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Multidimensional Approach to Implementation of Continuous Process Improvement Utilizing Small Run Analysis in a Shipyard Environment

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OF
CONTINUOUS PROCESS IMPROVEMENT
UTILIZING
SMALL RUN ANALYSIS
IN A
SHIPYARD ENVIRONMENT

BY

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ABSTRACT

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Paul Ray Hollandsworth
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Nationally, both public and private shipyards are experiencing a high rework rate (over 40%) in the fabrication of plug connectors used for electronic systems onboard Navy vessels. The shipyard's survival depends on acquiring the elements necessary to maintain a major industry in a position of continuous improvement that produces a better product than their competitors, at less cost, in a safe manner, and on schedule.

This research addresses the complex problem of how to introduce quality control methodologies within a job shop environment that assists in identifying variables that influence the rework rate of plug fabrication process over a four year period at Norfolk Naval Shipyard.

The research objective of implementing continuous process improvement in a job shop environment was addressed by: developing a multidimensional approach using

nontraditional statistical procedures designated Small Run Analysis, Pareto Analysis, Deming methodologies, and Concurrent Engineering. A new system to implement continuous process improvement and to measure the results of the new system for cost effectiveness and improvement of quality was developed.

The research has resulted in a successful pragmatic introduction of small run analysis in a job shop environment and lower rework rate through cooperation of both internal and external influences. Additionally, this research indicates that the system developed for continuous process improvement was not only cost effective but also transferable to public and private shipyards, leading to better understanding of information using data bases, automation, and networking in a shipyard environment.

DEDICATION

This dissertation is dedicated to my wife, April, who like the wind is not seen but whose presence and support is felt. She has allowed me the opportunity to soar from that support and reach heights that I often thought not possible. I acknowledge the sacrifices that she has made during this six year period. I would not have been able to do this dissertation without her help. I do love her so.

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CHAPTER I

BACKGROUND

Introduction

Over the past decade, private industries have been shedding extra management layers, paying more attention to customers and trying to design quality into their products.

Of course, federal agencies traditionally have hardly any competition, thus they have obligingly conformed to economic theory; without competition, there is little incentive to cut costs or improve services. Along comes the 1985 Gramm-Rudman-Hollings Bill, the budget deficit, and the push for privatization; and now the business of government is shaken just as the automobile and consumer electronics industries were ten years ago. With fewer resources to accomplish increased program demands, government managers are being forced to think more like their private sector counterparts.

Therefore, manufacturing companies around the globe who are achieving World Class Manufacturing status should be studied to ascertain what technologies and methodologies would be appropriate and could be transferred with particular emphasis to manufacturing processes in both the private and public shipbuilding and repair industry. Thereby, shipyards could develop concepts that provide executives and managers with timely information to make decisions that further the shipyard's total strategic operation plan and objectives for achieving it. These ideas should assist the mechanic in improving the production process thereby providing feedback to the engineering, planning, quality control, accounting and scheduling departments. If successful, the shipyards could experience both tangible and intangible benefits, such as:

1. lower total costs due to reduced waste
2. more efficient use of personnel, equipment and material
3. high quality products
4. reduced maintenance and warranty costs
5. enhanced flexibility in the production processes

This research proposes to add new insights to manufacturing processes with emphasis on the quality issues in a job shop environment for the public ship repair industry. The research involves a four year study at Norfolk Naval Shipyard in the Plug Shop (Shop 51P), a shop that was experiencing a 55% rework rate in the fabrication process. The research was accomplished by supporting the précis of implementing continuous process improvement through a multidimensional approach using nontraditional procedures termed Small Run Analysis, Pareto analysis, Deming methodologies, and Concurrent Engineering to achieve the benefits outlined above.

Quality

A survey conducted by Arthur D. Little, measured the pulse of U.S. manufacturers in their effort to regain the quality edge that they once possessed (Kendrick 1990). The survey covered more than 300 companies and spanned a wide cross section of geographical locations and manufacturing processes. The industries represented included: automakers and their suppliers; computers; semiconductors; telecommunications; defense electronics; industrial equipment; white goods; domestic appliances; and power tools. The companies surveyed were primarily U.S. based and ranged from $50 million in sales to companies of the Fortune 10. Individual plants as well as corporate offices participated in the survey.

The overall results of the survey indicated that companies rated quality as their top competitive priority twice as often as companies that rated cost at the top. Survey respondents rated supplier quality 71% and inadvertent quality planning during product process design as the most important quality related concern. Additionally 48% of the respondents considered inadequate process monitoring and control to be the most important quality concern.

Responses to the A. D. Little study show that quality control programs are being carried out and the relative success of their implementation are: reporting quality of performance measures 80%; documenting engineering changes and procedures 84%; strict final product inspection 71%. The QA/QC programs that the majority of the respondents are implementing are more strategic compared with the successful completed programs: total quality control 58%; supplier certification, 48%; and advanced quality planning, 39%.

These statistics reveal that companies are shifting emphasis from detection-oriented quality control programs to prevention-oriented quality control programs. The Quality Assurance/Quality Control programs being implemented are consistent with the quality issues that concern most companies such as supplier quality and inadequate quality planning during audit process design.

There is a definite trend as to how these companies have chosen to attack the quality program. They have addressed the procedural aspects of quality management first and are now addressing strategic areas of quality, as evidenced by the activity in total quality control, supplier certification, and simultaneous engineering. Statistical process controls (SPC) were successfully implemented by 51% of the respondents. SPC continues to be an area of considerable activity as another 40% of the respondents are implementing SPC.

Shipyard Industry

The shipyard industry plays an important part in the Commonwealth of Virginia's economy. Shipyards rank first and third as the largest employer in Virginia with a private shipyard employment of over 30,000 employees and a public shipyard with an employment level of over 10,000 civilian employees. In Hampton Roads, there are 22 public and private shipyards competing for business.

Approximately 70 percent of the shipyard workforce consist of blue collar employees who accomplish the building of new or repair of Naval ships. This work takes place both on the ships and in the shop areas. The remaining 30 percent are white collar employees who provide operational and management support in various shops and offices.

The threat of increased competition for ship repair work, impending fiscal restraints, projected workforce reductions, and increased complexity of ship overhauls all combine to force shipyards to reconsider its future posture in the competitive industry of ship repair. Decreased Defense funding for ship repair has resulted in fewer ships being scheduled for repair. Norfolk Naval Shipyard, along with seven other public yards throughout the United States, make up a $3.1 billion ship repair industry having to compete with the private industry for Military (Naval) ship overhauls. No longer is there guaranteed work for the employment of the skilled workforce. The evidence is clear, survival for the shipyard depends on producing a better product than their competitors at less cost, in a safe manner, and on schedule.

The shipyard needs strategic plans for the future that would embrace all the elements necessary to keep a major industry in a position of continuous improvement. Process improvement, customer satisfaction, measurement, employee involvement, and technological advances are the elements needed to form an integrated strategic plan for the shipyard to achieve its goal of continuous improvement.

Small/Short Run Analysis

A short run as defined by Thomas Pyzdek, President of Quality Publishing, is an environment that has a large number of jobs per operator in a production cycle (typically a week or month), with each job involving different products. A small run is a situation in which only a very few products of the same type are to be produced. An extreme case of a small production run is the one-of-a-kind product, such as casting a ship's anchor.

Short runs need not be small runs; a can manufacturing line can produce more than 100,000 cans in an hour or two. Likewise, small runs are not necessarily short runs. The Hubble Space Telescope took more than 15 years to get into orbit. It is possible, however, to have runs that are short and small. Programs such as just-in-time (JIT) inventory control are making this manufacturing operation more common.

Process control for either small or short runs involves similar strategies. Both situations involve markedly different approaches than those used in classic mass production. One should select the SPC tool that best fits the particular situation (Pyzdek 1993).

The key to controlling the quality of single parts is to concentrate on process elements rather than on product features. Although the single part process is a small run, it is not necessarily a short run. By examining the process rather than the part, improvement possibilities begin to emerge. The key is to find the process and define its elements so that they can be measured, controlled, and improved.

CHAPTER II

RESEARCH ISSUES/PROBLEMS

Clarification of issues that effect both private and public sectors, such as: quality issues both in the U.S. and worldwide; competition; costs; schedules;, and statistical techniques will serve as reminders of the complexity and dynamic relationships that must be understood for instituting continuous process improvement at a public shipyard.

Quality

Quality In The United States

There are some very visible signs that America is indeed on the threshold of quality. The first sign is in new product development that has become a focal point for implementing total quality systems. Not long ago a competitive approach in manufacturing industry was focusing primarily on the product, the metal, the material, the fabrics; not so much on the process, but the product.

There are two positive trends spreading through U.S. manufacturing facilities. Emphasis is on quality work processes and quality becoming a partner with innovation in many U.S. businesses.

The first of these is a very powerful way of silently overwhelming the competition. In the early stages of installing strong total quality systems, what is being accomplished in the company is far less visible than what is taking place in the product itself. When a company achieves this kind of total quality leadership and then relentlessly strives to retain it, it becomes very formidable in the international market. The second trend where quality is becoming a partner is where innovation underscores the fact that the greatly increased speed of innovation significantly increases the need for upstream total quality emphasis.

Unfortunately while some signs point to a concerted effort by U.S. businesses to make quality a top priority, there are still examples of companies relying on antiquated methods of product development and support. For example, many businesses still believe the way to keep a customer satisfied is to have an "always fix or replace the product for the buyer" motto. They believe this motto is honorable, and it is, but it is also failure driven. Products that are backed by such a philosophy will be outsold by products of manufacturers who develop products that consistently perform correctly during its life cycle.

Global Quality

Since the objective of the company is to position itself on a sustainable basis, factory automation and a quality product can help attain it. This is requiring a change to both non-technical (table 1) and technical (table 2) environments and is reflected in this new passion for quality improvement.

TABLE 1

THE CHANGING ENVIRONMENT - NON-TECHNICAL

	Conventional QC	The New Vision
Major Emphasis	Inspection to cut out defects (React)	"Up Front" QC to Prevent Bad Product (Anticipate)
Who is Responsible?	QC Engineer	Everybody--Led by Top Management
At What Point?	Mainly on Finished Product	Continuously Throughout the Process, Including Design and Vendor
Technology	Relatively Simple	Often Highly Complex
The Arena	Manufactured Goods	All Goods and Services
A basic goal of the New Vision: Understand and be responsive to customer needs while continuously improving products and productivity.		

Quality is not inspection. One thing that must be cautioned against is confusing inspection for quality. Many people translate quality into inspection. It is the old classic thing "let's make toast--you burn it--I'll scrape it." In the same light, the definition of "sorting" could be "ship the good ones and throw away the bad." It is a very interesting way of producing the products one's customers want since one will be paying for the product more than once. What is worse is, if one ships the bad products and one has another penalty. The customer may never buy from you again. The real sign of a company in trouble is one whose quality is completely dependent upon inspection.

TABLE 2

THE CHANGING ENVIRONMENT - TECHNICAL

	Conventional QC	The New Realities
The Goal	"Squeeze" Maximum Information from Sparse Data (Poor Data)	"Extract" From Voluminous, Continuously Changing, Frequently Automated Data (Data Rich)
The Mechanics	Manual Requires Simplicity in Implementation	Computerized: Requires Simplicity in Interpretation (Often By Lean Staff)
A Result	Concern With Statistical Efficiency	Concern With Comprehensiveness And Robustness
The Challenge: Obtain and communicate the key information that will drive quality improvement.		

In a good quality system, inspection plays a part. Instead of using the results of an inspection to sort the good from the bad, the results should be used to launch an investigation into the cause of the problem; the materials or parts you are buying, something in the process, human error, or whatever.

The definition of the term "Quality" is as easy as counting the people interested. Author David A. Garvin of the Harvard Business School offers eight separate dimensions to "Quality" in his book Managing Quality: The Strategic Competitive Edge (Garvin 1989). He lists these eight as: performance; features; reliability; conformance; durability; serviceability; aesthetics; and perceived quality. Each of these dimensions can be a source of a competitive advantage.

No longer is the focus only on the product or the process, it is ultimately on the customers. No longer is the responsibility on the design, manufacturing, marketing functions and top management: quality belongs to everyone. No longer does "Quality" only mean preventing problems, it also means creating opportunities.

