construction, and then discarded or modified. Consequently, one may see many procedural or operational changes during the construction of a single ship. Chapter 5 illustrates the efforts of one design-build team to expand the concept of a previously tested process improvement, and to increase its use on subsequent ships.

3. Theoretical background of organizational culture

3.0 Introduction

Volumes have been written about organizational culture and leadership; this chapter focuses on three areas: underlying assumptions that define culture, organizational learning as a means to challenge underlying assumptions, and the leader's role in changing corporate culture. As I will show, these topics are important to the aircraft carrier construction process because all cross-functional teams operate within the same corporate cultural constraints. The teams' effectiveness depends largely on how they interpret and respond to their environment. This in turn dictates what types of solutions they will develop.

3.1 Defining organizational culture

In Theory in Practice: Increasing Professional Effectiveness, Argyris and Schön define elements of human behavior that can be used to explain organizational culture. Three of the concepts proposed by the authors are theories of action, espoused theories of action, and theories-in-use. Theories, according to the authors, are vehicles for exploration, prediction, or control.

A *theory of action* can be a attributed to a person to explain or predict his behavior. In its simplest form, a theory of action could be defined as:

In situation S, if you want to achieve consequence C, under assumptions $a_1 \ldots a_n$, then do action A.

However, a theory of action attributed to an individual may not fully account for his behavior because the assumed theory of action is wrong or the influence of some other control has greater effect.

When asked how they would react in a given situation under certain assumptions, a subject typically will respond with their *espoused theory of action*. This is the theory that one communicates to others and professes to follow. The driver that actually governs the subject's behavior is called a *theory-in-use*.[4]

In Organizational Culture and Leadership, Schein builds on the work of Argyris and Schön to describe corporate culture. Schein asserts that a firm's culture may be revealed at three levels: artifacts, espoused values, and shared basic assumptions. *Artifacts*, which are the most superficial level, are easily observable. Examples include the firm's architecture, cleanliness, noise level, and products. Employee artifacts can be dress codes, language, and manner of address. Other examples are published lists of values, ceremonies, and organizational structure. Artifacts, though observable, are difficult to decipher because a firm may use them to project an image that does not accurately reflect its true culture. Consequently, someone examining artifacts may misinterpret their true meanings.

Espoused values are the ideals that members of a culture *say* are important. They are similar to espoused theories of action. Examples include making quality a top priority, putting people before profits, and calling R&D the key to success. Espoused values

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[4] Chris Argyris and Donald A. Schön, Theory in Practice: Increasing Professional Effectiveness (San Francisco, CA: Jossey-Bass, Inc., 1974) 5-7.

typically develop from the stated values of a group's leaders. If the actions taken as a result of these values are successful, the group may begin to put greater faith in them. Espoused values may ultimately develop into shared assumptions. However, espoused values do not always truly reflect underlying assumptions. For example, a group of people may claim that quality is a top priority, but maintaining throughput may take precedence in a crisis situation. Finally, espoused values may reflect more of what a company feels it should be or hopes to be in the future. While espoused values are more reliable indicators than artifacts, one must ensure that they are true reflections of culture.

Shared basic assumptions, which correspond to theories-in-use, are ideals that have become so common and accepted that they are ubiquitous and unvarying. Group members conform to these ideals without thinking about it and find other actions implausible. Examples include the idea that a firm should make a profit or that employees have the right to choose their after-hours activities. While shared basic assumptions actually define a culture, they are the most difficult level to uncover. Group members may not realize that certain ideas are assumptions because they seem inherently fundamental. Also, group members may be reluctant to reveal assumptions because they are undesirable or not aligned with their espoused values. An example is an implicit understanding that workers who become physically unable to do their job will be laid off rather than retrained.[5]

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[5] Edgar H. Schein, Organizational Culture and Leadership (San Francisco: Jossey-Bass Inc., 1992), 16-26.

3.2 Organizational Learning

It is clear that in today's constantly changing environment, successful organizations must evolve. It follows that this will involve a change in corporate culture. The concept of organizational learning is often used to describe a process by which a firm rethinks many of its business assumptions. Senge popularized the learning organization in his book The Fifth Discipline. There, he defines a learning organization as one "where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspirations are set free and where people are continually learning how to learn together."[6]

Argyris outlines two models, formally known as Model I and Model II, that are useful for distinguishing between different types of organizational learning. In Model I, human behavior is governed by four values or *variables*:

1. Achieve the purpose as the subjects define it
2. Win, do not lose
3. Suppress negative feelings
4. Emphasize rationality

In a group situation all members act unilaterally according to these rules and their basic assumptions. There is little personal feedback and group members do not test the assumptions under which they operate. This is called *single-loop learning* because all learning is within commonly held assumptions.[7] **Figure 3-1** illustrates an example of single-loop learning.

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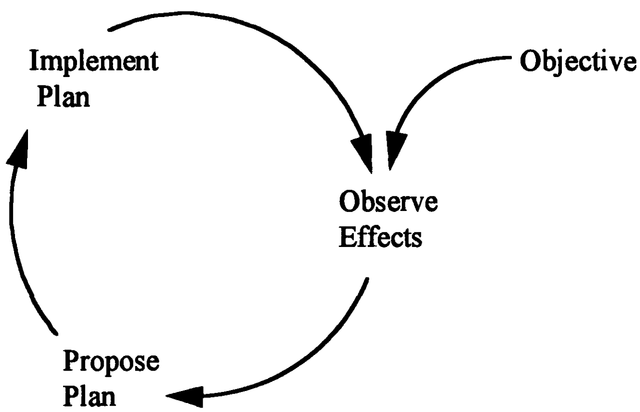
[6] Peter M. Senge, The Fifth Discipline (New York, NY: Currency-Doubleday) 1.

[7] Chris Argyris, Increasing Leadership Effectiveness (New York: John Wiley and Sons, Inc., 1976), 17.

Figure 3-1 Single-Loop Learning



In this case the group members observe the effects of a current plan and compare them to a desired objective. Based on the difference between the actual effects and the objective, a new plan is proposed, implemented and observed.

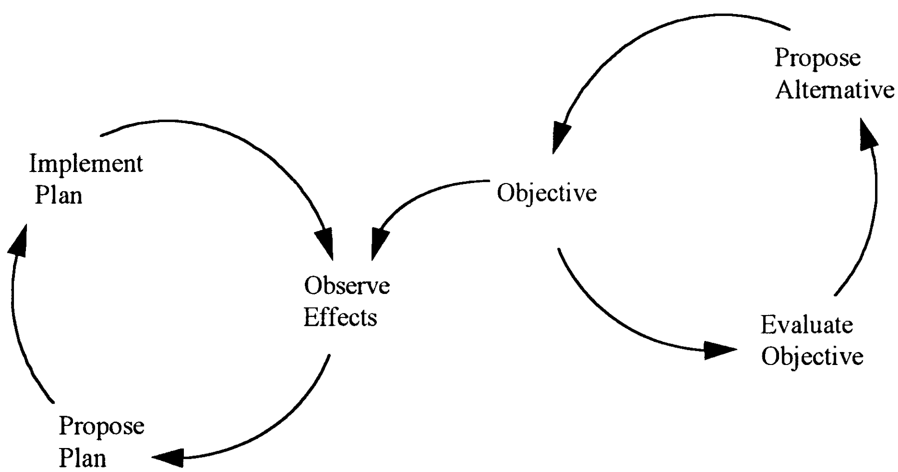
Continuous improvement programs are one example of single-loop learning. Groups strive to achieve their objectives by improving existing processes. This type of learning is useful because it enables groups to fine-tune their operations using continuous feedback. However, single-loop learning has disadvantages in that group members never question their objectives. Since members operate unilaterally under the aforementioned governing variables, there is more emphasis placed on conformity, saving face and avoiding conflict.

Model II behavior exhibits a different set of governing variables:

1. Valid information
2. Free and informed choice
3. Internal commitment

Group members operating under Model II variables also consider their personal objectives. However, since they desire valid information and informed choice, they are more apt to confront others' views. This means the objective which the group tries to achieve may be challenged and modified.[8] Model II behavior is often associated with *double-loop learning* because the cycles of process improvement and formulation of objectives interact continuously. **Figure 3-2** illustrates double-loop learning.

Figure 3-2 Double-Loop Learning



Here, the group not only observes the effects of its processes, it evaluates and modifies the objective against which the effects are compared. Double-loop learning is useful in moving toward a higher level of group effectiveness.

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[8] Ibid., 20.

It is important to note that both Model I and Model II behavior are useful types of organizational learning. Model I is useful in routine decision making and is probably more effective in crisis situations where challenging assumptions may be counter-productive. Model II behavior is most effective in major decisions that require analysis of complex situations and a variety of alternatives. Schein asserts that the latter type of organizational learning is necessary for changing an organization's culture.[9]

3.3 The leader's role in changing corporate culture

The process of creating a learning organization and changing its culture begins with its leader. Schein distinguishes between a leader, who creates and changes culture, and a manager who lives within a culture.[10] The leader's role varies with the size and age of the organization. If an organization matures and remains successful for a long time, its culture becomes more firmly entrenched. As long as the firm's culture remains aligned with its external operating environment, it will continue to succeed. However, if the competitive environment shifts and the firm fails to respond, or adapts very slowly, it will enter a period of gradual decline. This is evidenced in many "smoke stack" industries such as railroads and steel production.[11]

The first step for a firm in this situation is to empower a potential leader who can recognize the need to change its culture. This new leader must first have a vision of where the organization should go. Second, he must be able to dissect and understand the organization's culture as it exists and determine which of its assumptions will help and

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[9] Schein, 22.

[10] Ibid., 5.

[11] Ibid., 155.

which will hinder fulfillment of the organizational mission. Third, the leader must have the intervention skills and authority to make the necessary changes.[12]

Schein outlines several methods leaders use to effect cultural change in firms. These range from organizational development, which is a planned change process that can take years to accomplish, to change through turn-arounds, an abrupt process that involves a great deal of upheaval. Subsequent chapters in this thesis examine how leaders of cross-functional teams in the aircraft carrier program cope with the firm's culture.

3.4 Research methodology and observations

In order to better understand the impact of cross-functional teams I attempted to define some of NNS's cultural characteristics. In some cases the teams I studied exhibit Model I behavior in that they do not challenge underlying assumptions. In other cases the teams exhibit Model II behavior because they challenge and attempt to modify long standing theories-in-use. In my study, I followed Schein's methodology for understanding culture. I first examined artifacts and attempted to learn some of the company's espoused values. Through interviews and participating in various teams I formulated hypotheses about the company's shared basic assumptions.

3.4.1 Artifacts

NNS stands on its original site. It has grown substantially since its founding, but many of its buildings are very old. Construction of new buildings has slowed in recent years, but renovation of existing buildings continues. Cranes dominate the skyline and seem to be in continuous use. The roads are crowded with large vehicles that transport

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[12] Ibid., 378

material and assemblies in various stages of completion. Raw material covers much of the land not dedicated to construction, and deliveries to the yard are seldom seen. The platen is the center of visible activity with crews working steadily on the enormous superlifts. The yard and its equipment have a very utilitarian air and seem dedicated to getting material to the workers at the platen and onto the ship.

Work in the yard and on the ship progresses steadily, but not at a frenetic pace. A ship under construction is loud, cluttered, and full of activity. Workers are methodical in their actions, but don't seem to emphasize expediency or efficiency. The ship looks rough and neglected until the finishing work begins. There is little attention paid to keeping it neat.

3.4.2 Espoused values

NNS has amicable relations with its employees. Despite dwindling defense expenditures and a gradual downsizing of the NNS workforce, the company attempts to take care of its employees. Likewise, there is a tremendous amount of loyalty by employees toward the company evidenced by the pride they take in their work.

NNS developed its "Mission Essential Statement of Beliefs and Values." This statement validates many of the artifacts seen throughout the yard. The values state a commitment to people and recognize their contribution. Additionally, there is an emphasis on quality, continuous improvement and prudent risk taking.

NNS conducts two types of periodic surveys of its employees. The first is a semi-annual organizational assessment survey. Questionnaires are sent to a random sample of the workforce for anonymous responses. The second survey is an exit interview with departing employees. These surveys confirm that employees are most satisfied with their work and least satisfied with their compensation. Additionally, quality ranks very highly. One concludes that employees enjoy their work and are proud of their products. However, the declining defense business has limited the company's ability to reward its employees financially and has created tension between work and its rewards.

The Director of carrier programs hosts a weekly luncheon with foremen from various carrier projects. These are a means of establishing communications with the workforce. While the luncheons promote open discussion, they are structured around a brief survey given to the participants. The survey mirrors the exit interview questions and is designed to gauge the relative satisfaction with various aspects of work. The results mirror those of the interviews almost exactly. Employees rank their work and quality highest. They are least satisfied with compensation. Numerous comments during the luncheons involve the foremen's ability to supervise their workers. Many complain that the administrative burdens and wider scope of supervisory responsibilities limit their ability to manage projects. Foremen desire more hands-on construction work and less administrative and clerical activity. They often comment "give me the people and the material and get out of my way and I'll get the job done."

These espoused values focus on employees' desire to do quality work without the administrative restrictions. Foremen are less enthusiastic about new procedures or equipment aimed at streamlining their work than they are about having more time for supervising workers and the ability to use motivational techniques like spot promotions and raises.

3.4.3 Shared basic assumptions

After five months of observations I postulated three shared basic assumptions. The list is not complete and time constraints prevent rigorous validation. However, my discussions with employees indicate that most believe in these elements.

3.4.3.1 We build great ships

Without exception, waterfront personnel who work on the ship and platen, will tell outsiders that they build great ships. They also exhibit a great deal of pride in this. While some may acknowledge that the company may not perform at its best, none dispute that the ships, particularly the military ships, are the finest built anywhere. It appears, however, that employees focus more on the quality of the finished product rather than the construction process. I seldom encountered anyone who said that NNS's shipbuilding *process* was the finest in the world. This should not be construed to mean that employees had unfavorable opinions of their processes. Rather, it seems that results are more highly regarded than processes.

3.4.3.2 Quality is most important

A second assumption follows closely on the first. Without question, most employees describe quality as being important. Many employees see themselves as craftsmen in a time-honored profession. Quality workmanship is viewed as a means of distinguishing oneself. Many efforts to improve processes exist in the company. However, it appears that many proposals are rejected if they would diminish quality in any way. One should not infer that the company sacrifices efficiency for the sake of quality. Instead, it appears that the impact on quality is a major consideration in most decisions.

3.4.3.3 High Tech is not always the answer

There is a resistance to new technology by many employees, particularly those on the waterfront. The company as a whole is very progressive, especially in the area of CAD/CAM and database utilization. At the foreman level, however, adoption of personal computers is slow. Many feel that a technology's value must be proven before it is accepted. However, once a technology is accepted, it is used extensively and is not readily discarded. This phenomenon may have its roots in the gradual downsizing of the company. The company has slowed its hiring of supervisors and hence has relatively older labor force. Since many of these people did not grow up in the computer age, they are less likely to be familiar with computers and willing to use them.

The preceding observations should not be taken as proven facts. They are hypotheses based on limited contact with a complex organization. Further, they should not be interpreted as being entirely positive or negative. In each case they could be either. For example, resistance to technology could be considered as a negative trait. However, one might argue that it prevents the company from investing excessive time and money in new fads. The challenge for company leaders is to evaluate the validity of these and other hypotheses and determine their impact on achieving their vision for the company's future.

3.5 Conclusion

This chapter outlines some of the current literature on organizational culture, learning and leadership. It describes the differences between single- and double-loop learning and establishes a framework for exploring each type in the context of cross-functional teams. Finally, it presents some observations and hypotheses about the company's culture.

4. Design-Build teams and the Process Innovation teams

4.0 Introduction

The carrier program's design-build teams and the Process Innovation teams represent different types of learning organizations with different approaches to improving construction efficiency. This chapter reviews some of the accomplishments of each type of team and illustrates examples of single and double-loop learning. Some of the cultural differences between the groups are discussed and serve to explain some of the differences in their operating methods.

4.1 Background on design-build teams

Design-build teams, which are cross-functional teams that seek to improve the construction process, have been used at NNS for years. It is convenient to begin the analysis in 1981, the year NNS began building aircraft carriers using modular construction. **Table 4.1** lists the aircraft carriers built by NNS since that time.

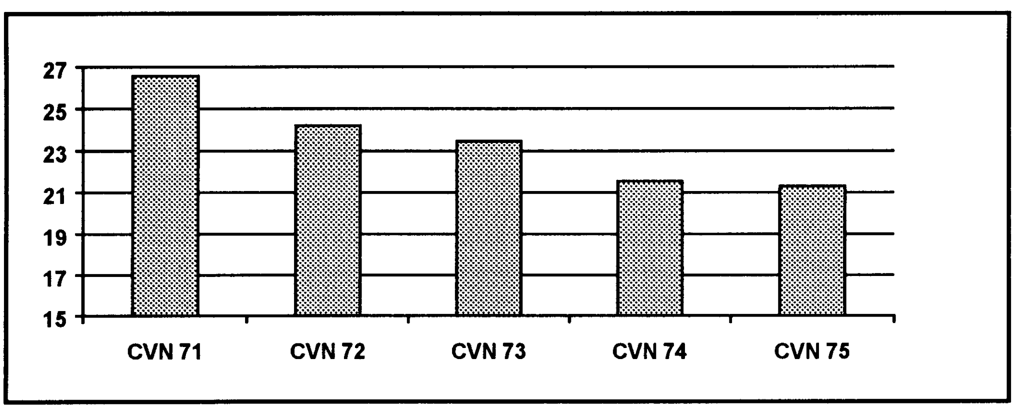
Table 4.1 Carriers built using modular construction

Number	*Ship*	*Keel Laid*	*Delivered*
CVN 71	Theodore Roosevelt	Oct 1981	Oct 1986
CVN 72	Abraham Lincoln	Nov 1984	Nov 1989
CVN 73	George Washington	Aug 1986	Jun 1992
CVN 74	John C. Stennis	Mar 1991	Nov 1995
CVN 75	Harry S. Truman	Nov 1993	Jun 1998 (projected)
CVN 76	Ronald Reagan	Feb 1998	Dec 2002 (projected)

NNS has used modular construction in tanker construction for years. The tankers' boxy shape and limited outfitting make them well suited for this method. However, aircraft carriers, with their complicated curves, high levels of outfitting, and cramped quarters made modular construction a daunting task.

When the USS Theodore Roosevelt was planned, engineering and design personnel divided the ship into modules. This breakdown, while not arbitrary, was not based on any precedent in carrier construction. The breakdown has evolved continually since then. Much of this change was driven by engineering. However, tradespeople and project managers have generated and implemented many ideas through design-build teams. The net result has been increased module size and a corresponding decrease in man-hours spent per ship. **Figure 4-1** illustrates this decrease. Throughout this period design-build teams have expanded the scope of their studies to include almost every facet of construction, from welding to electrical work.

Figure 4-1 Shipboard Manhours (millions)



4.1.1 Structure

Design-build teams in the carrier program are informal and transient. There is no central team coordinator and no defined method of documenting the teams' activities.

Additionally, design-build teams have no set composition. They typically include members from project management, the skilled trades, and engineering.

The tradespeople offer insights into the details of the work and frequently propose new construction methods. Examples are new welding and joining techniques. Project managers examine the impact of the proposed changes on scheduling and manning requirements. They frequently consult with personnel from material sourcing to ensure the availability of parts and supplies. Designers and engineers may be part of a design-build team, or they may be consulted once a team decides to proceed with an idea. Since many design-build initiatives involve structural changes, engineers are essential in evaluating the proposed changes in the early stages. Chapter 5 shows that engineering plays a larger downstream role in making official changes to the ship's design.

Production planners and production controllers may also participate on teams. Planners are responsible for breaking down work, grouping it, and generating a schedule. Controllers monitor schedule performance during construction. While it is assumed that work can be grouped and scheduled if it proves to be technically feasible, planners can often provide insights about the viability of a proposal. Most production planners began their careers as tradespeople. Their experience in shipboard and shop work combined with their in-depth knowledge of work breakdown from all parts of a ship make them an invaluable resource. Planners review every change proposal and become, *de facto*, a central repository of ideas, methods, and results. Despite their knowledge, planners' contributions to innovative construction methods are sometimes overlooked and underutilized.

Typically, a design-build team is disbanded after it has finished examining an issue. This approach has advantages and disadvantages. Transient teams have more flexibility. Because teams have only required personnel, they are leaner and more efficient. Finally, because teams are formed and meet only as needed, the work is less likely to become monotonous and burdensome.

Conversely, the teams' transient nature has several disadvantages. First, they never have the opportunity to develop into "high performance" teams. Current organizational research indicates that teams move through a series of stages before becoming efficient operating groups. These stages involve forming the team and an initial turbulent period as members begin interacting. The team then begins to learn the personalities and habits of the individuals. Group operating methods begin to develop and the team evolves into an efficient unit. It is unlikely that many of the design-build teams work together long enough to progress through all stages. Second and perhaps more important, the teams' transient nature may inhibit the development of any corporate knowledge. The design-build teams currently have no central record of ideas that have been proposed and pursued. Consequently, the same ideas or their variants may be tried repeatedly by different groups.

Because of the design-build teams' informality, their efforts and achievements frequently go unnoticed. Until this research and the concurrent work of a construction supervisor, there was no compilation of design-build team projects. This would indicate that there is no central coordination of the teams' activities in relation to the rest of the firm. Consequently, there is no assurance that design-build teams are pursuing the most beneficial projects.

4.1.2 Activities and Accomplishments

Projects undertaken by design-build teams since the advent of modular construction in carriers cover a wide range of topics. The following examples are by no means comprehensive and the technical details are omitted. However, the selected projects illustrate the broad scope of design-build teams activities and demonstrate both single and double-loop learning.

Many of the design-build team projects involve increasing pre-outfitting of construction modules. One of the most successful projects undertaken was the redesign of the integrated catapult control stations (ICCS cabs). There are two of these fully-enclosed stations on each Nimitz class carrier. They control the launching of all aircraft. The cabs historically were built in place on the carrier's flight deck, which caused congestion and poor coordination of shipboard work. Additionally, the work was open to the elements and required six material transports between the steel production facility, the machine shop and the ship. This method took a total of 28 months to complete and cost 30,000 manhours.

To overcome these problems during construction of the USS *John C. Stennis*, a team that called itself the "shooters," was assembled. Personnel from production control, design, the trades, and project management developed a plan to build the ICCS cabs as a completed unit in the shops. This method allowed for a controlled work environment, only two transports, 20 months construction time and a cost of 24,000 manhours.