What is "Quality"? The question seems to elicit hundreds, if not thousands, of responses, but if you ask "Quality" experts you will hear only one definition that cuts to the core of all these perceptions: "Quality is meeting the requirements of the customer."

Shipyard Industry

Private And Public Shipyards In The U.S.

The United States General Accounting Office (GAO) released an audit report on Navy Maintenance (U.S. Congress, House 1990) that stated that the Navy ship repair business is running over budget and behind schedule in both the public and the private yards. Most of the cost overrun occurs on private shipyard contracts but the audit did not name the 44 private yards that were reviewed. Most scheduling delays were recorded in the eight public Naval shipyards.

In private yards, repair costs have exceeded contract amounts by an average of about 31 percent. Cost overruns at the Naval shipyards averaged about 3 percent. The GAO report went on to say ". . . that this figure is not fully comparable to the growth in the private shipyards because government estimates for work at public shipyards generally include a ten percent growth factor not included in the contract award process for the private yards."

Some of the reasons for the delays and increased costs at the public shipyards were similar to those in the private yards. These were poorly defined work package specifications, problems encountered obtaining materials, and unplanned work subsequently added.

Shipyard's Complexity/Dynamics Issues

Total Quality Management (TQM)

Specifications for quality have never been a requirement of the Navy even though the Navy is undergoing a total quality management (TQM) program. There are no stringent requirements for suppliers of either material or services to the shipyards. The concept of total quality management in government was instituted in 1988.

Cost Variables

This leads to still another attribute that differentiates the public shipyards from the private shipyards: cost. There is no profit motive in the public shipyards. The public shipyards operate on a break-even policy but are more expensive. For example, if a private shipyard decides that they need a nuclear welder, they hire one and when the job is finished they let the welder go. On the other hand, Norfolk Naval Shipyard maintains a nuclear welder in case they need one not only for current workload but for some future situation. This is a different philosophy than the private shipyard but having a nuclear welder on-hand means that there is flexibility built-in to meet the mandate of "Readiness for the security of the Nation." This approach along with other management factors such as acquisition and Congressional dictates are more costly and therefore is reflected in the public shipyard's bids.

Acquisition

In the acquisition of equipment, if the private yards want some new market item that has a fast payback, they are not bound by any governmental rules or regulations and can have the product bought and installed immediately. The public yards, on the other hand, have to submit a plan two years in advance and have the budget approved. This regulation requires the public shipyards to be better planners or it would place the public yards in a continual catch-up mode with the private shipyards.

There is also the experience that even though the funding has been put in the budget, planned, and the documentation submitted for contract award, the project could be canceled because the funding was taken away at the last minute by Congress for another priority. Both the private and public yards do not have control of their destiny. They are subject to public law, political reflections of Congress, GAO, Corporate Headquarters, Military Sponsors, and the President.

Statistical Process Control (SPC)

Some of the shipyards have started statistical process control but are experiencing some difficulties since the engineers are either not properly trained or have never had the requirement to use this technique.

Small/Short Run Analysis

Up to this point in time, shipyards have not had any experience utilizing small run analysis. The industrial engineers have applied traditional SPC techniques that dictated what type of characteristics of the process should be collected, analyzed and charted. The nature of the manufacturing processes in a shipyard necessitate their own nontraditional methodologies. When small and short runs are common, as in a shipyard operation, the history of a given process can be lost among the charts of many different parts. A variables measurement on a continuous scale provides more information than does a discrete attribute classification.

In spite of the disadvantages, sometimes it is necessary to use attribute data. In such cases, special methods, such as stabilized attribute control charts and demerit control charts, must be used to control small run processes.

When plotting attribute data statistics from small run processes, two difficulties are often encountered.

1. Varying subgroup sizes, which result in messy charts with different control limits for each subgroup, distorted chart scales that mask significant variations, and chart patterns that are difficult to interpret because they are affected by sample size changes and true process changes.

2. A small number of subgroups per production run, which makes it difficult to track long-term process

trends because the trends are broken up among many different control charts for individual parts.

Because of these two difficulties, many people think that SPC in not practical unless large, long runs are involved. "This mind-set is incorrect. In many cases, stabilized attribute charts can be used to eliminate these problems (Pyzdek 1993)." Although they are more complicated than classical control charts, stabilized attribute control charts offer a way to implement SPC in processes that are difficult to control. Stabilized attribute charts can be used for processes producing part features that are essentially the same from one part feature to the next. Production lot sizes and sample sizes can vary without visibly affecting the chart.

Summary

The research objective is to introduce quality control methodologies within a shipyard environment that assist in identifying variables that influence the rework rate of the plug fabrication process at Norfolk Naval Shipyard's plug shop, called Shop 51P. What will be presented is a four year effort led by this author as project manager of various groups at Norfolk Naval Shipyard to grapple with quality problems in a job shop operation. In conjunction with addressing Total Quality Management issues, a second order process improvement can be achieved utilizing nontraditional statistical techniques. The tools available for this research and those technologies that could be appropriately transferred will be:

1. review of small/short run analysis;
2. automation;
3. Dr. Deming's principles of first bringing a process into statistical control before it can be improved;
4. review the effectiveness of Pareto Analysis;
5. charting;
6. data base applications;
7. establish a baseline;
8. measure the cost effectiveness of any changes to the plug fabrication process that purports to reduce Shop 51P's rework rate.

CHAPTER III

LITERATURE REVIEW

What will be demonstrated in this research for a public shipyard is that multidimensional approaches can be combined to address changing complex work processes in a job shop environment. This research will investigate the resources and information developed in the areas of TQM concepts for complex manufacturing processes in a job shop domain, primarily: quality strategies; the fabrication of plugs/cables in the shipbuilding/repair industry; and small run analysis.

Quality Strategies

For a TQM program to be successful, it must have the support of top management. To gain this support, top management must be aware of the following challenges (Deming 1985):

1. Overcoming the obstacles to transferring technology from the laboratory to the plant floor.

2. Breaking down organizational chimneys and building teams that blend with technology.

3. Training and educating employees to operate in a high technology environment.

If successful the payoffs can be substantial. For example, consider some of the things "aggressive companies" can achieve by paying attention to their manufacturing processes and becoming "competitive": 90 percent reductions in work-in-process inventory, material handling costs, and production lead-time; 75 percent reduction in setup time; 30-40 percent reduction in floor space; 70-90 percent improvement in quality; 10-25 percent reduction in direct labor; 15-40 percent reduction in indirect labor; and 5-20 percent reduction in purchased part costs (Vasilash 1989).

For U.S. manufactured goods, production costs typically consist of materials (55%), direct labor (10%) and overhead (35%). Because direct labor is no longer the major cost of production, TQM projects target other, more substantial, cost components.

Additionally the Manufacturing Studies Board of the National Research Council (Industry Week 24, October 1988) predicts that organizations implementing TQM should realize reductions in engineering costs (15-30%) and work-in-process inventory (30-60%), as well as gains of as much as 500% in engineering productivity and product quality, and as much as 300% in capital equipment operating time.

The Deming Quality Management and philosophy approach assumes that a worker does not come to work to turn out a bad product. He takes pride in his work. Therefore, if a problem exists, it is the result of the worker not having the right tool, the proper training or there is something wrong with the process that can only be addressed by management. Dr. Deming purports a controversial premise when he cites that 85% of all problems that exist in manufacturing processes are attributed to management (Townsend and Gebhardt 1990). One of the basic tenets Dr. Deming proposes is that no one should be blamed or penalized for performance one cannot govern or control. The violation of this principle can only lead to frustration and dissatisfaction with the job and therefore, lower production (Deming 1985). Dr. Deming also states that the job of management is not supervision but leadership, that they must work on the sources of improvement, the intent of quality of the product and of service, and the translation of intent into design and actual product. He also teaches as previously stated that this leadership role must be there to remove barriers that make it impossible for a worker to do ones job with pride of workmanship. Additionally, management must act on the corrections proposed (Scherkenbach 1988; Walton 1991).

When one achieves the state of statistical control, it does not mean everything is finished; it means do not take action on the remaining variables that are charted. If one continued to make adjustments to the process then it could create additional variation and more trouble. Therefore, without appropriate statistical methods, as in the job shop domain of shipyards, attempts to improve a process is hit or miss, with results that usually make matters worse (Shewart 1939 and 1980; Deming 1982a; Harrington 1987; Neave 1990; Scherkenbach 1991).

Dr. Deming has been quoted as saying,

> "There will be no room for managers who do not know how to work with their people to produce high quality goods at low costs. High reliability cannot be secured without worker cooperation...In the competitive worlds of the future, companies which have not mastered these ideas will simply disappear. There will be no excuses (Townsend and Gebhardt 1990)."

Differing opinions on the importance of statistical quality control abound. Dr. Deming asserts that, "Everyone in the company must learn the rudiments of the statistical control of quality, not just to solve a problem, but as a plan to define problems and the causes thereof" (Gitlow 1987). Another view is suggested by Dr. Joseph M. Juran:

> "Statistical quality control is a useful thing, particularly in process improvement, process control. It is one of the important tools to use, and we're getting good results. But there are many other things that are needed, and we've got to stop regarding it as a cure-all or a panacea (Juran 1974)."

Tom Peters offers the observation that "Statistical quality control is important if the attitude of the people is right (Townsend and Gebhardt 1990)."

Shipyard Plugs/Cabling

Only three articles were found on plugs/cabling during the literature search. The first article described an automated computer system designed in 1976 called "Cabling and Wire" that addressed installation design and production in the area of equipment cabling and wire hookup for new Navy ships (Mellis 1976). It should be noted that this was the computer system in-place at Norfolk Naval Shipyard that was modified in 1989. The second article was a work management manual on electrical work for shipboard installation (Peterson 1982). The third article provided a macro overview on the possible disasters with the continuing usage of wire cable and benefits of fiber optics cable on Navy vessels (Hendricks, Verle, Pokrywka and Creek 1989).

Small/Short Run Analysis

There were very few articles on small/short run analysis and none addressed the public shipyard repair domain.

One article addressed the classical SPC methods such as $\overline{X}$ and R charts that were developed in the era of mass production of identical parts. It went on to say that traditional SPC methods could be slightly modified to work with short and small runs. For example, $\overline{X}$ and R control charts can be created using moving averages and moving ranges (Pyzdek 1989). There are, however, SPC methods particularly well-suited for short and small runs.

1. Exact method: As more data become available, the exact method updates control limits until no further updates are needed and standard control chart factors can be used.

2. Code value charts: The exact method can be used to adjust the control limits when code value charts are created with limited data.

3. Stabilized control charts for variables: Since stabilized control charts are independent of the unit measure, they can be thought of as true process control charts. The exact method adjusts the control limits for stabilized charts created with limited data.

The exact method, adapted from the work of F.S. Hillier (Hillier 1969) and the work of F. Proschan and I.R. Savage, (Proschan and Savage 1960) applies to short runs and any situation in which a small number subgroups will be used to set up a control chart.

A.J. Duncan described a similar transformation for attribute charts (p charts in particular) and called the resulting chart a stabilized p chart. The charts of transformed variables data can also be called stabilized charts (Duncan 1974).

Therefore the ability to easily see process trends and changes in spite of changing part numbers and sample sizes is the big advantage of stabilized control charts. Their disadvantages are:

1. They convert a number that is easy to understand; the number of defects or defectives, into a confusing statistic with no intuitive meaning. This problem can only be corrected through training in and experience with applying the technique.

2. They involve tedious calculations. This problem can be eliminated by using computers or programmable calculators (Pyzdek 1993).

Lastly, the remaining articles primarily discussed the theory behind the development of small/short run analysis (Bothe 1988, 1989; Nelson 1989). Davis Bothe, President of International Quality Institute, stated that the reason there were no published articles of success with small run techniques in businesses is because his clients do not want it publicly known. His clients felt the need to be secretive about using this technique; it was their edge over the competition. It has already been stated that in the research presented, job shop environments need their own techniques because their requirements are different than in mass production industries.

Summary

The literature search shows there were many sources on quality strategies. One has to choose a strategy since this research is broken into two parts where the separation is accomplished when the plug fabrication process is brought into statistical control. The Deming principles will be adopted for developing the methodology of bringing the fabrication process into statistical control.

As another part of the quality strategy, there was very little documentation in using multiple disciplines to address complex manufacturing processes especially in a job shop climate. The problem of identifying the many variables that effect the rework rate in Shop 51P will require multiple tools, such as Pareto Analysis. There was no research that identified multidisciplines as beneficial, would work at cross-purposes to this quality approach, or if results from a Pareto Analysis could be coded in order to advance to the next step of ultimately achieving continuous process improvement.

There were no articles addressing continuous process improvement for shipyard plugs/cabling. The only method of standardizing the plug fabrication and wire hookup onboard ships was in a 1976 computer based system. The high rework rate for plug fabrication in both the private and public shipyards appear to be widely accepted in the industry as the price of doing business.

Finally, due to the nature of plug fabrication, another statistical methodology will be needed that is not grounded solely in Shewhart's work but based on a domain where there are small production runs. The traditional SPC methodology will not work. Small Run Analysis will be utilized for this research even though there were limited articles on the development of the Small/Short Run Analysis and no articles on the pragmatic successes using this nontraditional approach.

CHAPTER IV

APPROACHES/DESIGN

The multidimensional methodologies for this research are a combination of generic and specific steps. Generically, the type of fieldwork investigation is characteristic of qualitative and quantitative (Q&Q) research. The study is divided into two parts with the phases delimited when the plug fabrication process, a job shop operation, was brought into statistical control as defined by the quality principles of Dr. Deming. The specific stages to the research are outlined below.

1. External and internal influences who contributed to the rework rate of the electrical plugs needed to be identified through a computer tracking system and Performance Action Team.

2. Pareto Analysis was used to group the frequency of nonconformities.

3. Small Run Analysis was utilized as the statistical process control technique for the binomial

distribution of attribute data with a nonconstant subgroup.

4. Concurrent Engineering techniques were employed to develop a different approach to the plug fabrication process that would further reduce the rework rate.

5. Using the baseline already established from Part I, measurements from the new approach were recorded and using the Small Run Analysis, the continuous improvement goal was evaluated for success or failure due to this perturbation.

Qualitative And Quantitative Research

This research presents qualitative and quantitative (Q&Q) approaches, which becomes particularly useful where one needs to understand stratified groups, particular problems, or unique situations in great depth, and where one can identify cases rich in information; rich in the sense that a great deal can be learned from a few exemplars of the phenomenon in question. For example, a great deal can often be learned on improving a process by studying select variables, defects, internal and external influences, and successes. Stake (1981) has argued that good Q&Q research can "provide more valid portrayals, better bases for personal understanding of what is going on, and solid grounds for considering action." Qualitative evaluations often yield such rich research data.

Qualitative studies are particularly valuable when the evaluation aims to capture individual differences or unique variations from one program setting to another, or from one program experience to another. A study can be a person, an event, a program, an organization, a time period, a critical incident, or a community. Regardless of the unit of analysis, a qualitative research seeks to describe that unit in depth and detail, in context, and holistically. The more a program or treatment aims at individualized outcomes, the greater the appropriateness of qualitative case methods. The more a program emphasizes common outcomes for all participants, the greater may be the appropriateness of standardized quantitative measures of performance and change (Patton 1990).

Gharajedaghi and Ackoff are quite insistent that a system as a whole cannot be understood by analysis of separate parts. They argue that "the essential properties of a system are lost when it is taken apart; for example, a disassembled person cannot live." Furthermore, the function and meaning of the parts are lost when separated from the whole (Gharajedaghi and Ackoff 1985).

Considering evaluation design alternatives leads directly to consideration of the relative strengths and weaknesses of qualitative and quantitative data. Qualitative methods permit the evaluator to study selected issues in depth and detail. Approaching fieldwork without being constrained by predetermined categories of analysis, contributes to depth, openness, and detail of qualitative inquiry. Quantitative methods, on the other hand, require the use of standardized measures so that the varying perspectives and experiences of people can be fit into a limited number of predetermined response categories to which numbers are assigned.

The advantage of a quantitative approach is that it is possible to measure the reactions of many people to a limited set of questions, thus facilitating comparison and statistical aggregation of the data. This gives a broad, generalizable set of findings presented succinctly and parsimoniously. By contrast, qualitative methods typically produce a wealth of detailed information about a much smaller number of people and cases. This increases understanding of the cases and situations studied but reduces generalizability (Patton 1990).

In qualitative inquiry the researcher is the instrument. Validity in qualitative methods, therefore, hinges largely on the skill, competence, and rigor of the person doing fieldwork. Guba and Lincoln comment on this aspect of qualitative research ("naturalistic inquiry") as follows:

> Since as often as not the naturalistic inquirer is himself the instrument, changes resulting from fatigue, shifts in knowledge, and co-optation, as well as variations resulting from differences in

> training, skill, and experience among different "instruments," easily occur. But this loss in rigor is more than offset by the flexibility, insight, and ability to build on tacit knowledge that is the peculiar province of the human instrument (Guba and Lincoln 1981).

Because qualitative and quantitative methods involve differing strengths and weaknesses, they constitute alternative, but not mutually exclusive, strategies for research. Both qualitative and quantitative data can be collected in the same study.

Deming Approach

Dr. Deming's espouses that repeated measurements of the same item over a period of time must show statistical control in order for the instrument and the worker to qualify as a method of measurement. The method must be reproducible within specified limits with different workers. A statistical chart detects the existence of a cause of variation that lies outside the system. It does not find the cause. Dr. Deming's approach also states that if a process is in a state of statistical control, all special causes that have been detected, have been removed. The remaining variation must be left to chance, that is to common causes, unless a special cause turns up and is removed. It should be noted that this was another reason for the 1989 computer application that was developed in Part I to generate a discrepancy list for continual feedback for management to try to adjust and correct problems as they were found.

Influences On Rework Rate

The information provided from the computer reports of Part I measured the deficient quality characteristics Shop 51P felt pertinent to the plug fabrication process. These deficiencies were then assigned to a control chart that depicted the stability and the changes that have been made to the plug process during 1988-1989.

As was previously stated, a discrepancy list was accumulated over two years that documented the problems of noncompliance experienced by Shop 51P. Figure 1 depicts the

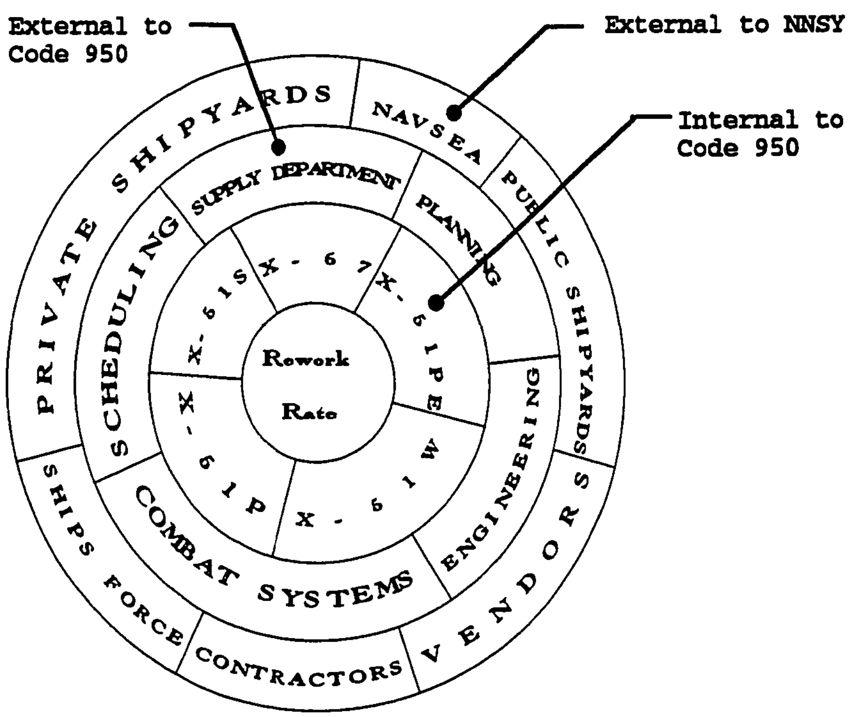

Figure 1. Influences on Rework Rate

different influences on Shop 51P's operations. On the basis of the adoption of Total Quality Leadership (TQL), a Performance Action Team (PAT) was formed to review the discrepancy list and recommend appropriate groupings. The PAT was comprised of mechanics (both internal and external to Shop 51P), engineers, and material specialists who had expertise in the plug fabrication process. The PAT was charged with reducing the complexity of the rework process into manageable increments. The list was collated and grouped into internal and external variables. The discrepancy list developed by the PAT identified 109 variables that were coded into eight major categories. The categories are: Planning; Ship's Force; Workmanship; Other Shops/Codes; Material; Technical; Instructions; and Equipment (Form 1 of Appendix A). The coded variables could then be charted to depict more easily what categories contributed to the rework problem.

The coded discrepancy list highlighted the internal influences on Shop 51P in a category titled "Workmanship" Items. There are 51 items that could render a plug as a nonconforming unit and are the only variables that Shop 51P had direct control over. Therefore, upper management of Shop 51P had a target of 51 items that could be addressed to bring Shop 51P plug fabrication process into statistical control.

Shop 51P Data Characteristics

The plug fabrication data for Shop 51P involves random processes for which there are only two possible outcomes. The outcomes occur without any fixed pattern, and the probability of either outcome remains unchanged for each trial. Processes with these characteristics are called Bernoulli processes. For example, the plugs are prefabricated in the shop and tested and are classified as being "acceptable" or "defective. The probability of selecting any type of plug within the shop/shipboard process remains unchanged for each trial, the sample size of Bernoulli trials is described by the binomial distribution.

In order to simplify the expression of the characteristics of Bernoulli processes, a specified or desired outcome of a trial will be termed a success. In some instances the proportion of trials that yields successes is known with certainty. Whatever the results of a finite number of trials, the acceptance of the validity of this long-run fraction is unchanged. Since Shop 51P operational elements appear to follow these characteristics, the next decision will be to determine whether the data is categorized as having a binomial or a Poisson distribution.

Discrete data is the result of counting defects or defective pieces in a sample so that only whole numbers or integers may occur. But the notion of a "trial" for a Poisson distribution requires the special definition of a continuum of time, space, or some other dimension as being divided into sufficiently small units so that the likelihood of more than one success per unit is extremely small. In this manner, each small unit is a trial, and not more than one success will occur in a given trial. The binomial and Poisson distribution probabilities form the models for process control charts for nonconformities and nonconforming, respectively. The difference between the binomial probability distribution and its limiting form, the Poisson probability distribution, becomes negligible when the probability of success is very small and the sample size is large.

In this research, a binomial probability distribution was used for the Pareto Analysis.

Pareto Analysis

Villefredo Pareto was a 19th century economist who documented the distribution of wealth during that time period. Most wealth was concentrated among the "vital few" of the populace, while the great majority of the "trivial many" lived in poverty, perhaps a brilliant revelation during his time but common knowledge today. Dr. Joseph Juran formalized the use of this principle to describe management conditions in 1954 recognizing that this type of distribution is a universal rule that fits most conditions; thus the use of a Pareto chart became a powerful management tool for prioritizing problems (Affourtit and Affourtit 1982).

Pareto Analysis is used to identify and evaluate types of nonconformities. In many cases in industry, studies arise out of the initial use of control charts for attribute data. When attribute data are collected and categorized by type of nonconformity, data become available on the frequency of use of various types. This data may be used to then direct attention of upper management to the most common problems. The steps used in performing a Pareto Analysis are:

1. Identify the types of nonconformities. If past controlled chart data have been categorized, then developing the list will be easy. Otherwise, new procedures of data collection may have to be instituted and data collected over some period of time before the analysis can be performed .
2. Determine frequency for various categories.
3. List the nonconformities in descending order of each frequency.
4. Calculate the frequency percentage for each category and the cumulative frequency.
5. Set up scales for the Pareto diagram. The Y axis on the left side gives the actual frequency of the category in the sample. The Y axis on the right side applies to the cumulative frequency percentage.

6. Plot the Pareto frequency bars and overlay the cumulative frequency percentage to develop this chart.

If the Pareto diagram is set up following the steps indicated, it will direct attention of management to the most frequent nonconformities but not necessarily to the most important. When the list contains some that may be considered extremely serious and others that may be considered trivial, a weighting scheme would be used to modify the frequency count and order resulting from steps two and three.

"Charts only reflect conditions which exist and are absolutely worthless unless appropriate action is taken (Charbonneau and Webster 1978)."