This example illustrates incremental improvement achieved through the cooperation of several different departments. This effort represents single-loop learning because it increased construction efficiency within the boundaries of traditional procedures. In other words, the team took modular construction and pre-outfitting to a higher level by completely assembling and outfitting a small unit. The result was a tremendous cost and time savings. This project was supported by virtually all participants and was completed in a relatively short time. It also established a model for future projects. On subsequent ships another compartment, the nucleonics room, was similarly built and outfitted before installation. On the USS *Ronald Reagan* an entire elevator shaft will be pre-fabricated and installed to compensate for a customer-mandated design change. As demonstrated by this example, incremental improvement through single-loop learning can have a dramatic impact on construction efficiency. However, one should also recognize that it has its limitations. Single-loop learning does not allow for radical changes that require a questioning of traditional assumptions, in this case the efficiency of modular construction and pre-outfitting.

Design-build teams may also exhibit double-loop learning where some assumptions are challenged. One example, the introduction of stud welding, is noteworthy. This procedure uses a special gun to fuse the end of a large metal stud to steel. The studs are used as attachments for a variety of permanent and temporary equipment. Stud welding is fast, portable, and easy to learn. It represents a significant time and cost savings. One of its greatest advantages is that it can be performed by non-welders. This allows many workers to accomplish tasks that would have normally been delayed if a qualified welder were not available. Moreover, stud welding reduces costs because the studs can be removed quickly and easily after use. In contrast, traditional welding required arcing to remove attachments. This procedure frequently resulted in scars that must be repaired.

The adoption of stud welding throughout the yard was due largely to the efforts of the welding engineers, in conjunction with the trades and engineering. The welding engineers introduced the concept as an alternative to traditional welding techniques. The procedure was initially met with skepticism. However, design-build team members realized the project's potential and adopted this radically different welding technique. Additionally, stud welding has been used in many applications beyond those originally envisioned. Studs are now used to mount jack clamps to hold steel plates together during joining, to mount permanent light fixtures, to mount temporary hoists for positioning equipment, and to mount staging on the ship's exterior. Many of these applications have been subsequently patented. In 1993 the welding shop created a booklet titled "Stud Welding at Newport News Shipbuilding." This manual has been used to increase the use of stud welding both in the carrier program and other parts of the yard.

This design-build project is significant for two reasons. First, it demonstrates a more radical change from current procedures than many other design-build team initiatives. This effort represents double-loop learning because team members challenged many of their assumptions about welding and attaching equipment. The result of their efforts was a very different approach. Second, the welding manual represents an attempt to codify their successes and procedures and then disseminate them to the rest of the yard.

4.1.3 The design-build team subculture

Design-build teams focus more on incremental improvement than on radical change. Consequently, single-loop learning appears to dominate their activities. This section explores the cultural aspects of the design-build teams and offers reasons why they may be more prone to single-loop learning . The data are drawn from my observations and interviews with some of the teams and their members.

4.1.3.1 Artifacts

One of my strongest impressions of NNS employees is their tenure. The steady downsizing has curtailed the number of younger employees, particularly at the foreman level and above. Rarely did I speak to someone who had been in the yard less than ten years. It was not uncommon to encounter those with thirty or even forty years of experience. In most cases they grew up in the Newport News areas and often their fathers worked in the shipyard before them. The recent downsizing of NNS has increased the average age of the workforce. Layoffs typically affected the more junior workers and there has been little hiring of new workers. While this may lead to a more experienced workforce, I believe it also robs the company of young workers with new ideas. This may be most evident in the level of computer familiarity. The company has disproportionately few workers who grew up with computers and who are comfortable using them.

The overwhelming majority of waterfront workers are male. Production planning has the largest number of women workers, followed by the engineering department. . Waterfront workers, including many of the project supervisors, dress in traditional work clothes such as khaki work pants and open collared shirts. Uniforms are not worn at

NNS. Engineers will dress more formally. Many wear ties. Production planners and controllers dress casually.

Waterfront workers are a vigorous and rough group. Most of them are reasonably fit and lead active work lives. Many, particularly foremen and supervisors, seem to take a dim view of those who "can't take it." I once observed a welding foreman who had cut his hand wrap the wound with a paper napkin and bind it with electrical tape. He then went about his work. Several supervisors have spoken disparagingly of workers who visit the medical clinic frequently. One of the yard's strongest attributes is its action orientation. This attitude drives employees to make improvements. However, there seems to be a greater emphasis on doing things than planning how they will be done.

Most waterfront personnel seem to possess a vast knowledge of the ship's details. Many can identify from memory not only scores of ship compartments, but also the module in which they are built and much of the outfitting that goes into them. These men typically attend a design-build meeting without any drawings or manuals. They are also able to discuss the work as it evolved from ship to ship. In contrast, engineers are more apt to have a drawing when they discuss a problem. Production planners seem to have strong knowledge of the work breakdown. They will often consult printouts of the production schedule, but only for details.

Design-build team members are highly skilled and rely heavily on their extensive experience. They are action-oriented and prefer to make things happen rather than contemplate alternatives. Their emphasis seems to be avoiding past mistakes and improving on previous successes. Consequently, they seldom challenge long-standing assumptions and concentrate on incremental improvement.

4.1.3.2 Espoused values

Although there is no formal design-build team organization, there are members who serve to tie the various teams together. One such person, Walt Kwiatkowski, chaired several of the most successful teams. When we first met, Walt told me, "We do not exist. We have no charter. We don't have formal rules. We don't get special recognition. And we don't get paid extra for this." Walt's words exemplified many of the attitudes of team members. They were proud of their work and felt that they made meaningful contributions to the company. However, they did not want to feel encumbered by bureaucracy and formality. Most design-build team members professed greater value in doing things than talking about them.

4.2 Background on Process Innovation Teams

The Process Innovation organization was established in February of 1996. Its original charter was to improve the shipbuilding process throughout the yard. The group hoped to examine the overall process as well as its component parts, then optimize the global production effort. Until this time the company's individual projects and divisions had operated by optimizing locally. The establishment of the Process Innovation teams also marked the rollout of the "2X = Full Speed Ahead" program. The 2X program was an initiative designed to cut throughput time in half by increasing process efficiency. While the original charter of the Process Innovation teams was to encompass all production programs at NNS, they have focused primarily on the new Double Eagle container ships. Once established in this area, the teams will begin applying their processes to other programs.

4.2.1 Structure

The Process Innovation teams are organized under the Vice President of Strategy and Process Innovation. There are seven teams that examine different phases of the production process. These are:

1. Quick wins and Measurements
2. Planning and scheduling
3. Design
4. Material sourcing and control
5. Steel fabrication
6. Outfitting
7. Information technology

Each team has a team leader and varying numbers of permanent team members. Other personnel who are not assigned to the division may support the teams on an as-needed basis. The teams are currently involved in about fifty projects. Each project typically draws people from multiple teams, and team members may participate on numerous projects.

The operations of the Process Innovation group is broken into four phases. During Phase I the team leaders and working spaces were chosen. While all team leaders were chosen from within the company, an outside consulting company was retained throughout the program's development to provide assistance and guidance. Once the leaders were chosen, they began recruiting team members. These people also came from within the company. The teams then underwent training on team building and the fundamentals of process innovation. Much of this training was based on the current lean manufacturing theory and involved reading some of the popular literature on the topic.

Most of the team members I interviewed had read or knew of books such as The Machine that Changed the World, Re-engineering the Corporation, and The Goal.

The teams chose office space in the company's main administration building. This allowed all of the teams to be co-located. Additionally, they were close to the company's executives and major administrative functions. On the other hand, this location separated them from engineering, production control, and the waterfront.

During Phase II the teams began studying and mapping the processes they hoped to modify. This involved interviewing the people who do the work and studying the processes. They then identified opportunities for improvement. The teams also benchmarked other companies, including foreign shipbuilders and companies outside of the shipbuilding industry. To maintain the momentum gained during the initial rollout, the teams did "road shows" in which they made presentations to key personnel explaining their goals and methods.

The Process Innovation teams currently are completing Phase III in which they redesign their respective processes. This effort involves analyzing the studies they had made during Phase II and developing improved work methods. Most of the work has been accomplished within the groups with the aid of the outside consultant. During this time the teams have made intermediate improvements in many areas and published them in a "quick wins" newsletter. The newsletter helped keep the 2X program present in the minds of shipyard employees.

Phase IV represents the boldest step in the Process Innovation effort. It is the implementation and transformation stage. During this phase the teams will begin implementing, on a large scale, many of the improvements they had developed. While implementation will be an on-going process, it will require enormous effort by the teams and cooperation from the rest of the yard.

4.2.2 Activities and Accomplishments

A summary of the Process Innovation teams' projects is beyond the scope of this thesis. However, one example, the implementation of a demand-pull system in a steel assembly shop, is significant. The steel fabrication team devised and implemented a kanban system for a production shop that builds a variety of steel shapes. Many of the assemblies are unique or built in very small quantities. The teams determined that it was necessary to sequence the work based on customer demand and then build the assemblies in the sequences. The customer demands were exploded into material requirements. The material was then sequenced at the front end of the process and used when workers got a visual "kanban" signal that it was time to start production.

4.2.3 The Process Innovation subculture

My limited exposure to the teams prevents me from making a thorough investigation of the culture and from forming reliable hypotheses about the shared basic assumptions. However, observations of readily available clues present a fairly strong contrast with the design-build teams.

4.2.3.1 Artifacts

One of the most visible aspects of the 2X program is its ubiquitous logo. There are banners hung throughout the yard, full size advertisements on buses, and a friendly reminder on one's computer screen at log on. During the rollout of the program everyone received sweatshirts, which are still seen throughout the yard. The previously mentioned newsletter also serves as a periodic reminder of the group's influence.

A tour of the groups' working spaces reveal a dynamic environment. The team leaders have small offices shared with some of their members. The walls are covered with charts and diagrams and everyone has a computer. Group meeting spaces are located near the office spaces. These areas are outfitted with flipcharts and whiteboards. They provide a great environment for brainstorming and very dynamic group interaction.

The team members are very enthusiastic about their work. They are typically younger than many of the waterfront workers and do not wear traditional work clothes. Without exception, team members were willing to share their ideas with me and spent a great deal of time explaining their work. Also, team members usually could, produce a document or presentation that covered any topic.

4.2.3.2 Espoused values

Process Innovation members feel that their charter is essential to the survival of the company. However, one senses that the team members often feel unsupported, especially by the rest of the yard. This often leads to a sense of frustration. Team members also indicate a belief that many employees do not recognize the need to improve manufacturing processes. Also, team members have a strong belief in the value of new ideas and technology.

4.3 Conclusion

The two types of teams at NNS exhibit different cultures. The design-build teams emphasize continuous improvement of existing processes. They are more action oriented and rely less on a formal structure to accomplish their objective. While this may enable the teams to react quickly to opportunities, it can prevent pursuit of the most efficient projects.

The 2X teams emphasize innovation over improvement. They are more likely to propose a radical rather than incremental changes of processes. The 2X teams have a much more formal structure and stable team membership. This can lead to greater team performance, but can also inhibit spontaneous thinking. Some argue that membership on a permanent team takes the members away from the operations and they lose touch with current problems. The 2X teams spend more time planning their activities and are much more methodical about their proposals and implementation. Their approach is less appropriate in a fast paced environment.

Both types of teams have advantages and disadvantages. Additionally, each has proven successes and failures. The effectiveness of each can be improved and each can learn from the other.

5. Superlift Design-build team

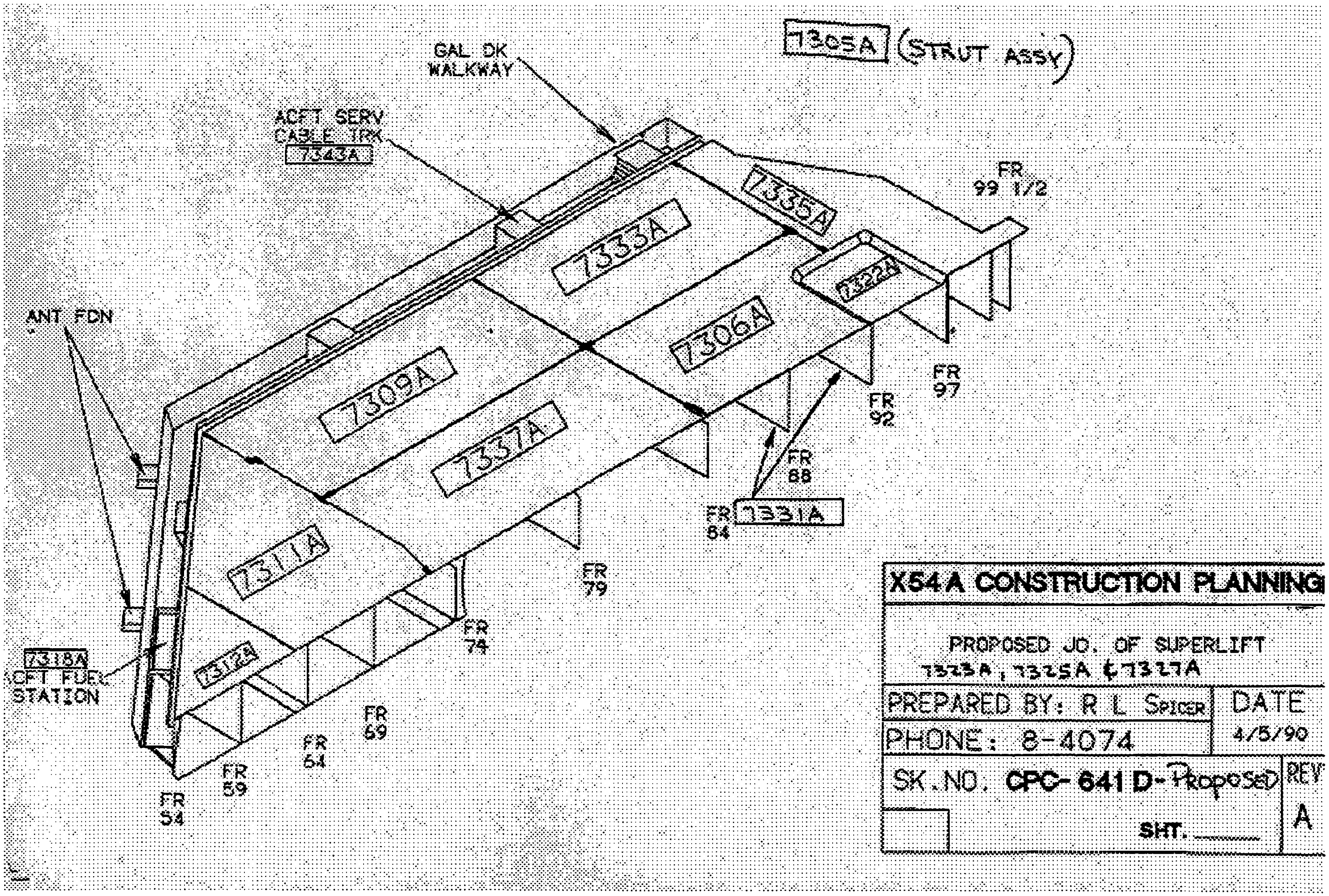
5.0 Introduction

This chapter examines the efforts of a design-build team to increase the outfitting of three superlifts on the next aircraft carrier to be built. Emphasis is placed on the team's ability to systematically solve a complex problem. The superlifts evaluated by the team are significant because of the substantial amount of staging, or scaffolding, currently used to outfit the ship once erection is completed. The efforts of the design-build team are instructive because of the variety of people involved and the need to overcome resistance to the idea by some members. This chapter explores the interactions of the team members, the work done by engineering to validate the final proposal and concludes with a suggested model for future teams.

5.1 Problem statement

Figure 5-1 illustrates superlifts 7323, 7325, and 7327 as a single, joined unit. These superlifts comprise a sponson, or protrusion from the ship's hull. The sponson spans only one level, extending from the flight deck to the level just below it. Inside the sponson are maintenance and office compartments, a weapons storage room, and a machinery room that houses the retraction engine for one of the ship's catapults. Outboard of the sponson is a catwalk that runs the perimeter of the flight deck.

Figure 5-1 Starboard Sponson Superlift



There are numerous antennas, lights, and speakers mounted on the catwalk. Beneath the sponson are some pipe assemblies and a ventilation duct. The underside of the sponson is insulated with a thick rubber mat that is adhered to the steel and painted.

With traditional construction methods, the underside of the three superlifts are fitted with scaffolding, or staged, prior to erection on the ship. The area of the staging is approximately 7500 square feet. Once the erection is complete, the staging is used to install the rubber insulation and to access the pipe assemblies, ventilation duct, and the electrical equipment beneath the catwalk. Once installation is complete, the staging is removed using cranes and portable lifts. The construction superintendent for superlifts proposed installing these items prior to erection and eliminating the staging. This proposal represented two types of cost reduction:

- The direct costs of staging plus the manhours to install and remove it.
- The costs associated with installing the equipment shipboard in cramped quarters rather than dockside at ground level.

There are two major complications with the proposal. First, the insulation must be installed *after* the components inside the sponson are mounted. These components, including machinery, benches, and lockers, are welded to the deck. Any welding done after the insulation is attached will, at best, ruin the adhesive and cause the insulation to fall off, and at worst destroy the insulation layer and possibly cause it to ignite. This means that eliminating the staging requires all inside equipment to be mounted before erecting the superlift.

The second complication is the electrical equipment installed on the catwalk. It too would have to be installed while the superlift is on the platen. While the equipment is weather proof, it is somewhat delicate and would be subjected to the elements and the hazards of a construction environment for over two years.

These complications are exacerbated by the fact that any rework done outside the sponson must be done from portable man-lifts in the absence of installed staging. The potential for eliminating any cost savings through expensive rework is very real.

5.2 The superlift design-build team

Design-build teams are formed for a variety of reasons. Frequently, suggestions generated through the company's Opportunity for Improvement (OFI) program are the impetus for a team's formation. Suggestions are reviewed by appropriate departments for feasibility. Those worth pursuing are often referred to supervisors who frequently work on design-build teams. They, in turn, will establish a team to investigate the proposal further. Alternatively, teams are sometimes formed at the request of a supervisor who wishes to explore a design improvement. The proposal outlined above was initially submitted as an OFI. The suggestion encountered substantial delays in processing, so a team was formed at the request of the initiating construction superintendent. The author was asked to participate on the team as part of his thesis project.

5.2.1 Assembling the team

The first step in assembling the design-build team was gaining familiarity with the project. Next, the construction superintendent identified potential team members. Primary members were foremen from the various trades that would work on the superlifts, representatives from production planning, and engineers. The author's initial role was meeting the team members individually to describe the proposal and get feedback. Without exception, the foremen were always willing to meet and discuss the proposal.

Individual meetings were structured to gather information on feasibility rather than to sell a new idea. This introduction allowed the true experts to give their honest opinion of the proposal.

Neither the concept of increased pre-outfitting nor stage reduction were new to the team members. Previous projects had succeeded in eliminating staging on small areas of the ship. Increased pre-outfitting had been a long-standing objective of the construction division and previous design-build teams. Consequently, the proposal represented incremental improvements very similar to previous projects. However, this project was significant because of its scale and potential for large cost savings. It was also significant because of the high cost of failure.

Most of the foremen would carefully consider the proposal and describe, either on drawings or on the ship, their concerns. Many were optimistic about the proposal, some indifferent, and a few adamantly against it. Additional time was spent with those who opposed the idea in order to understand the difficulties in their jobs and their concerns with the project.

5.2.2 Formal team meetings

Once the individual meetings were complete and many of the issues surrounding the proposal had been discussed, the superintendent called a team meeting. The purpose of the meeting was to discuss the proposal collectively, discuss complications, and work through them. After providing an overview of the proposal, its advantages and cost savings, the construction superintendent opened the meeting to discussion. One foreman who had expressed many reservations presented a memo outlining his concerns. Other group members began to raise concerns, but none offered any solutions. As the number of reservations increased, so did sentiment against the project. The meeting adjourned with a decidedly negative attitude.

The superintendent and the author discussed the issues after the meeting . It was decided that the major problem was the magnitude of the changes suggested. The proposal took the foremen out of their comfort zone and forced them to ensure all work was complete prior to erecting the superlifts. To counter their resistance, each of the raised concerns would be addressed individually. Since many of these concerns involved the technical feasibility of the proposal, the engineering department was consulted on a variety of issues ranging from detailed outfitting requirements to the structural analysis. Of primary concern was the number of electrical components installed on the perimeter of the superlift. The foremen felt that there was a sufficient number to justify delaying installation since there was potential for extensive rework due to damage. A second issue was the location of junction boxes for the electrical components. The Navy wants to minimize the number of splices in the electrical system. When electrical equipment is installed outside the ship, the cables must be connected prior to erection if there will be no staging. However, if there is no junction box nearby, the cable must be coiled and stored inside the superlift until it joined to the ship. Coiled cable sitting on the deck will almost always be damaged during the construction phase. In this case, damaged cable would be very expensive to replace if no staging were available. The engineers' analysis revealed that there were actually few components on the catwalk and only one component did not connect to a junction box inside the superlift.

A third issue was the structural connections between the three superlifts. Since the superlifts were lifted to the ship individually and had to be welded together, staging was required beneath the erection breaks. The superintendent felt that the two smaller superlifts could be joined on the platen. This would eliminate one erection break, the need for associated scaffolding, and allow more pre-outfitting to take place around the break area.

These findings were presented to those who had expressed reservations. They agreed that some of the problems were not as serious as they originally believed. They maintained however, that they were uncomfortable with the idea.

The superintendent called a second meeting and invited the engineers and production planners who worked to combine the superlifts to answer any questions about their findings. The superintendent opened the second meeting by reviewing the proposal. Next, the author presented cost benefits and the recent findings of the engineers and production planners. Since the modified proposal was presented as less radical, team members began to express optimism. Most agreed that the proposal was feasible and that it would result in significant time and money savings if successful. Further, in light of the compressed construction schedule, everyone felt that it was most beneficial to maximize the pre-outfitting. With everyone in agreement that the proposal was worth pursuing, the production planning supervisor outlined the next steps to be taken by his organization. The superintendent adjourned the meeting with the recommendation that the proposal be implemented. He added that there were other areas of the ship that could benefit from increased pre-outfitting and that the group should reconvene later to address these opportunities.

5.2.3 Implementation

With the construction of these superlifts still five years away, the next steps involved planning and engineering the changes. The process began in the production planning group where a proposal for the combined superlifts was drafted and sent to engineering. The proposal was evaluated for both weight and distortion limits. After the structural modification was approved, production planning unlinked material and work items that were grouped with the original superlifts. Then the material and other work items were grouped with the new, larger superlift. While the finished product remains the same, much of the grouping will change because more work can now be accomplished on the platen. For instance, equipment and structures that spanned the break between the two smaller superlifts could now be installed while on the platen. This unplanned benefit of the original proposal will yield some cost savings. For example, joining the two smaller units into one on the deck is much easier and cost effective than joining them together on the ship. Also, since one erection break was eliminated, the amount of potential pre-outfitting also increased. This also increased the construction cost effectiveness.