Small Run Analysis

One of the dangers that is sensed in statistical process control (SPC) activities is that familiarity or success with one technique can lead to a method-dominated approach in which the practitioner has one tool and tries to solve all problems using that approach. In contrast to this is a problem centered approach in which the nature of the problem or the stage of its investigation suggests which is the most appropriate or cost effective tool from among the many tools available to the knowledgeable practitioner.

In the traditional quality control operation this type of measurement is called "measurement of attribute data."

For this research, attribute control charts are useful in identifying problems and establishing priority areas for further examination and corrective action. This approach may assist in this selection of priority areas for the introduction of control charts of variable type data or for special problem solving attention. It should be noted that since attribute data distinguish only whether a part is good or bad, the amount of information contained in binary data is minimal at best. Variable data tells how good or how bad, so it is not surprising that attribute charts are less sensitive to changes in the process than variable data, for example, "$\overline{X}$" and "R" charts (Shewhart 1931; Bothe 1989). Before describing the different types of attribute charts, it is important to make the distinction between nonconformity and nonconforming unit.

Nonconformity is a fault that causes a unit to fail to meet specification (for example, a dent in an appliance, a paint blemish on an automobile, a scratch on furniture, porosity, a missing environmental seal on an electronic plug). It is possible to have more than one nonconformity on a single unit. The number of nonconformities found in samples taken from a stable process can be approximated by the Poisson Distribution on which "c" and "u" charts are based. The definition of nonconforming is a unit that fails to meet a certain specification due to the presence of one or more nonconformities. It only takes one nonconformity to make a unit nonconforming. The number or percentage of nonconforming units found in samples taken from a stable process follows a binomial distribution in which one would use either "np" or "p" charts.

Since Shop 51P operates in a job shop environment, which by it's very nature, causes great difficulty in applying the powerful methods of statistical process control (SPC) to its processes because of limited lot sizes. As described in the literature research a different approach, termed small run analysis, will be presented rather than SPC methodology that is based on mass production long runs (Bothe 1989).

These small production runs cause problems when attempting to use the traditional Shewhart charts, because there is never enough data to calculate control limits in a timely manner. Usually the run for a given part is over before the limits can be calculated and drawn on the chart. Therefore, in the case of a Shop 51 plug fabricator, the mechanic would have to wait until after the job is completed before he discovers whether the process was in or out of control.

Small run analysis allows a mechanic to plot different types of plugs on the same chart. Standardizing the data allows the mechanic to develop one common set of control limits on the chart which apply to all plugs plotted, thus eliminating the need for hundreds of separate charts (Nelson 1989).

A "small run" is any situation where there is insufficient subgroup data for a given part to calculate traditional Shewhart control limits in a timely manner. This may occur because:

1. The lot size is extremely small (only 1 to 15 pieces)--Even with a subgroup size of n = 1 or 2, not enough plot points are generated during the run to calculate traditional control limits, where the number of plotted subgroups is recommended to be at least 15. Without control limits, the chart is of little use to a mechanic.

2. The lot size is large (more than 100 pieces) but very few subgroups are collected during the run. A stamping operation running a certain part number may produce over 1,000 pieces per hour with a subgroup taken every half hour. If this part number is run for only two hours then just four plot points will be generated, again not enough to calculate traditional control limits.

To resolve many of the problems associated with applying SPC methodologies to attribute data of short production runs, several new control charts have been developed by the International Quality Institute (International Quality Institute 1989). Figure 2 is

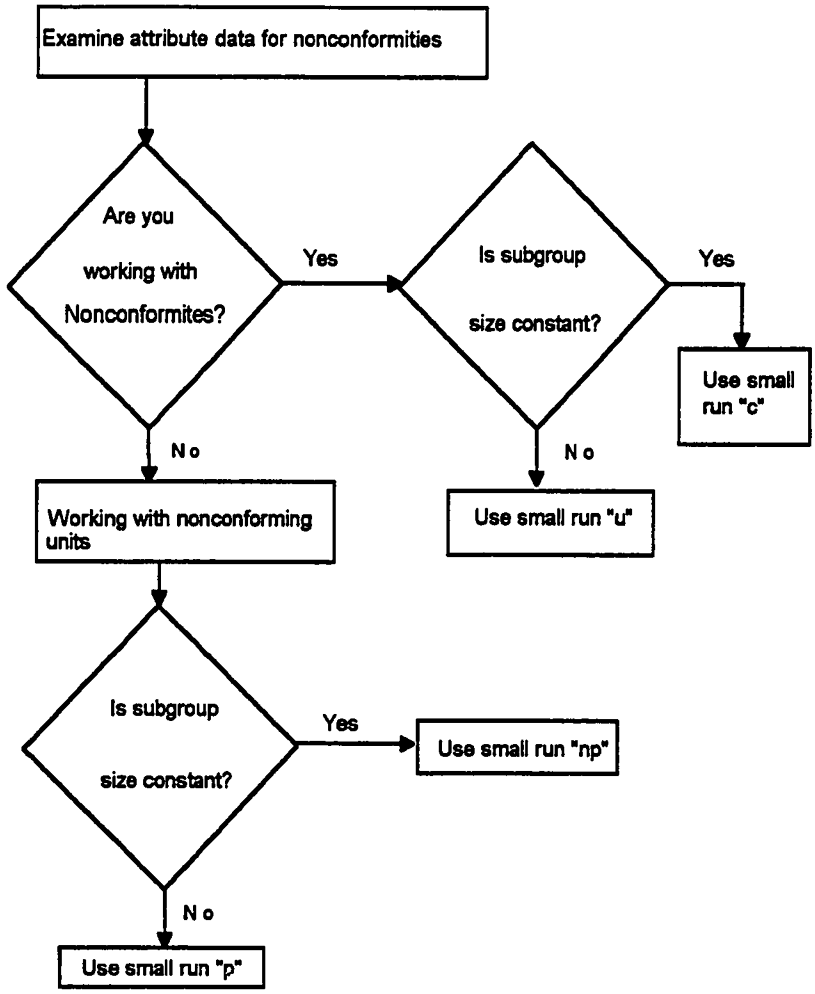

Figure 2. Guide to Small Run Attribute Charts

designed to assist in selecting the proper small run chart when working with attribute data.

Since the plug process is evaluated on nonconforming units and the subgroup is not constant, as portrayed in Figure 2, Shop 51P will be using percentage or small run "p" charts.

Small Run p Chart

This chart will be is used when several different plugs are fabricated on the same process with subgroups checked periodically to determine if the pieces in it are "good" or "bad" (conforming or nonconforming) but a constant subgroup size for given pieces cannot be maintained.

The subgroup size may vary for each piece and for each subgroup.

1. Plot Point--The number of nonconforming units found in the subgroup (np) is divided by the subgroup (n) to calculate the percentage of nonconforming units (p) in the subgroup. This subgroup percentage is coded by first subtracting the expected average (Target $\bar{p}$), then dividing this difference by the standard deviation (similar to calculating Z-scores)

$$\text{p Plot Point} = \frac{p - \text{Target } \bar{p}}{\sqrt{\text{Target } \bar{p}(1-\text{Target } \bar{p})/n}} \tag{4.1}$$

The center line (CL) for the Small Run p chart is 0. If p equals the target $\bar{p}$ value, then the plot point falls right on this center line of 0.

$$CL_p = 0 \tag{4.2}$$

The control limits (UCL/LCL) for this chart are $\pm$ 3, which represents the $\pm$ 3 sigma limits of the traditional p chart.

(4.3) $$UCL_p = +3 \qquad LCL_p = -3$$

The Small Run p Chart measures the results of each subgroup in terms of standard deviations from the average. If p is more than $\pm$ 3 sigma larger than the Target $\bar{p}$, the plot point (also called an outlier) falls outside the control limits, indicating an assignable cause of variation is present or as Deming describes it, "special cause."

The Small Run p Chart assumes: first, the process output data follows a binomial distribution on the sample subgroup; second, the subgroup size used for each plug type should be large enough to expect an average of at least two nonconforming units per subgroup. Third, for attribute data charts, use the following formula for the expected value of the process parameter being charted.

(4.4) $$\text{Target } \bar{p} = \frac{np}{m}$$

Where "m" is the number of historical pieces examined, "np" is the number of nonconforming units found on the "m" units checked and "n" is the subgroup size for the selected plug type (International Quality Institute, 1988). It can also equal:

$$\text{Target } \bar{p} = \bar{p} \quad (4.5)$$

Concurrent Engineering

Full benefits from Concurrent Engineering can be derived for an organization, such as Norfolk Naval Shipyard, by integrating the Design Division and Production more completely. Concurrent Engineering (CE) and quality can serve as the currency that links isolated economies.

The best-laid plans and the most prodigious efforts will not prove effective however, without the critical element of these three keys: communication, global impact, and culture.

Communication involves identification and definition of mission-critical data. All members of the team need to have the same understanding of terms. It sometimes requires "data semantics" to resolve conflicting views and reach consensus. The dissemination of critical data across the enterprise requires global access to, common understanding of, the business data. The various tools, ownership, and security issues all come into play in the arena where knowledge is power. Getting a person on the project to share the knowledge that makes him such an important player in the group may be one of the most delicate tasks involved in CE implementation.

These features will be understood and utilized in Part II when both the Engineering Division and Shop 51P are brought together for better communication and when both groups are tasked to solve the external influences that Engineering has on the plug fabrication process. The participants will receive feedback from the Pareto Analysis and the Small Run Analysis as to the impact of changes being proposed. Both groups will have to break down the cultural barriers if this effort is to succeed. During Part II implementation, it will be important to evaluate existing in-house tools such as standard data elements, local area network, and automated processes and then measuring their effectiveness in reducing the plug rework rate.

Summary

This chapter outlines the design of the research by specifically detailing the approaches used to address continuous process improvement for the plug fabrication process in Shop 51P. The Deming principles will be the foundation for both parts of the research spanning four years.

To achieve statistical control as defined by Dr. Deming, a computer program was developed to document the variables the were effecting the rework rate on the plugs. It was discovered that there were two type of influences on the fabrication process, internal and external. A Performance Action Team was developed to group the 109 variables into categories. The categories were coded and a Pareto Analysis was applied to ascertain the greatest effect on the rework rate. In 1989, it was determined that plug fabrication was not in statistical control using the "p" chart from Small Run Analysis and that Shop 51P could only control the internal variables inside the shop and would have to work on reducing the rework rate internally and bring the process into statistical control before attempting a continuous process improvement with external influences.

If this effort is successful then a baseline could be established to measure the effectiveness of the new system. Using the Concurrent Engineering features, both Shop 51P personnel and an external influence would be identified by the Pareto Analysis as the next major contributor to the rework rate. These two "contributors" will work together to develop a new system that would be compared to the baseline for: cost effectiveness; reduction in rework rate; and effectiveness in bringing the plug fabrication process into statistical control to illustrate the concept of continuous process improvement.

CHAPTER V

DATA COLLECTION/ANALYSIS

Part I

Introduction

Norfolk Naval Shipyard, along with other public and private shipyards, was experiencing a very high rework rate (over 40%) in the fabrication of connectors (plugs) which provide electrical connections between electronic systems. In May 1989, the Production Electrical Department requested the Quality Assurance Office, and the Management Engineering and Information Office, assist in forming a rework study team that would work with the first line supervisor to investigate this problem area in Shop 51 Plug Section. This author was project manager of the rework study team that decided to adopt the Deming philosophy and apply it to this particular rework problem. The Deming approach assumes that the worker does not come to work to turn out a bad product; he takes pride in his work. Therefore, if a problem exists, it is the result of the worker not having the right tools, the proper training, or that there was something wrong with the process.

Operation

In May 1989, the rework study team met with the electrical foreman in charge of the Production Electrical Department's Plug Section (Shop 51P) in an effort to learn the process of connector fabrication. Shop 51P was made up of 54 mechanics working three shifts a day. The first shift was staffed with thirty-four (34) people, whereas the second and third shifts were comprised of ten (10) people per shift. The shop was responsible for fabricating electrical connectors and cables on both surface ships and submarines. Usually one end of the cable was prefabricated in the shop and the other end was made aboard the vessel at the site of equipment installation.