The proposal for the new superlift and its associated material will be sent to engineering where new drawings will be created. Next, detail planners will determine the exact work steps that must take place during the construction phase and the manufacturing phase. A detailed bill of material will be drafted and then work packages for both the manufacturing and construction phases will be developed.

The proposed changes to the structure will then be complete and the information will be stored within the company's files until construction begins. At that time material will be sourced and work packages for the manufacturing phase will be issued to initiate production. Once the sub-assemblies come out of the fabrication shop, they will be joined into the new superlift on the platen. Materials required for pre-outfitting will be available in the supply system and can be installed prior to the unit's erection on the ship.

5.3 Summary

Execution of this design-build team's proposal will not occur until sometime in 1999. There is good reason to believe that more changes will be made to ship's design and build strategy before that time. Consequently, it is difficult to quantify cost benefits resulting from the teams' efforts. Several estimates of savings resulting from eliminating the staging were used in the analysis of the proposal and are shown in the table below.

		Amount	Unit Cost	Total Cost
Material	stage boards	7500 ft	3.06	22,950
	spauls	800 ft	4.15	3,320
Labor	installation	320 hrs	40.00	12,800
	removal	600 hrs	40.00	24,000
TOTAL				$63,070

These figures do not include the use of a forklift and operator for two weeks during installation and a crane and operator for three weeks during removal. Additionally, one cannot accurately estimate the savings resulting from work being completed more efficiently on the platen than on the ship. A rule-of-thumb used within NNS is work that takes one manhour in the shop will take three hours on the platen or eight hours in the ship. Accordingly, one could predict a sixty-two percent savings on labor performed on the platen that would have normally be done shipboard. Finally, the proposal will reduce the time needed to complete the ship's construction. It is difficult to estimate this benefit as well. However, it is clear that one of NNS's major concerns is cycle time reduction so that drydock and platen can be used for other contracts, notably the Double Eagle tankers.

5.4 Conclusions

While the project was successfully implemented and should result in reasonable cost savings, it is not clear that the team was truly a success. Two factors standout as possible short-comings. First, the project was one originated by a construction superintendent in an area familiar to him. While no one would dispute that the superintendent's forty years of shipbuilding experience enabled him to identify potential areas for improvement, it is not clear that this project generated the greatest return on investment. The total cost savings will probably exceed $100,000 but this is actually a very small percentage of a $4 billion contract.

The second short-coming was the team's methods for achieving their goal. This team, as do many process improvement teams, focused on incremental rather than radical change. Increased pre-outfitting and, to some extent, stage reduction, has long been an improvement objective at NNS. The team took these efforts to a higher level. This is not meant to downplay their purpose, but merely to point out that they did not question their usual construction procedures.

This design-build team clearly exhibited the four traits of Model I behavior described in earlier chapters. First, they operated under long-standing assumptions about their work. By not challenging these assumptions, they limited the possibility of finding a break-through innovation. Second, team members defined individual goals and tried to achieve them. Clearly, the construction superintendent wanted to see the project implemented because it would result in large cost and time savings. Team members also wanted to realize cost savings, but were additionally concerned about their individual bottom lines. It became evident that some team members had serious reservations about the proposal, not because of the impact of failure on the company, but on them. Interestingly, those most opposed to the idea were typically involved in the final or finishing work. The author speculates that the compounding effect of slipped schedules and uncompleted work items would most adversely affect those in the final stages of construction. Consequently, they would experience the greatest cost overruns due to excessive overtime and rework.

Team members never explained their reservations this way. Rather, they presented logical arguments against the proposal. These typically concerned the project's overall disadvantages and dangers rather than those encountered by a single group. This is a third characteristic of Model I behavior, in which participants emphasize rationality. Noteworthy is the response of the construction superintendent and author. They countered every argument with facts from engineering and design, thus maintaining their own rationality. At no time during the team or individual meetings did anyone attempt to understand the true concerns or interests of other team members.

Finally, team members attempted to minimize expressing negative feelings. While the project was very unpopular with certain people, the meetings never turned ugly. Each person presented logical arguments for and against the proposal, but never attempted to lay any personal blame. Without exception, those who opposed the plan always concluded by stating that in the event it was approved, they would support it completely.

Leadership theory postulates four responses to change: resistance, compliance, commitment, and internalization.[13] Ideally, team leaders would like to move members to the commitment or internalization stage. It is clear that some members of this design-build team did not reach that stage, while some did become committed to the plan and worked hard to see it succeed. Others at best only complied with its implementation.

In summary, the group achieved the stated goals of its leader, but did not develop into a high performance team. It clearly remained at a level of incremental improvement and Model I behavior. However, these impediments did not prevent it from making contributions to the company's productivity. But, one can argue that the contributions were not as great as they could have been.

5.5 A model for future design-build teams

The following suggestions are presented as a means of increasing the effectiveness of design-build teams in aircraft carrier construction. Some of these are already in place on other design-build teams and some of the Process Innovation teams. These proposals could also be useful in other areas of process improvement within the company.

Establish a methodology for evaluating project benefits. The OFI system is useful for collecting ideas for process improvement. These proposals are evaluated and screened for feasibility. It was not clear to the author that they were ranked by payback to ensure those projects with the greatest return were pursued most aggressively.

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[13] Adapted from Yukl (1989) Leadership in Organizations, Prentice-Hall: Englewood Cliffs, NJ, pg. 44.

Develop a repository of proposals. The OFI system maintains submissions on file. Projects pursued outside of the OFI system are not tracked, however. Additionally, there does not seem to be a system of recording proposals examined and rejected by design build teams as unfeasible . For example, one team examined the reconfiguration and pre-outfitting of several weapons elevators, only one of which was ultimately modified. There is no accessible database of such rejections outside of minutes of team meetings and the knowledge held by participating members. One can be certain that some proposals are tried multiple times because initiators are unaware of previous attempts.

Develop a more formal structure for teams. This could include regular team membership, publicized minutes of meetings, and recognition for successes and attempts. Although the less formal nature of the teams is often a strength because members feel less constrained, they lose some efficiencies by not structuring their activities more. Also, more publicity of their actions would increase high-level interest and possibly gain more support for their efforts.

Emphasize better team dynamics. The author does not suggest that all teams should strive for Model II behavior, as there are many instances when questioning underlying assumptions can be counter-productive, especially on more basic tasks. However, some design-build teams have succeeded in developing innovative improvements that clearly changed the construction process. An excellent example is the adoption of stud welding. It would be useful for design-build teams to carefully consider their objectives before deciding on a solution. More important, teams should attempt to develop more open attitudes about the proposals and solutions. As the superlift design-build team example shows, there was significant resistance to the proposal, but no one ever shared their true reasons for resistance. Such openness does not occur naturally. Effective team dynamics is the responsibility of its leader. This person should emphasize team learning and evaluation of individual incentives in addition to reaching an agreeable solution.

These suggestions will not make all design-build teams successes. Nor will they be easy to implement. However, they can make the already successful efforts of design-build teams at NNS even more effective.

6. SPF Process Innovation team

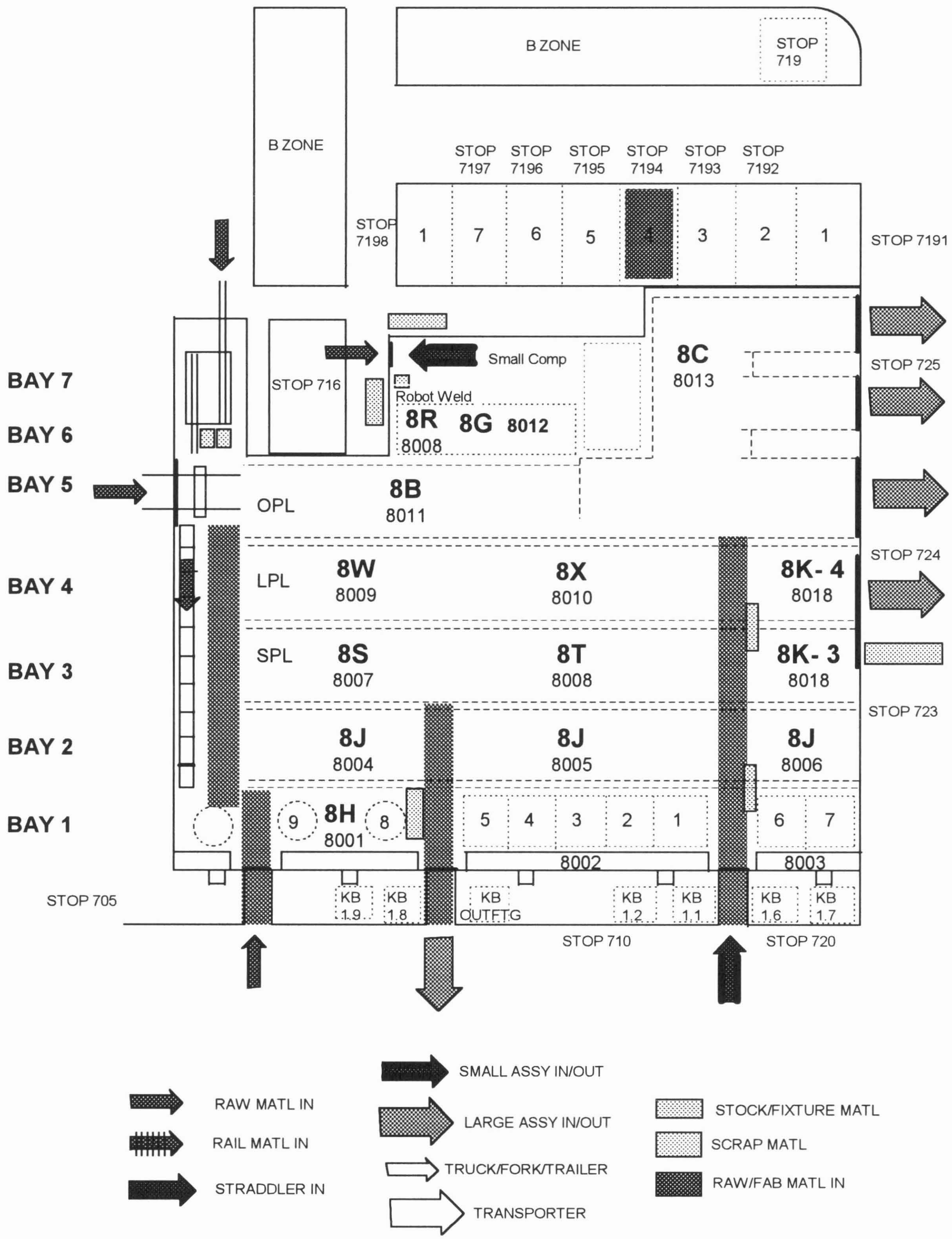
6.0 Introduction

This chapter explores the efforts of the Manufacturing Process Innovation team to implement demand-based manufacturing in the Steel Production Facility (SPF). The team's efforts are significant for two reasons. First, it was one of the first 2X teams to enter the implementation phase and did so in one of the company's major functional areas. Second, demand-based manufacturing represented a radical change from the SPF's traditional production methods. This chapter provides background on the SPF, its production record and the 2X team's proposals for changing production methods. The interactions between the team and SPF personnel and some preliminary results from the pilot program are also presented. The chapter concludes with some observations about the team's ability to implement change and some recommendations for future team initiatives.

6.1 Problem Statement

Figure 6-1 illustrates a plan view of the SPF. The 2X team's initial focus was on Bay 1, shown at the bottom of the schematic. This part of the SPF builds *base groups* using steel plate and *webs* supplied by the fabrication shop. Historically, the base groups were completely assembled at one of five stations. The build sequence and schedule were set forth by the Group and Index Scheduling system, GIS. The SPF and upstream manufacturing operations worked in accordance to it. Completed base groups were sent to the platen or the blast and coat facility for priming.

Figure 6-1 Steel Production Facility



Source: Dean Major, Process Innovation Team, Newport News Shipbuilding, unpublished. 1996

Using these procedures, the five stations frequently were blocked due to downstream delays and a queue of materials formed at the beginning of the manufacturing stage. Second, seldom did all upstream suppliers work in accordance to the GIS and the flow of material was erratic. Often there would be a surplus of one item and none of others. In an interesting quirk of the GIS and the company's measurement system, an upstream supplier could have days of WIP waiting in front of a blocked downstream process and still be considered delinquent in its deliveries according to the GIS. Consequently, the upstream process would continue to produce at its normal rate although the material could not be used. This inevitably led to excess WIP, extra tracking and control efforts, and sometimes damaged or lost material.

It is also significant to note that different materials were used different base groups. Therefore, when material was called for, shop personnel had to locate the exact piece that had been fabricated for the job. Additionally, the enormous size and weight of the parts made sifting through material and pulling it from inventory a time consuming and expensive effort.

The 2X team analyzed the manufacturing process and proposed two broad changes. The first was to change to an assembly line system within Bay 1. This meant moving each base group through all five stations sequentially. While the projected cycle time for a base group remained approximately the same, it was hoped that the flow of assemblies would lead to steadier work and eliminate blocked stations. The second change was the implementation of a kanban system to feed material to the stations. Kanbans had already been implemented on the web line, the upstream supplier of webs to the SPF. Now, kanbans would also be used to control the flow of material between the Fab Shop and the SPF. It was hoped that this would reduce WIP and eliminate lost material.

6.2 The SPF Process Innovation team

The SPF team consisted of members from the Steel Fabrication 2X Team, the Measurements 2X Team, external consultants, and personnel from the SPF. Some of the team members had been working in the Fabrication Shop, an upstream supplier to the SPF, which had recently implemented a kanban system. The Steel Fabrication 2X team was implementing Demand Based Manufacturing (DBM) sequentially throughout the steel production process. The Fab Shop built *webs* for the SPF to use in base groups. The implementation of the demand-based manufacturing in the SPF would help stabilize demand and strengthen the performance of the Fab Shop. Conversely, a reliable source of webs would strengthen the performance of the SPF.

The SPF team moved its offices from the company's administrative building to the factory floor. There they could directly observe the plant layout and daily operations. Additionally, they had immediate access to the employees that would be responsible for implementing the new procedures. The team worked in a single large room that had an adjoining conference room. The office was outfitted with several computers and printers. The walls were covered with drawings and production breakdowns. These breakdowns were used to develop production lists that would later establish a manufacturing sequence.

The team worked full time in the SPF offices. Since they were all involved in multiple projects, they often left to attend meetings in other parts of the yard. The team held weekly meetings to evaluate their progress on the SPF project.

6.3 Objectives and Procedures

The primary thrust of the 2X team's efforts was to deliver base groups to the construction divisions on time, with minimum variability. While the SPF had long been seen as a bottleneck in the ship production sequence, the team felt that there was sufficient capacity if production throughput were optimized.

Development and implementation of demand-based manufacturing within the SPF followed two parallel paths. The first of these was the development of a material pull system for the shop. The second was creating a training procedure for employees. The team began developing ideas for the pull system first. However, since their work required inputs from shop personnel, it soon became apparent that they would need to indoctrinate them into demand-based manufacturing in order to convince them of the need to cooperate.

6.3.1 Training

Members of the 2X team used three methods of introducing demand-based manufacturing to shop employees. The first was individual and group rollout meetings. These meetings were an opportunity to introduce the ideas of a pull system to supervisors and above. Perhaps the biggest obstacle during these meetings was overcoming mental models about production scheduling. The GIS system was so firmly ingrained, it became difficult to convince people that work could be done any other way. Sometimes employees would raise questions that made it apparent that they were trying to fit demand-based manufacturing within a build-to-schedule framework. In order to overcome these obstacles team members began by discussing the fundamental precepts of a push system and then contrasted them with a pull system.

A second training method was the use of simulations. Outside consultants who assisted in the development and implementation of the system ran structured training sessions for small groups. These training sessions involved two simulations. The first demonstrated the impact of variability. This demonstration was identical to the matchstick game in The Goal[14]. Employees were introduced to the idea that average throughput of individual processes do not accurately represent the throughput of a system, especially if variability was high.

The second simulation involved building small plastic components that had numerous variations. During the base case, components were built according to a schedule. Because of unequal cycle times for each step, there was excess WIP at some processes, and stockouts at others. Additionally, since each step produced to a schedule in preset batch sizes, the unequal process times led to misalignment of components at final assembly. Components needed for a process were unavailable even though other varieties were available in abundance. Then production system was reconfigured as a demand-based system. Participants created kanbans at each process to hold one unit of each variety. Production occurred as needed and was driven by the demand at the final step. The pace, or *takt*, of the process was set and limited by the cycle time of the slowest process. The reconfiguration resulted in higher throughput, no stockouts, and lower WIP.

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[14] Eliyahu M. Goldratt, The Goal (Great Barrington: North River Press, 1992), 104.

Because of the small group size for these simulations, participation was limited to supervisors. The simulations were very effective in illustrating some of the problems associated with push-type manufacturing processes. Participants could relate to many of the problems encountered. Unfortunately, when asked about the relevance of the reconfigured production system many felt that it would work in other types of manufacturing, but not shipbuilding. Others, however believed that such a system could be implemented with some modifications.

The third training tool used was a demand-based manufacturing implementation manual. This manual, developed internally, was intended for use by all employees involved in the demand-based manufacturing system. It set forth in clear and concise terms the fundamental concepts of a pull system. Definitions of key terms and important concepts are highlighted in callout boxes. The manual provides step by step guidelines for developing and implementing a demand-based manufacturing system within a small processing unit. Employees are not expected to develop a system themselves. Rather, they are to participate in the development under the guidance of a core project team that has the necessary skills and experience.

Using this three-pronged approach, the 2X team was able to introduce the ideas of demand-based manufacturing first to shop superintendents. They in turn brought in supervisors most likely to understand and support the new program. With this core group in place, the 2X team began to formulate plans for a demand-based manufacturing system within a particular shop.

6.3.2 Development

The first and greatest challenge in implementing demand-based manufacturing in the steel production facility was the development of an alternative to the GIS. Given the ubiquity of the GIS and its interactions with all other functions within the shipyard, the team decided to develop a complementary system rather than a replacement. The key elements of a successful demand-based manufacturing system in this type of environment is an accurate and complete production *sequence*. A sequence differs from a *schedule* in that it dictates only what will be made and in what order, not when. A demand-based manufacturing system reacts well to changes in a schedule, but poorly to a change in sequence. This is because the sequence determines what resources and processes will be needed in production. The schedule is not really necessary since the timing is set by the pull of material through the kanbans. Consequently, an unchanging sequence is shifted easily through time (provided materials are available) to meet customers' demand.

Development of a sequence began with the GIS. Team members, with the aid of employees from the SPF and downstream processes, determined the delivery sequence of the base groups to the construction stage. Working backwards, each base group was broken down into component parts in the order they were needed. If necessary, these parts were further broken down until a complete list of production, in the order it was required, was developed. **Figure 6-2** illustrates a sample sequence list. These lists were developed and manipulated in MS Excel. While this software may not have been the optimal choice for this type of work, it was widely used throughout the yard and enabled employees to develop and use the list without learning new software.

Figure 6-2 Sample Sequence List

Actual Shop	Hull	Group	GIS Description (Abbr.)	Number of	Web Sub Assy's
10/21/96	649	1501D-7	Floors Pre-Assy IWO Centerline	14	
	649	1401D-	Brackets for Transverse Webs IWO	24	For 1401D-
10/21/96	649	1401D-3	Transverse Webs at FRS59,60,61,62	8	
10/21/96	649	1401D-9	Transverse Webs IWO Stool FRS 62.5	4	
	649	1402D-	Brackets for Transverse Web IWO	24	For 1402D-
10/21/96	649	1402D-3	Transverse Webs at FRS59,60,61,62	8	
10/21/96	649	1402D-9	Transverse Webs IWO Stool FRS 62.5	4	
10/21/96	649	1901D-	Frames 101-105 P/A	6	
10/21/96	649	1901D-	Frames 101-105 P/A	10	
10/21/96	649	1901D-	Breasthooks 21-23, 25-27 P/A	16	
	649	1601D-	Brackets for Transverse Web IWO	24	For 1601D-
10/25/96	649	1601D-7	Pre-Assemble Floors	14	
	649	1501D-	Brackets for Transverse Web IWO	24	For 1501D-
10/28/96	649	1501D-3	Transverse Webs at FRS64,65,66,67	8	
10/28/96	649	1501D-9	Transverse Webs IWO Stool FRS 67.5	4	
	649	1502D-	Brackets for Transverse Web IWO	24	For 1502D-
10/28/96	649	1502D-3	Transverse Webs at FRS64,65,66,67	8	
10/28/96	649	1502D-9	Transverse Webs IWO Stool FRS 67.5	4	
10/28/96	649	1001D-3	Transv Frames Betn 13050 LVL	31	
10/28/96	649	1001D-5	Tranv Frames AP To FR 12 Below	33	
11/1/96	649	1601D-3	Transverse Webs	8	

The critical success factor of the new pull system was strict adherence to the production sequence. The 2X team required that downstream operations deliver forecast requirements for two, four, and six week periods. While the forecasts could be changed, every effort was made to lock in the two-week sequence. This required strict discipline from an organization that frequently shifted production plans and expedited. However, it's important to note that this discipline was a critical first step in driving out much of the variability within the shipbuilding process.

With a sequence list in place, the team set out to link production steps that were geographically separate. This linkage was accomplished with kanbans. Unlike some kanban systems that rely on cards or tickets to transfer information to upstream processes, the system at NNS used physical storage locations. The storage points were large to accommodate the product's size. An empty kanban triggered production by the process immediately upstream from it.

Material was transported between some processes on pallets. Large transporters carried the pallets between manufacturing units and to the construction zone. Historically, the transporters were called when needed and they delivered the material to an open space near the next production process. Under the new system, pallets of material to be transported were always placed in a well-defined location (a kanban). When the production order was filled, a visual signal, usually a sign, informed transporter drivers that the pallet was ready for delivery. The pallet also indicated the exact location for delivery, which was also a kanban. Material transport therefore had two pre-requisites. First, a supply kanban required a complete pallet of material. Second, a demand kanban had to be empty, signaling impending need for the material.

Because each component was unique, and extremely large, loading the pallets was a non-trivial task. Pallets, when delivered to a process, required the first item to be on top of the stack. Consequently, the upstream production unit built and loaded the last item first. This reverse sequencing could be repeated further upstream if the material went through several steps. Again, successful operation of the system required strict adherence to the build sequence.

In summary, the demand-based manufacturing plan proposed by the 2X team was simple and elegant. It linked geographically separate manufacturing processes by means of visual cues. These cues and the production sequence were designed to be easy to use and understand. Employees unfamiliar with the concepts of demand-based manufacturing could quickly and easily adapt to the system. With their training and operating procedures in place, the 2X team began developing an implementation strategy.

6.3.3 Implementation

Implementation of demand-based manufacturing in the SPF began on January 6, 1997, after the author's departure. However, during the preceding months the team members spent a great deal of time laying the necessary ground work for a successful rollout. The 2X team methodically laid out timelines using MS Project. These schedules outline the necessary development and training items including identifying process steps and capacities, developing a sequence list and conducting training sessions. While the team experienced numerous setbacks and obstacles, two are significant from the author's perspective.