Shop 51P had a manual that all mechanics were to study, review, understand and sign off indicating their understanding of the plug fabrication process. A lead mechanic was required to receive the prints for the specific job and determine from the drawing, the required material needed for the job. With this information, he constructed a prefabrication book. One job can involve dozens of connectors. The shop mechanic was to be provided prefab information on the jobs, for example, what length the cables need to be, the material needed for assembly (requiring the connector or the plug, the backshell, the spaghetti, cable markers, cable clamps), and outlines of a set procedure which requires a certain check off list. Figures 3 and 4 provide two examples of how a connector was fabricated. The connector was inspected by both a Shop 51P inspector and a Combat Systems inspector.

After half the cable was checked out for continuity or shorts and was deemed complete, the cable was taken aboard the ship and given to shop personnel who route the cable through the causeway, bands the cable, and takes the unfinished end of the cable to the correct termination point. Shop 51P then fabricates the connector to complete the cable and perform a final test.

The plug mechanics were required to: ring-out the cables and plugs; correct all discrepancies; sign-off on Connector Fabrication Control sheets and return the paper work to the shop mechanic; prepare the cable for the internal Shop 51P inspector and Combat system's inspector;

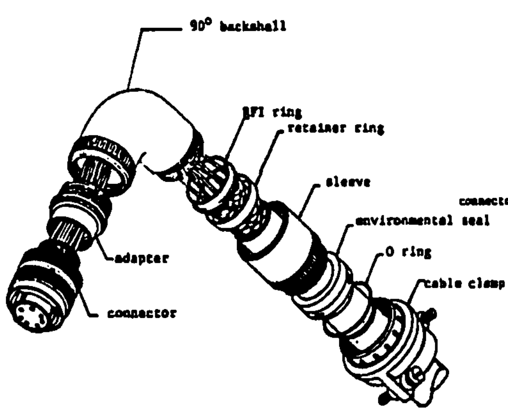

Figure 3. Exploded
View Angle Plug Connector

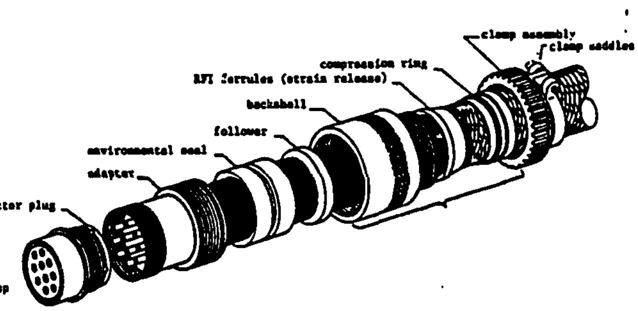

Figure 4. Exploded
View Straight Plug Connector

have proper tools to fabricate connectors; expedite missing material; and inform the shop mechanic of any problems.

Additionally, the Quality Circle (QC) in Shop 51 (a voluntary group of shop mechanics whose sole purpose was to identify problems and provide solutions) realized that the rework rate reflected badly on Shop 51P. They decided that a possible solution could be the formation of teams of mechanics. There were occasions in which the job on the ship was overmanned and they felt that the teamwork concept would achieve better coordination.

The basic premise for this QC development was that the teams were to be established by the job. Number of team members would depend on the size of job. At the beginning of the job, supervisors would assign people to the team. This team would stay together as long as the job allowed. Upon completion of the job, the team could be disbanded and members of the team assigned to other teams. Pending workload, the team could be maintained and assigned another job. Once a team had been established, supervisors could not pull team members without first discussing the change with team leaders. When a team was established, members of team would elect the team leader.

The team leader's responsibilities consisted of talking with team members and made a list of what each member felt was their strong and weak skills. This list was to be used as an initial starting point to establish what specific training was needed for each member, and was to be followed up by a comparison to the Quality Assurance (QA) discrepancy list. When possible, team leaders were to ensure that members would be given the opportunity to work plugs in which the mechanics were weak to provide corrective training.

Variables Affecting Rework

During calendar years 1988 and 1989, Shop 51P targeted 5% as their internal operational defective rate. Figure 5 depicts what was experienced during that time frame.

Rework was a very complex problem. There were many variables that could have contributed to the high rework rate experienced at Norfolk Naval Shipyard. One must be able to identify the variables and break them into two different groups, internal and external. Upper management in the production shop would be able to control and affect

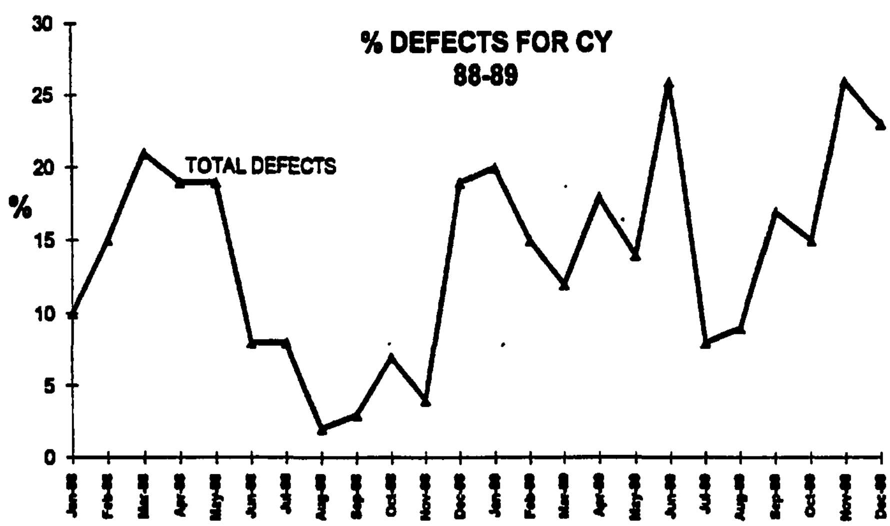

Figure 5. 1988-1989 Total Defect Rate

those variables that were internal. The external variables must be dealt with at a different level. The variables needed to be identified, reviewed, ascertained whether value added was being achieved with this variable, find out whether it was causing a bottleneck, and what were the associated costs of these variables.

It is during the initial stage that caution is paramount in sifting through information from interviews. One has to decide whether the "surfaced" or discovered variables are in pristine form, or whether the variables are cultural, political, or management style. Additionally, the variables should be used as a descriptor (measurable) when one categorizes problems experienced and identified in using the statistical charts. Then one would further refine this information as to whether the discrepancies were common causes or special causes. The following observations are made by the rework study team.

Communication

There appeared to be a lack of communication between Shop 51P and other sections within the Production Electrical Department. This observation was based upon a job reviewed by the rework study team resulting from an on-site visit aboard Ship A. The work had been prefabricated, given to Production Electrical Department's Waterfront Section (Shop 51W) for routing, and upon inspection, Shop 51W had signed off that their work had been accomplished. Inspection by the rework study team showed that this was not the case. Therefore, Shop 51P was required to follow up and finish the work that Shop 51W was supposed to have done.

Material

Shop 51P was required to fabricate connectors that were solder and crimp types. An internal study by Shop 51P had shown that if the crimp type connectors were used, a large cost saving could be achieved. The solder type connectors were usually two or three times the cost of the crimp connector and the same multiplier could be applied in the fabrication process. For example, a solder type connector would cost $96 and take approximately 14 hours to fabricate. The crimp connector would cost $32 and would take approximately 4 hours to fabricate. After the connector was fabricated, checked out, inspected, signed off, given to Shop 51W, routed, made up on the other end, and connected, other problems arose.

When an equipment connector was fabricated, many times the cable had to be bent 90 degrees to allow for the equipment to be returned to its original space. In the process of moving, damage would occur that sometimes caused the connector to fail on the final ring-out. If it was a solder type connector and if the problem was in the middle of an 80 pin pattern, several hours of work may have been required to remove the other solder joints to get to that one malfunctioning pin. On the other hand, the crimp type connector would take only 10 to 15 minutes to pull out the malfunctioning pin, reconnect it and move on to another job. Shop 51P had requested that this substitute be provided to achieve a cost saving, but to date were having problems getting the necessary approvals at the NAVSEA level.

Quality Control

As was previously stated, the mechanics were advised of the rework problem in Shop 51P. The Quality Circle felt that a team approach would result in a reduction of rework. It was determined that using the team approach did not provide the means for tracking the fabrication of the connector back to the individual mechanic. Therefore, there was anonymity in the audit trail.

Inspection

In May 1989, after a plug was fabricated, it was inspected by specified personnel in Shop 51P. An internal quality assurance group was established, and those individuals were required to inspect all plugs and sign off as to whether or not the connector met the necessary specifications, for example: that the correct backshell was used; the environmental seal was properly installed; and the backshell was engraved.

Training

The rework study team was informed that there were new mechanics continually coming through the plug section. Since a contributing factor to the high rework rate was inexperience, certain types of training were required in the fabrication of plugs. The Shop 51P foreman was trying to cross-train all individuals to provide back-up support as the need arose.

Costs

To bring to light what the costs associated with this rework rate were, it was necessary to analyze what actually took place after the mechanic fabricated the plug. Figures 6 and 7 were flow charts that outlined what happened in the event of rework and remake, respectively. Tables 1 and 2 of

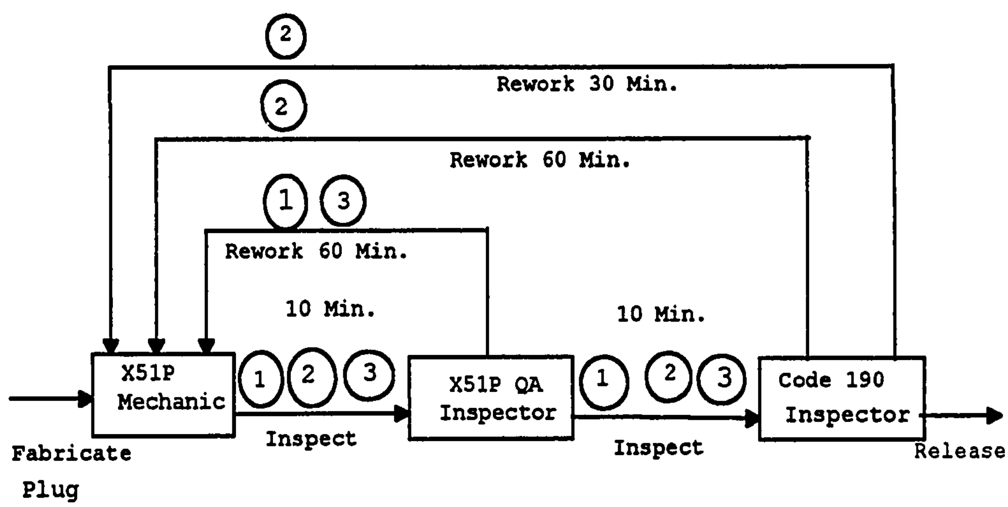

Figure 6. Rework Schematic

Appendix B provide the time and costs associated with each process.

Shop 51P provided documentation outlining a job completed on Ship B. This job consisted of the fabrication of 285 plugs on SYSTEM A which, after inspection by both Shop 51P and Combat Systems, resulted in a 55% rejection rate (see table 1 of Appendix B). Table 3 of Appendix B outlined the associated costs for both inspections and rework to be $14,876. The cost of rework for this job was $11,547 that translated to an additional cost of $40.51 per plug.

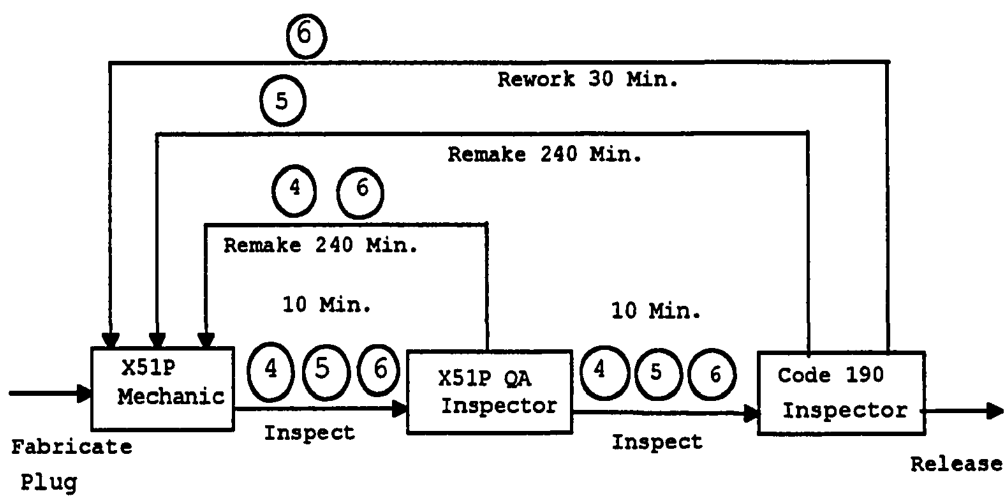

Figure 7. Remake Schematic

Management Reports

There appeared to be a lack of management reports for the mechanic's foreman and for upper management. Management realized that a problem existed, but without any feedback systems to alert anyone, they could not develop a feasible solution. It was difficult for upper management to address these problems without any areas on which to target their concerns.

Paperwork

The mechanic was required to fill out three forms while fabricating the plug. However, before the job was started, the lead mechanic had spent between 150 and 400 man-hours compiling a material order list to have necessary material (connectors, cable, backshells, etc.,) on-hand when the job became available to prevent peaks, valleys and bottlenecks during work periods.

Blueprints

It was observed that the lead mechanic would work up the job order so that the material could be ordered. To order effectively the material, a set of blueprints would be obtained from Planning and Estimating Division or Design Division of the Engineering Department. Blueprints would sometime cause problems throughout the Production Electrical Department. Not using the latest revision would often result in rework.

Audit Trails

In May 1989, when the backshell specifications were ordered incorrectly, quoted cable length were incorrect, or wrong connectors were constructed, there were no audit trails available to identify the engineer that designed the system, the estimator that provided the incorrect standard or the mechanic that fabricated the plug.

Shift

Problems also surfaced because each shift was not fabricating the same number of plugs per person. For example, it appeared that the second and third shifts were behind in production. This could have been attributed to the lack of supervision on those shifts or mechanics failure to follow the earlier shift's instructions.

Supervision

Upper management hired three additional supervisors to address the shift issue. Additionally, there were communication problems between Shop 51P and 51W due to the lack of understanding from one supervisor to another as to their respective responsibilities.

Set Up

Often there were problems in the cable preparation; for example, sometimes the wrong backshell or connector was provided. Additionally, the mechanic had a difficult time understanding the order of assembly; for example, the placement of the environmental seal could be reversed as illustrated in Figures 3 and 4. Many times the exploded view, depicted in Figures 3 and 4, provided to the mechanic would not be up-to-date. Finally, there was a question as to the quality of the craftsmanship. In setting up the connector, the mechanic often needed additional technical information. Lack of training appeared to be the key contributing factor.

Feedback Systems

Shop 51P was allowed to place a charge against the plug fabrication based on a standard of time developed by the Planning and Estimating Division (P&E). There was feedback system in existence, such that when P&E decided that it should take 8 hours to fabricate a plug and it actually took 14 hours, Shop 51P was required to fill out a form for P&E. The reverse was also true. If the mechanic was given 14 hours to fabricate a plug and it took 8 hours, Shop 51P was to fill out the same form for feedback purposes. Even though the system was supposedly in place, the rework study team found this system to be ineffective. Problems were also created when mechanics pointed out that they were experiencing material problems on the ship. P&E would often acknowledge that they had the same problem on the last ship of the same class. Since the feedback loop necessary to correct the discrepancy was not working, no one had taken the responsibility to correct the discrepancy. It became apparent that a better system was needed.

To summarize how the rework study team looked into the very complex problem of reviewing rework variables: communications; material; quality control; internal/external inspections; training; costs; cooperation; lack of management reports; paperwork for both the mechanic and for the development of the job order; blueprints and the latest revisions; lack of audit trails; shift; supervision; setup (cable preparation, assembly, craftsmanship, and technical information); and feedback systems affecting the fabrication of plugs.

A mechanism was needed to identify those variables that were measurable, specifically: paperwork; material; inspections; quality control; training; setup; and feedback systems. In June 1989, 109 variables (see Form 1 of Appendix A) were found to influence the plug rework rate. It should also be understood that only one variable was needed to place the plug in a state of nonconformance since inspection of the plug resulted in a binomial outcome, either pass or fail.

Action Taken

1. To reduce paperwork, three forms were combined into one (Form 2 of Appendix A). This form provided a new format for both the immediate management and the mechanic, using a computer application resident on the WANG VS-65 in the

Production Electrical Department with a terminal and printer in Shop 51P. If information on the plugs and connectors were checked and found to be correct, that information would be entered into the data base. This data base would then be used to generate a material listing, the job, and the fabrication sheet for the mechanic on similar class ships.

For example, on the complex submarine class, Norfolk Naval Shipyard was scheduled to do six ships, the first of which was the Ship C. This computer application was tested and this information entered into the data base for Ship C. When this information was checked and verified, the information was put into a data base and was used for the next five sister ships on the same type of work to be done, thereby eliminating redundant efforts by the planner, mechanic and management. Additionally, P&E was able to use this historical information to check the proficiency and productivity of the plug section, because there was a comparison of the fabricating process on the exact same plug for the exact same system on the same class ship. This provided better information on what the problems experienced were and assisted management in targeting better solutions.

2. To assign responsibility to the right person, it was recommended that the inspections provided by Combat Systems be totally eliminated and be the sole responsibility of Shop 51P. This did two things: it reduced the time for inspections and, therefore, the charges in fabrication, and

placed responsibility with the person who did the work. Therefore, knowing who was responsible would help Shop 51P do a better job.

Quality Control concepts would, therefore, follow if some of these plans were instituted. Additional responsibility was placed on the internal Shop 51P Quality Assurance inspectors, because they were required to find all mistakes and not try to help a fellow mechanic by allowing poor workmanship to pass. This suggestion was well received, and the Quality Assurance inspectors in Shop 51P felt that they were up to this task.

3. Feedback systems were instituted as modules in the computerization of this system. The rework study team identified the type of management reports needed for mid-and-upper management to do their job, and what type of data elements needed to be collected. Management reviewed the recommendations and concurred. Data Processing Division developed the computer application that generated the necessary management reports and provided other helpful suggestions.

4. It was recommended that after the computer system had been designed, tested, debugged and refined, Shop 51P would not be an isolated testbed. Other shops throughout the shipyard could benefit from this concept. Therefore, after this work was done, upper management would take a look at possibly expanding this system into other shops within

the shipyard and, if successful, possibly into other shipyards.

Evaluation Of Recommendations

To evaluate the causal effects of the recommendations outlined above and with additional rework study team efforts of addressing common cause/special cause for the variables, it was agreed that a period of time needed to elapse. This interim allowed for feedback from both Shop 51P mechanics and management which pinpointed areas for "fine-tuning" the process. The following is from NNSY management report dated November 1989.

1. Computer Application. The Data Processing Division developed and installed the computer application in August 1989. Since installation, the management of Shop 51P and the study team requested additional reporting capabilities. The Shop 51P computer application had the following features:

   a. Management Reports. Utilizing the data elements outlined from Form 2 of Appendix A, management can receive information sorted by: cable type; cable length; cable status; work area unit number connector; adapter; backshell; work status; cable diagram; system; job order; fabricator; inspector; shift; discrepancy code; cost; and by ship or class of ship.

b. Historical Information. The data base consisted of: when the job has been finished; the work order completed; the material breakdown; hours worked; and the problems experienced. This would eliminate the duplication of effort for the same work on the next ship of the same class (e.g., Ship C class will have five sister ships with basically the same work package). A feedback system incorporated in the computer application will address the following: areas where corrective action was needed (e.g. workmanship, training, material, blueprints) to prevent reoccurrence; P&E to reevaluate time standards; and provide further connector documentation on the crimp versus the solder controversy.

c. Shop 51P. An initial premise to the study was that the worker did not come to work to make a bad product. Also, it was understood that whatever information was developed would not be punitive in nature to the mechanic. According to the Deming approach, unless a process was in statistical control, any perturbation to the process cannot be properly evaluated since there is no strong one-to-one correlation with any change to the results being directly attributed to that perturbation. The results being experienced could be imputable to either random variation or noise in the system. Therefore, it was this author's role first, to insure that the work process was in statistical control so that when perturbations were made to the system, that the results were based solely on that perturbation. Therefore, recommendations for changes to the internal variables were based on the effort to remove barriers for the mechanic and to bring the process into statistical control. The computer application did highlight areas of weakness by person, shift, plug or system. This has assisted management and team leaders for training proposals, cost analysis, quality control, inspections, and audit trails to the responsible parties.

d. Paperwork Reduction. Initially, paperwork was reduced by 2/3 by combining three forms into one. If a data base was already established on the upcoming work for the same class of ship, then almost 99% of the activity of paperwork preparation has been eliminated. The only exception would be if there was a new revision not established in the data base. The time set aside to work up the new job order has been eliminated and Form 2 of Appendix A will be printed for the mechanic with the needed material, locations, check-off list, inspection information and a place for final sign-offs. Also the data base provided information for the manual generation of spaghetti labels for the upcoming connectors.

e. Assist to Other Codes. After the data base was finished for Ship B, the rework study team contacted Combat System to see if they could benefit from the information already developed. NAVSEA requires Combat Systems Division to investigate and verify (I&V) all cables on a job. Due to lack of staff, Combat Systems Division requested that Shop 51P could take over this responsibility. In subsequent meetings, Combat Systems Division's staff stated that the I&V sheet (Form 3 of Appendix A) had thirty-one (31) items that needed to be initialed. Therefore, a job of 300 cables would require 9300 initials (300 cables x 31 initials). After some discussion, it was revealed that the initials in each square were needed to provide an audit trail per regulations. Since the information needed for

Form 3 of Appendix A was already in the data base, it was agreed that an extra report would be generated to satisfy this NAVSEA requirement. The initials for the report would be computer-generated from the final sign-off sheet. The Data Processing Division finalized this request which placed no extra burden or paperwork on Shop 51P and changed the existing procedures for Combat System Division while continuing to meet the NAVSEA requirement.

2. Rejection Rate. With the institution of the recommendations and through the efforts of the mechanics and management of Shop 51P, there was a drastic reduction of rework. During the interim, from August to November 1989, the internal rework rate for Shop 51P was reduced from a sample job of 55% to under 6%. As of November 1989, that had been further reduced to less than 3%.

3. Costs. Some of the items addressed have resulted in either cost savings or cost avoidances. Both of these areas are presented, in table 3. This data is for approximately 10,000 plugs a year.

TABLE 3

SUMMARY OF COST SAVINGS AND COST AVOIDANCE

Appendix B	Description	Low	High
Table 4	Eliminate Combat System inspectors	$60,000	$120,000
Table 5	Reduce rework rate	$325,600	$325,600
Table 6	Reduce paperwork	$1,281,750	$1,281,750
Table 7	Computerizing Combat System I&V Report	$180,000	$180,000
	Total	$1,847,350	$1,907,350

Part II

Figure 5 depicted that Shop 51P was not successful in bringing the plug process into statistical control during 1988, but with the review by the rework study team and implementation of their recommendations an effect was noted in the later part of 1989.

As established in Chapter IV, a discrepancy list was developed that grouped defects by category. This information was coded and readdressed the issue of what influences were contributing to rework rate displayed in Figure 5. A Pareto Analysis was performed on the coded defects with the results shown in Figure 8.