The first is the lack of computer skills by many NNS employees. 2X team members are very capable computer users. However, many employees were not familiar with basic word processing and spreadsheet programs. This created problems for the team because they could not expect to get accurate sequence lists in standard format from those who had the information. Consequently, the team members had to do much of the list development themselves using raw data. Since the team members were not as familiar with the manufacturing process, they frequently had to consult with employees from the manufacturing shops for clarification.

As mentioned in earlier chapters, resistance to some technologies is a characteristic of some parts of the shipyard. It is not clear whether the lack of computer skills resulted from resistance to learning them or a lack of learning opportunities. It is not true that all employees lacked basic computer skills. Many, in fact, had extensive skills. It was evident however, that the lack of skills in the areas of concern to the 2X team hindered their effectiveness.

The second and greater obstacle was the "not invented here" syndrome. Because the SPF and the rest of the shipyard had always operated under a push system, the pull system proposal was met with much skepticism. Employees, convinced that manufacturing ship components was unlike other manufacturing, did not believe that a pull system would work in their company. Unfortunately, this attitude existed not only at low levels. Higher level managers frequently expressed skepticism in the new methods. The SPF, they explained, had turned out ample steel during NNS's peak production years. The installation of new robotic lines had not increased output as expected. In fact, many felt that the SPF's capacity had been reduced. To them, this demand-based manufacturing system was just another hyped-up fad that would have little positive effect. Instead, many shop personnel wished for the old methods that kept the lines running at full capacity. While more traditional methods had turned out more gross tonnage, it is not clear that the cost per ton was less. There is some speculation that efficiency was still low but high volumes allowed it to be discounted.

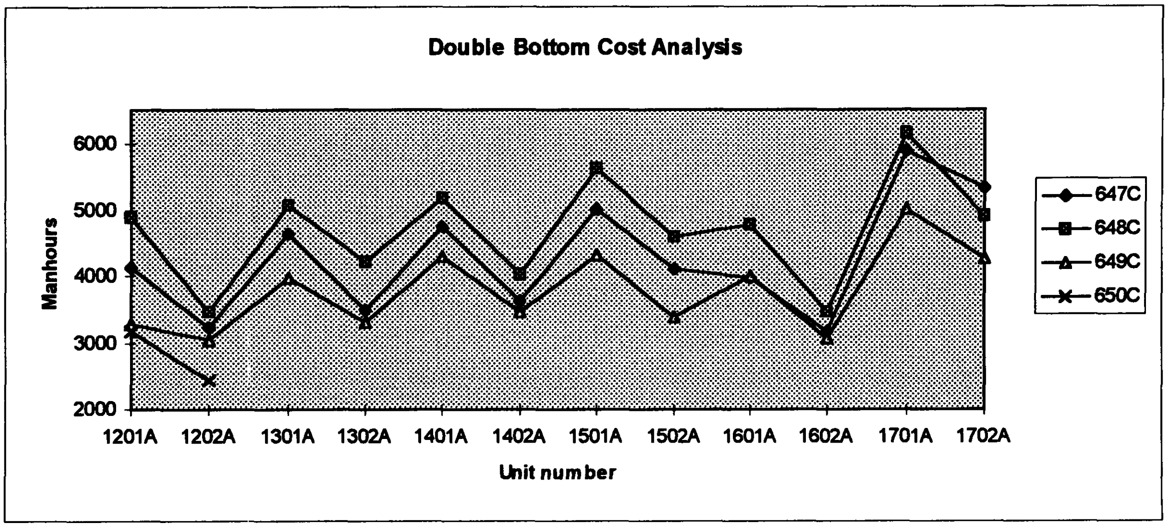
The 2X team seems to have dealt with the second obstacle rather well. They managed to get high level support for a pilot program in the fabrication shop and then in the SPF. Team members formed a core group of superintendents and supervisors that understood and appreciated the benefits of demand-based manufacturing. The training, development, and implementation phases were carefully planned and methodically executed. Finally, the team gained credibility through the "show me" test. The pilot in the Fab Shop began improving delivery time and quality very quickly. Since the Fab Shop fed the SPF, it provided a stable platform from which to launch subsequent demand-based manufacturing programs in downstream operations.

An important, but often overlooked, team activity was regular status meetings with management. By keeping management appraised of the team's progress and successes, they were to maintain momentum for further expansion. The visibility of the team and its programs began to convince employees that Process Innovation was not just a passing fad.

6.4 Results

Since demand-based manufacturing rollout in the SPF began just recently, there is little data on its long-term effectiveness. However, preliminary results indicate measurable improvements. **Figure 6-3** below illustrates the decreased manhours used for twelve identical units from the first four Double Eagle tankers. Demand-based manufacturing was not in place during the fabrication of Hulls 647C and 648C. These hulls have higher manhour requirements for equivalent base unit construction. Demand-based manufacturing was implemented during the construction of Hull 649C and significant manhour reductions were realized. The average percent decrease in manhours in Hull 649C over 648C is 19%.

Figure 6-3 Manhours for Selected Double Bottom Units



6.5 Conclusions

The 2X team's approach to change is dramatically different from that of the design-build team. Several differences warrant special attention. First, the team proposed radical rather than incremental change. This means challenging long-standing assumptions about manufacturing, namely building to a schedule rather than to demand. This challenging of assumptions is characteristic of the Model II learning organization described in Chapter 3. Implementing radical change is typically more difficult and frequently more risky, but the payoffs can be greater.

Second, the 2X teams used more of a top-down approach. The team was sponsored at the corporate level and could command a certain amount of compliance. The team's high level gave it the ability to survey possible areas for improvement. Team members worked on the project full-time and had the necessary resources to develop and implement a comprehensive plan.

There were certain elements that limited the team's success. First, because of their high level, they were often perceived as outsiders by shop personnel. The team sought to alleviate this by moving their offices to the factory floor. Also, since they brought in ideas developed outside the shipyard, they encountered the "not invented here" syndrome. This problem was exacerbated by the fact that many of the demand-based manufacturing methodologies were developed for more traditional types of manufacturing. Employees frequently reacted very negatively to the idea that concepts developed for automobile manufacturers could be adapted for use in the shipyard.

The 2X team countered skepticism in two ways. First the training and simulations demonstrated that many of the problems demand-based manufacturing was designed to eliminate were identical to those encountered at NNS. It followed then that demand-based manufacturing might also provide similar solutions. More significant, however, the team targeted a high potential area for a pilot program. By making improvements in that area, the team was able to gain converts from the ranks of skeptical employees and establish a beachhead for subsequent implementation.

The 2X team was able to build on its success and those of other Process Innovation teams by recording and publishing their activities. By meeting frequently and discussing problems and solutions as well as successes and failures, the teams developed a semi-formal repository of ideas and methodologies for implementing change. These efforts contributed to the creation of a learning organization that could build on past successes and avoid previous pitfalls.

In summary, the 2X team successfully implemented a significant change in one of the shipyard's most troubled units. They accomplished this change by challenging long-standing assumptions by carefully developing a training and implementation plan to make the change manageable for the affected parties.

7. Conclusions and Recommendations

7.0 Cross-functional teams

Cross-functional teams have demonstrated the ability to innovate and improve manufacturing processes at Newport News Shipbuilding. More significant, they have been important instruments of change in an industry experiencing significant increases in competition. Design-build teams are informal, transient teams that focus their attentions on a specific project rather than a process. Their bottom-up approach is useful in gaining grassroots support. Additionally, since team members come from the operating ranks, their familiarity with the project and level of experience are tremendous. These teams often lack high-level guidance, but have nevertheless been successful in implementing significant changes in the construction process.

The Process Innovation teams are much more formal. They tend to focus on broad processes that encompass several projects. Their top-down approach helps them identify projects with the greatest returns. Unfortunately, since they are sometimes seen as outsiders by the company's rank and file, their suggestions are often not well received. However, their high-level support and structured operating methods have enabled them to enjoy several successes.

These teams have one important factor in common. Both teams are constrained by a common corporate culture. This culture has positive and negative aspects. The teams' success and effectiveness depend on their ability to recognize, adapt to, or change these cultural constraints. I found that my analysis of these two teams offered important insights because they illustrate many characteristics of the corporate culture and highlight some of the limitations it imposes.

Paramount is the fact that *effectiveness may be limited by preconceived ideas about solutions*. Too often problems are viewed through the lens of previous dilemmas. Similarly, the solution is seen as a variation of an earlier course of action. For cross-functional teams to have real impact on construction effectiveness, they must be able to develop innovative solutions to ever-changing problems. This in turn may require rethinking many of their assumptions about the shipbuilding process.

One important assumption that deserves consideration is that shipbuilding is not like other manufacturing. A recent study by the National Shipbuilding Research Program noted that:

> If we truly intend to attain World Class Throughput, our yards must *manufacture ships*. Design for manufacture, Engineer for manufacture, Plan for manufacture, Procure for manufacture, and Facilitate for manufacture; dedicating total yard systems to this end. Do we build ships, construct ships, or manufacture ship? World class shipbuilding manufactures ships.[15]

Aircraft carriers will never be mass produced like razor blades. This does not mean that a shipyard cannot learn valuable techniques from the automobile or aircraft industry. The tendency for employees to dismiss a methodology because it comes from a non-shipbuilding industry limits the range of possible solutions. A cross-functional team that explores alternatives different from any previously tried will increase the chance of finding real productivity breakthroughs.

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[15] National Shipbuilding Research Program. Investigate Methods of Improving Production Throughput in a Shipyard (Washington: US Department of the Navy, 1995), 8.

A second obstacle is the resistance to new technologies. This refers primarily to the lack of widespread use of computers, but other examples exist. That computer usage increases productivity is not necessarily clear. There is some evidence that productivity does not increase because people spend more time playing on their machines or working for perfection because it is easy to continue fine-tuning a product. However, there are many cases where basic word processing and spreadsheet skills can greatly simplify daily tasks. Electronic mail is another area where efficiency and productivity can be enhanced. No one would consider operating a shipyard without a phone system, yet electronic mail is somehow perceived by many employees as an unnecessary and insignificant means of communication.

Downsizing during the last decade may have decreased the proportion of computer literate employees at NNS. However, the company maintains a comprehensive computer training program for most anyone interested. There seems to be little interest in acquiring these skills. As long at those skills are perceived as unimportant by supervisors, this is unlikely to change.

The *learning organization* is a model popularized by Peter Senge and others. Fundamentally, a learning organization is one that values new ideas, technologies and methodologies as much as experience and tenure. Experience counts for much at NNS, and there is good reason for this. The long cycle time of the product requires a person to work in a position for several years before he or she can see its different aspects. However, should experience eclipse the ability to develop new methods, a firm is destined to fall behind in its innovations.

The key element in each of these points is leadership. Fundamentally, management is about the status quo. Leadership is about change. The successes of various design-build teams and Process Innovation teams depended on their leadership. Those teams that challenged the *status quo* did so because of their leaders. The less successful teams usually were content to work within the boundaries of existing assumptions and achieved only incremental improvement, it any. However, it is important to note that leadership means more that pushing through a new idea. True leadership means changing attitudes so that innovation is not only accepted, but actively sought.