By breaking down the process, it enlightened the plug section upper management as to what control they had in

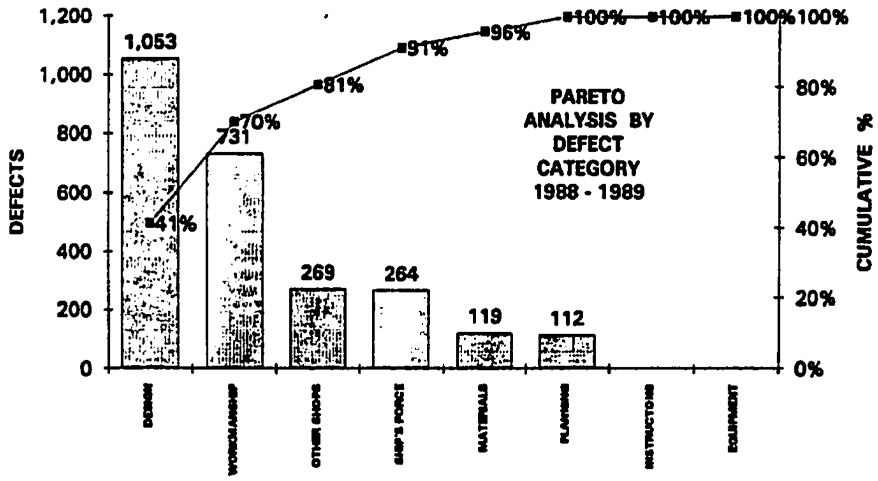

Figure 8. 1988-1989 Pareto Analysis by Category

correcting the rework rate for the plug fabrication process. This analysis showed whether the problems were upstream in design, by the Engineering Division, or in the Supply operation providing material; whether their problems were in internal operations in fabricating the plug; or if the installation of the cables onboard ship were the major

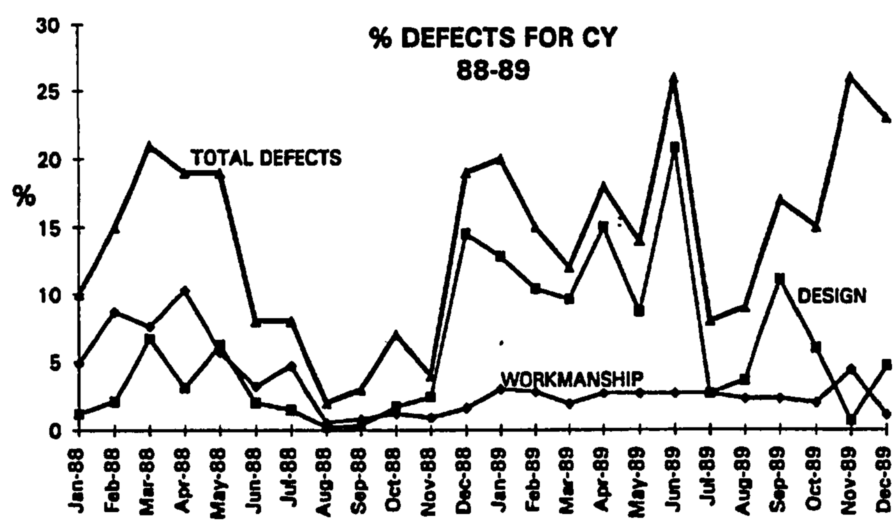

Figure 9. 1988-1989 Total Defects By Category

contributors. Figure 9 is Figure 5 redrawn but with the aggregated data further broken down.

Two categories titled Design and Workmanship contributed 70% to the rework rate during the 1988-1989 time frame. It should be noted that only two categories were represented along with the "Total Defects" in Figure 9. The major influence contributing to the defect rate was the category, "Design." Shop 51P was included in the chart to reflect the "Workmanship" item's contribution. The "Total Defect" line was made up from the cumulative coded categories. For example, in Figure 9 July 1989 showed that the Total Defects rate was 9% but both Design and Shop 51P only contributed 2% each with the other categories at 5%.

> ...The ultimate object is not only to detect trouble but also to find it, and such discovery naturally involves classification. The engineer who is successful in dividing his data initially into rational subgroups based upon rational hypotheses is therefore inherently better off in the long run than the one who is not thus successful (Shewhart 1931).

Figure 10 portrayed a small run "p" chart representing nonconformance for the category of "Workmanship" utilizing equation 4.1. It shows that the plug process was not in statistical control during the 1988-1989 time frame.

$$(4.1)\ \text{p Plot Point (May 1988)} = \frac{5.7\% - 5\%}{\sqrt{[5.0\%(100\%-5\%)/1262]}} = 1.14$$

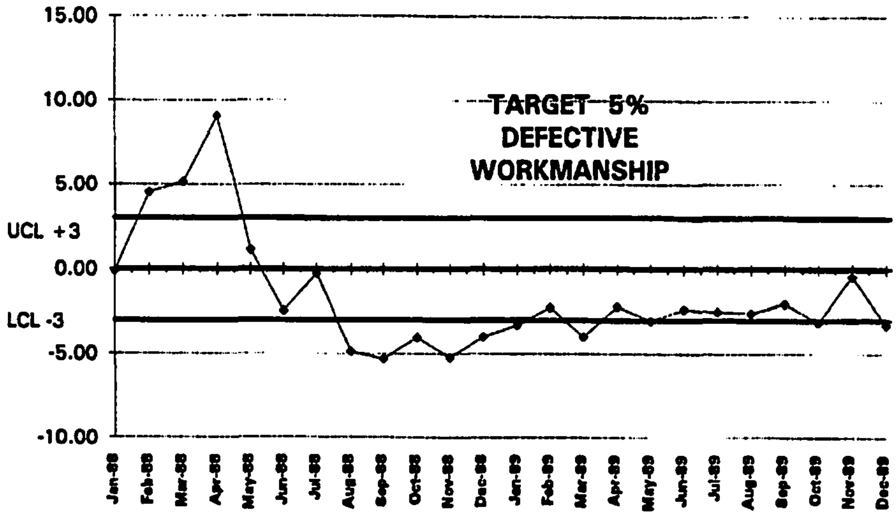

Figure 10. 1988-1989 Small Run p Chart Target 5%

Interim 1990-1991

Through continuous improvements made by both management and mechanics, Shop 51P strived for a reduction in the category of Workmanship from 5% down to 2% rework rate during the calendar years 1990 and 1991. Figure 11 depicts

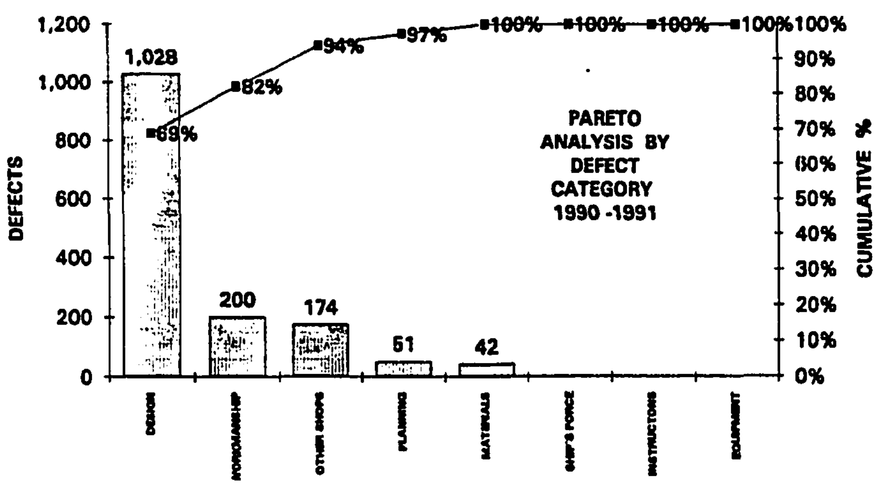

Figure 11. 1990-1991 Pareto Analysis by Category

the results of the Pareto Analysis for this time period. As in the previous years, Design and Workmanship were the top two categories, contributing 82% of the defects.

As illustrated in table 4, one category primarily remained the same, whereas, the other category achieved a major reduction.

TABLE 4

Catagory Comparison 1988 - 1991

Category	1988-1989	1990-1991
Design	1053 defects	1028 defects
Workmanship	731 defects	200 defects

On the basis of the Pareto Analysis, Figure 12 portrays the defective rate for 1990-1991.

Workmanship appeared to be stabilizing but Design was not brought under statistical control. To see if the

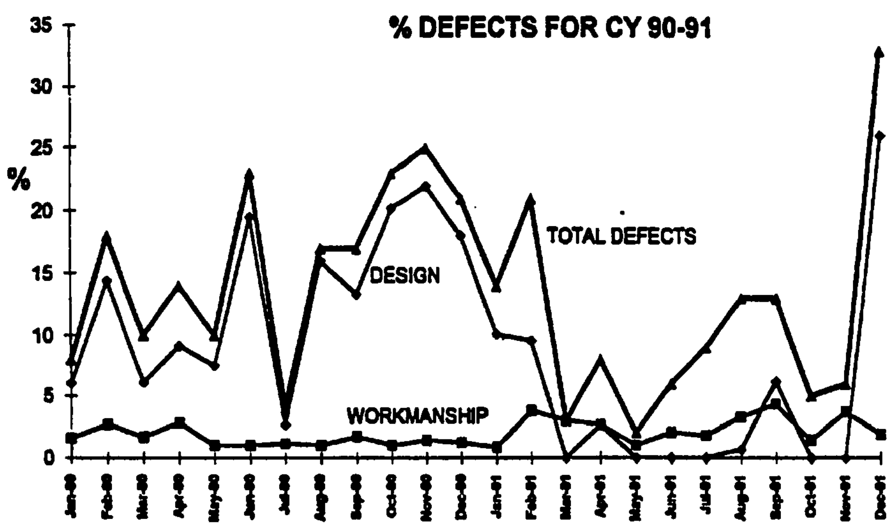

Figure 12. 1990-1991 Total Defect Rate By Category

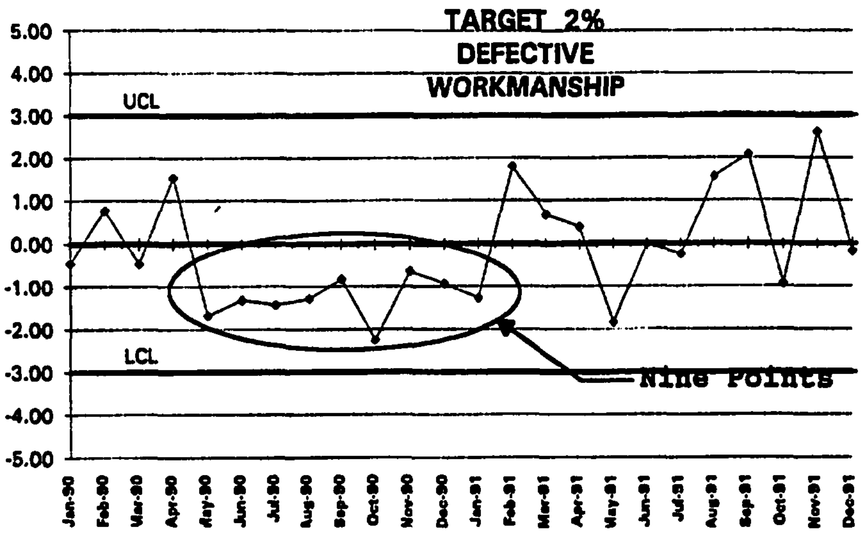

Figure 13. 1990-1991 Small Run p Chart Target 2%

Workmanship category was in statistical control, a small run analysis (Figure 13) was calculated using a target $\bar{p}$ of 2% defective.

One of the more valuable uses of run charts is to identify meaningful trends or shifts in the average. For example when monitoring any system, it is expected that one would find an equal amount of data points falling above and below the average, in this specific case "0." Therefore when nine points "run" on one side as depicted in Figure 13, it indicates a statistically unusual event and that the average had changed. If the shift is favorable, it should be made a permanent part of the system. If it is unfavorable, it should be eliminated (Hansen 1963; Grant and Leavenworth 1988). Figure 14 reflects a favorable shift for Shop 51P because their rework rate $\bar{p}$ shifted from 2% to

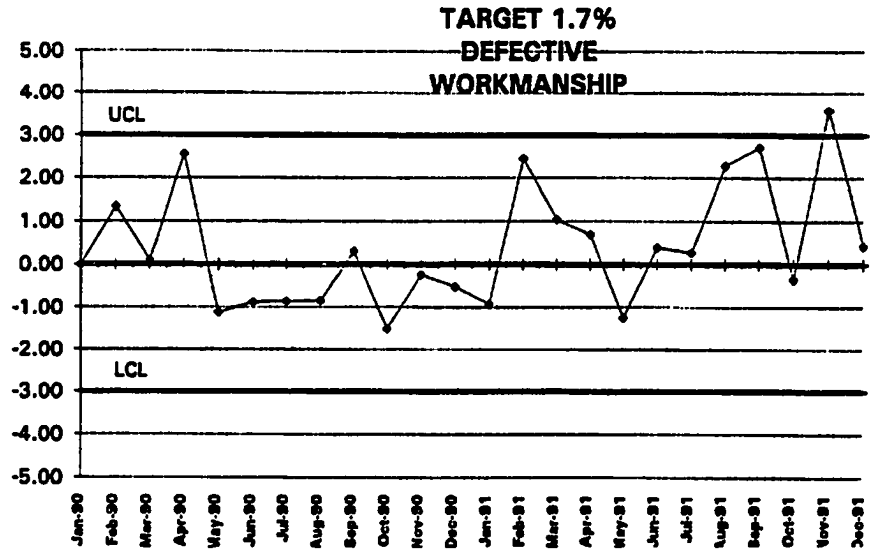

Figure 14. 1990-1991 Small Run p Chart Target 1.7%

1.7%. As illustrated in this graph, Shop 51P (internal category titled Workmanship) was in statistical control with tests of variables that affected the process being useful only with a target $\bar{p}$ of 1.7%.