7.1 Recommendations

Previous chapters have outlined some recommendations for improving design-build teams and the Process Innovation teams. A final suggestion is closer interaction between the two. One significant shortcoming of the Process Innovation teams is the lack, actual or perceived, of expertise by some members. Design-build team members typically have the necessary expertise, but lack the structure and guidance to pursue the high-return projects. This usually means focusing on a particular problem rather than addressing the larger process. Joint efforts where the Process Innovation organization is able to identify areas for improvement and then solicit the expert advice of a design-build team would probably return greater benefits than the individual efforts of either party. Such a symbiotic relationship will not occur naturally. Again, the key element will be leadership. Someone must initiate a combination. Further, direction of the team will require the skills of a team leader that is able to understand the interests of all parties and develop a solid working relationship.

A suggested starting point is the final assembly platen. Pre-outfitting on the platen is the link between manufacturing and construction phases of shipbuilding. Additionally, it connects the major internal suppliers; material, planning, and engineering[16]. This makes it an ideal location for cross-functional teams to develop production innovations. Design-build teams currently investigate many projects on the platen. The Steel Fabrication process innovation team is involved in transforming the SPF, the platen's primary supplier. It is a natural extension to begin integrating cross-functional teams in this area. Significant gains can be made by implementing a design for manufacturability program where platen workers help determine optimum base group configuration. Conversely, inputs from the platen will enable the SPF to better plan its production requirement and schedule. This will lead to more reliable deliveries of material from the SPF to its customer.

7.1.1 Culture

NNS is in the midst of major change. The recent spin-off and the re-entry into the commercial market have placed tremendous stresses on the company. Simultaneously, the company is attempting to transform itself into a world-class shipbuilder; moving beyond its historic status as a builder of top-quality ships for a limited naval market. Despite all of the attention paid to the transformation, one item may be overlooked. A company's culture is the primary determinant in the success of any transformation attempt. Too often firms consider new methods, technologies, organization structures, incentive plans, and training programs as the key to successful change. Few consider the impact of acceptance and rejection by employees.

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[16] Ibid., 39

John Kotter stated in a recent article that "change sticks when it becomes 'the way we do things around here.'"[17] Any firm hoping to transform itself must make new mental models a fundamental part of its culture. In other words, it must replace its current shared basic assumptions with new ones that reflect the desired operating modes. This requires strong leadership over a period of several years. Schein outlines the critical roles of a leader managing change:

1. Perceive accurately and in depth what is happening in the environment.
2. Create enough disconfirming information to motivate the organization to change without creating too much anxiety.
3. Provide psychological safety by either providing a vision of how to change and in what direction, or by creating a process of visioning that allows the organization itself to find a path.
4. Acknowledge uncertainty.
5. Embrace errors in the learning process as inevitable and desirable.
6. Manage all phases of the change process, especially the management of anxiety as some cultural assumptions are given up and new learning begins.[18]

Although these roles are normally assumed to belong to a firm's senior management, they can be applicable at a lower level. The author believes these are important functions of any successful cross-functional team leader. Teams, either design-build or Process Innovation, depend on the effectiveness of their leadership. The choice of a team leader should not be taken lightly. While experience and tenure are important when making design or process changes, the ability of a team leader to think proactively, promote innovation, and manage uncertainty and risk are perhaps more essential. Team leaders

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[17] John P. Kotter. "Leading Change: Why Transformation Efforts Fail," Harvard Business Review (March-April 1995): 67.

should be selected based on their ability to contribute to company's transformation to world class status. Those who promote the *status quo* are not leaders and have no place directing the efforts of the company's cross-functional teams.

[18] Schein, 385

Appendix A: Computer Simulations of the SPF

Introduction

Prior to creation of the Process Innovation teams, NNS was involved in computer modeling of its facilities to estimate capacity. This work was conducted by a small group of industrial engineers using the ProModel software. Over a period of two years the group developed several models of increasing complexity. Using data from some industrial engineering analyses, they modeled all of the major manufacturing centers including individual machines and processes. Despite its thoroughness, the model was not very useful as a planning tool because it did not capture much of the uncertainty surrounding the shipbuilding process. Events such as schedule changes, shutdowns for inclement weather, and material shortages could not be accurately represented by the computer. However, the model was useful as a descriptor of some of the dynamics of the manufacturing process. Most notably, it could help identify some capacity constraints.

Unfortunately, the model was never widely used outside of the industrial engineering department. Its complexity, including modeling of stochastic processes, was sometimes too technical for use in management decision-making.

The model was used by the 2X team as it prepared to develop improvement procedures for the SPF and the Fab Shop that supplied it. Again, the simulation was not considered accurate for prediction or capacity planning. However, it was quite useful as a descriptor of the shops' characteristics. Further, the model could be reconfigured to illustrate the effects of an assembly line configuration within Bay 1 of the SPF as compared to the traditional fixed-station process.

Model Parameters

The model can be configured to look at a particular process in isolation. In order to create an even comparison, the assumption that the Fab Shop could supply the necessary materials was made for both cases. However, variability was introduced by modeling the number of employees available to work at each station as a discrete random variable with a user defined distribution. The parameters for this was defined as the number of workers unavailable on a given shift.

Cycle time for each process is based on the GIS, with some variability introduced. For the base case, each station is assumed to complete a base group in 360 hours (45 shifts). It is further assumed that there are no auxiliary work sites. This is not a realistic assumption because work is often performed at other areas of the SPF as needed. However, it is a useful assumption for the purposes of comparison. Additionally, stations may be blocked by work. This is a common occurrence in practice because access doors are located next to the end stations only.

For the process flow case, modules move through the five stations sequentially. Each station has a cycle time of 72 hours (one fifth of the cycle time used by the GIS). Variability in processing time is also introduced. Stations are blocked only by the work ahead of it. There are obviously no buffers given the size of the inventory. Again, no auxiliary stations are used.

There is a queue at the front of the manufacturing process. It has unlimited capacity for purposes of illustration. The queue size illustrates how far behind the system is falling. Other useful output parameters include the actual start date, the cycle duration, actual finish date and days delinquent. This data is collected automatically by ProModel and analyzed with a build in package. Additionally, the data can be exported to a MS Excel file.

The model was run for a time period of three years and three months, enough time for the next aircraft carrier and four Double Eagle tankers to pass through the SPF. The table below illustrates output statistics for the first twelve assemblies and summarizes the SPF performance for the remaining 108 units. Negative days late to start indicates an early start.

Hull	"Base A"	"location"	GIS SF Start	GIS SF Complete	Shop Est Start	Model Start	Model Complete	Days Duration	Days late to start	Delinquent to GIS Complete
649	1201	"Loc_SPFB1_N1"	9/22/96	11/10/96	10/21/96	9/23/96	11/11/96	49	-28	1
649	1202	"Loc_SPFB1_N2"	9/23/96	11/11/96	10/26/96	9/23/96	11/11/96	49	-33	0
649	1301	"Loc_SPFB1_C3"	10/1/96	11/19/96	10/30/96	10/1/96	11/19/96	49	-29	0
649	1302	"Loc_SPFB1_C7"	10/2/96	11/20/96	11/4/96	10/2/96	11/20/96	49	-33	0
649	1401	"Loc_SPFB1_C4"	10/31/96	12/19/96	11/7/96	10/31/96	12/19/96	49	-7	0
649	1402	"Loc_SPFB1_C6"	11/1/96	12/20/96	11/12/96	11/1/96	12/20/96	49	-11	0
649	1501	"Loc_SPFB1_N1"	11/9/96	12/28/96	11/11/96	11/11/96	12/30/96	49	0	2
649	1502	"Loc_SPFB1_N2"	11/10/96	12/29/96	11/14/96	11/11/96	12/30/96	49	-3	1
649	1206	"Loc_SPFB1_C3"	11/15/96	12/13/96	11/15/96	11/19/96	12/17/96	28	4	4
649	1207	"Loc_SPFB1_C7"	11/16/96	12/14/96	11/20/96	11/20/96	12/18/96	28	0	4
649	1306	"Loc_SPFB1_C3"	11/24/96	12/22/96	12/4/96	12/17/96	1/14/97	28	13	23
649	1307	"Loc_SPFB1_C7"	11/25/96	12/23/96	12/7/96	12/18/96	1/15/97	28	11	23
							Average	35	164	149
							Minimum	21	-33	0
							Maximum	49	348	273

This example illustrates the rapid decline in on-time delivery resulting from the fix-station method. Within two months the model predicts that base groups are delivered 23 days behind schedule. The maximum delinquency reaches 273 days by the final unit, with an average delinquent time of 149 days.

Data from the process flow method is summarized below.

Hull	"Base A"	"location"	GIS SF Start	GIS SF Complete	Shop Est Start	Model Start	Model Complete	Days Duration	Days late to start	Delinquent to GIS Complete
649	1201	"Loc_SPFB1_N1"	9/22/96	11/10/96	10/21/96	10/21/96	11/8/96	18	0	-2
649	1202	"Loc_SPFB1_C7"	9/23/96	11/11/96	10/26/96	10/26/96	11/15/96	20	0	4
649	1301	"Loc_SPFB1_N2"	10/1/96	11/19/96	10/30/96	10/30/96	11/19/96	20	0	0
649	1302	"Loc_SPFB1_C7"	10/2/96	11/20/96	11/4/96	11/4/96	11/22/96	18	0	2
649	1401	"Loc_SPFB1_C7"	10/31/96	12/19/96	11/7/96	11/7/96	11/27/96	20	0	-22
649	1402	"Loc_SPFB1_C7"	11/1/96	12/20/96	11/12/96	11/12/96	12/2/96	20	0	-18
649	1501	"Loc_SPFB1_N1"	11/9/96	12/28/96	11/11/96	11/11/96	11/29/96	18	0	-29
649	1502	"Loc_SPFB1_C7"	11/10/96	12/29/96	11/14/96	11/15/96	12/5/96	20	1	-24
649	1206	"Loc_SPFB1_N2"	11/15/96	12/13/96	11/15/96	11/19/96	12/6/96	17	4	-7
649	1207	"Loc_SPFB1_C7"	11/16/96	12/14/96	11/20/96	11/20/96	12/11/96	21	0	-3
649	1306	"Loc_SPFB1_C7"	11/24/96	12/22/96	12/4/96	12/4/96	12/24/96	20	0	2
649	1307	"Loc_SPFB1_C7"	11/25/96	12/23/96	12/7/96	12/9/96	12/27/96	18	2	4
							Average	20	20	-10
							Minimum	17	0	-45
							Maximum	21	91	33

In this case the number of days delinquent to the start schedule is much lower. After two months only three units began late, with average delinquency of just over two days. Over the entire process the average starting delinquency is only 20 days with a maximum of 91 days. More significant, however, is the delivery statistics. On average, units are delivered 10 days *early*. The minimum delinquency is 45 days early and the maximum is 33 days early.

Conclusions

While, this simulation is far from perfect, it does illustrate the impact of moving to a flow process over a fixed station method. The reduction of blocked stations seems to be the most important factor in the improvement. Empirically however, other factors seem to be at work. The flow system was implemented several months ago and has show significant improvements. Some supervisors speculate that a shorter cycle time at each station allows for better time management. In other words, it's easier for a foreman to remain on schedule if work must be completed in nine shifts rather than forty-five. This is especially true when the unit must move to the next station to make room for a subsequent one. There is much more pressure on supervisors to remain on schedule. Additionally, learning curve effects may play a role in the increased efficiency. Each station performs the same tasks on each unit, even though the units are different. The Double Eagle units, do not vary much, especially through the ship's midsection. This may also allow for greater efficiency due to learning effects since consecutive units may be identical. Finally, supply of the webs and other components have smoothed some since demand-based manufacturing was introduced in the Fab Shop. A more level supply of materials undoubtedly contributes to more effective use of resources at each station.

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