> Tests of variables that affect a process are useful only if they predict what will happen if this or that variable is increased or decreased. It is only with material produced in statistical control that one may talk about an experiment as a conceptual sample that could be extended to infinite size (Deming 1980).

Therefore, any change to the existing system would be a direct result of that perturbation and not a result of something that happened by chance. Internally Shop 51P had a stabilized or statistically controlled plug fabrication process, but now must go outside their realm of control to the Design Division to affect a positive change. The criteria for success will be if cost savings can be achieved and the overall defect rate further reduced.

1992 System

When a job order is received by a waterfront mechanic, he first must order and receive the drawings from the Design Division. Using these drawings, he manually composes a list of cable markers needed on the Shop Material Tag Figure 15.

Cable markers are required every 50 foot on the cable;

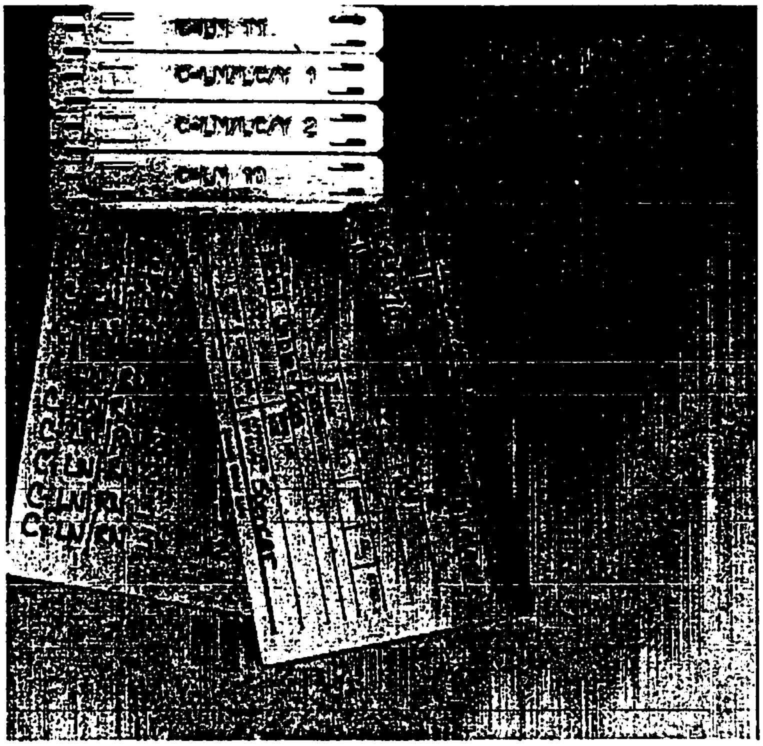

Figure 15. Shop Material Tag

at each end of every cable pulled; and before and after every entrance into a ship's space. The information is then typed from the handwritten Shop Material Tag onto an embosser that stamps out metal cable markers also illustrated in Figure 15.

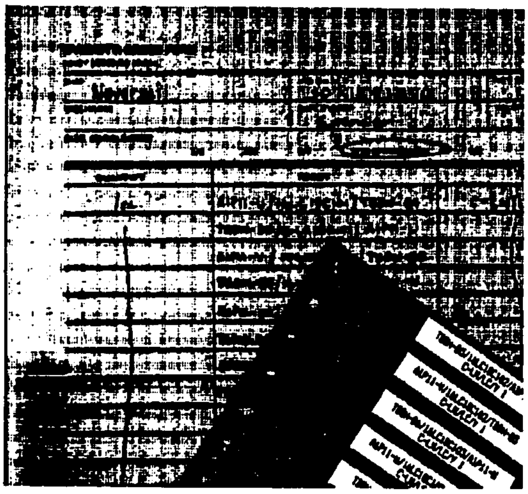

Figure 16. Spaghetti Order Form

Figure 17. Spaghetti on Wire

Using the same drawings, the mechanic hand-writes wire markers or spaghetti, that are needed to complete his job on the Spaghetti Order Form Figure 16.

Spaghetti/wire markers are used on each lead in every cable to identify location of hook up and what cable it is. These forms are carried to Shop 51P in Building 510. Mechanics in Shop 51P then input this information into a personal computer (PC) and prints both the associated cable markers and spaghetti/wire markers (see Figures 15 and 16). The waterfront mechanic then sorts these wire markers, which could number up to 80 pins per cable, according to cable number for his usage in the plug fabrication process. These wire markers are then placed over the wire and heat shrunk into place (Figure 17).

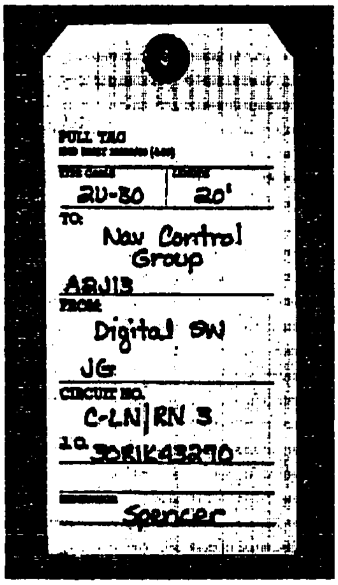

Figure 18. Cable Pull Tag

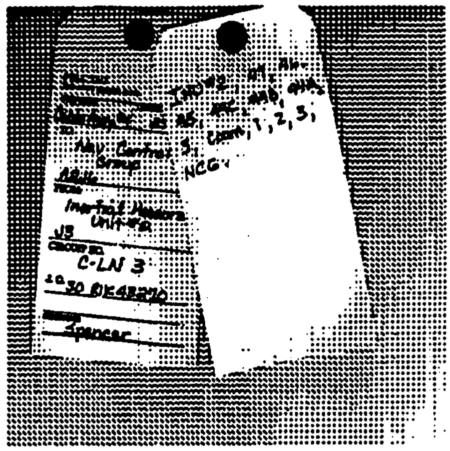

Figure 19. Cable Pull Tag with Routing

Cable pull-tags (Figure 18) are handwritten for each end of the cable for identification and are installed when the cable is installed in the ship.

Submarine mechanics also must write cable routing on pull tags (Figure 19). Submarine cables are required to follow specific routes in wireways designated by the Design Division. Up-to-date reports on job progress are nearly nonexistent for waterfront. Those reports are the results of many hours of hands-on counting of cables pulled, hooked-up, etc. Most mechanics are not knowledgeable about the number of cables in their system.

When a job order is received by a plug section mechanic, it must also be accompanied with a copy of the drawings from the Design Division. It should be noted that drawings from the Nuclear Department take a very long time to reach the production shops. Shop 51P mechanics use these drawings to extract information to complete a Connector Control Sheet (Form 4 of Appendix A).

This information is turned over to the Shop 51PE (Printing/Engraving) mechanic, who then enters the information into the WANG data base. Shop 51PE then prints a Fabrication Sheet (Form 2 of Appendix A) for each connector that is to be fabricated. This becomes an inspect and verify (I&V) document that is used to pre-kit connectors and I&V them.

Shop 51P has access to reports generated by this input that sorts jobs by unit, system, and cable number. Shop 51P can also generate up-to-date reports of job progress for the foreman (Form 5 of Appendix A).

The reports presently generated by Shop 51P are hand-carried to General Foreman, Code 190, and other shops at their request. Rework reports and process yield reports are forwarded to QA (Quality Assurance) officials as requested.

Qualitative Research For Change 1992

> It must be considered that there is nothing more difficult to carry out, nor more doubtful of success, nor more dangerous to handle, than to initiate a new order of things. For the reformer has enemies in all those who profit by the old order and only lukewarm defenders in all those who would profit by the new order, this lukewarmness arising partly from the incredulity of mankind, who do not truly believe in anything new until they have had actual experience of it. Thus it arises that on every opportunity for attacking the

> reformer, his opponents do so with zeal of partisans, the others only defend him half-heartedly, so that between them he runs great danger (Machiavelli 1513).

On the basis of presented Pareto Analysis, it has been determined that Design and Workmanship were the two major categories causing problems in the rework rate for the production of the electronic plugs fabrication. After several years of production working internally with the rework problems that they had control over, the Shop 51P mechanics were able to achieve statistical control. The Pareto Analysis has shown that one of the categories that was contributing to the rework rate of the plug was the Design Division. Now, based on Deming's Theory, a perturbation to the system is appropriate.

> Deming's Theorem No. 3 If you have a problem that came from somewhere and you cannot trace it to the source, the problem will stay right there (Deming 1982b).

Traceability is the ability to track problems to their origin. This may require reorganization of the work flow. There are two ways that work could be organized, either flow of authority (which is an organizational structure) or flow of work (which is procedural). The optimum organizational structure depends on the type of operation. Traceability permits accountability, a powerful motivating factor. More important, traceability is essential to locate problem causes. When work is mixed from more than one source, the input units combined will exhibit a wide variation that obscure some of the special causes.

When the Design Division was notified of the problem that they were causing farther down the line, they requested documentation proving this matter out. Shop 51P provided a convincing argument to the engineers by presenting documentation, charts, and statistics, that had been gathered during Shop 51P's statistical control effort. After several months of meetings and adopting the strategy utilizing Concurrent Engineering, it was decided that the Design Division would work with the Production Department in the cabling and hookup data base contents.

The Design Division provides information in the wire table that outlines: connection and hookup data; block wiring or cabling diagrams which outlines the material data, on connectors, the back shell, or adapter, the cable length, and the cable type; or equipment information as to the type of terminations and the jack numbers; a cable routing diagram that routes the cable through the different hangers and compartments.

It was discovered that the Engineering Division directly passes on information from the planning yard, for example, Newport News Shipyard and Drydock Company from its ship alteration drawings in a hard copy format. Shop 51P then has to reformat this information into a computer data base that not only contains the required data but also administers how the shop accomplishes and certifies the work. Specifically, this data base is used, not only for hookup, but also to manufacture cable tags, wire markers, job instructions and provides production with direct access to the technical data specified by the Engineering Division.

The Design and Engineering Divisions feel that an organizational paradigmatic change will be needed to bring about this perturbation. The design engineers also sense that there will be implementation problems. They believe that these problems will be brought about by the existing inertia of the engineers and the upcoming changes for designers by departing from the traditional drawing development practices, for example, block wiring diagrams, wiring tables, material lists, and arrangements. The engineers think that preparing this data base will support the production processes, particularly: the cable pulling/routing; material staging which is called kitting; the connectorization and the identification, but will do little to assist the engineering functions. Second, they sense there will be a lack of coordination between production and engineering resources, both in personnel and in systems necessary to streamline the data creation in use. Third, the planning yard (Newport News Shipyard and Dry Dock Company), which produces the ship alteration drawings and other installing activities, are beyond the control of the public shipyard, resulting in non-standardized formats. The system designed to address these issues and cause these organizational paradigmatic changes is designated, the Cable Management System.

Perturbation 1992

Cable Management System (CMS) originates in the engineering codes, with the development of a data base for each shipalt (ship alteration). This data base provides the following information, all of which was manually extracted by shop mechanics prior to CMS.

1. Shipalt
2. Ship name
3. Hull number
4. Cable designation (number)
5. Unit A designation
6. Unit B designation
7. Termination points for unit A and B
8. Connector part numbers
9. Connector pc numbers
10. Backshell part numbers
11. Backshell pc numbers
12. Compartment numbers for both units
13. Cable type
14. Estimated cable length
15. Cable status (new, existing, rerouted, etc.)
16. Cable routing, if applicable
17. Block diagram number

18. Thru-hull/local cable type
19. Cable Diameter
20. Formable hook-up
21. Notes and remarks

This data base is electronically transferred into Shop 51PE and is used to automate the following processes there by eliminating manual input.

1. Cable pull tags
2. Cable markers
3. Wire markers
4. Cable routing tags
5. Fabrication Sheets
6. Temporary wire markers
7. Reports

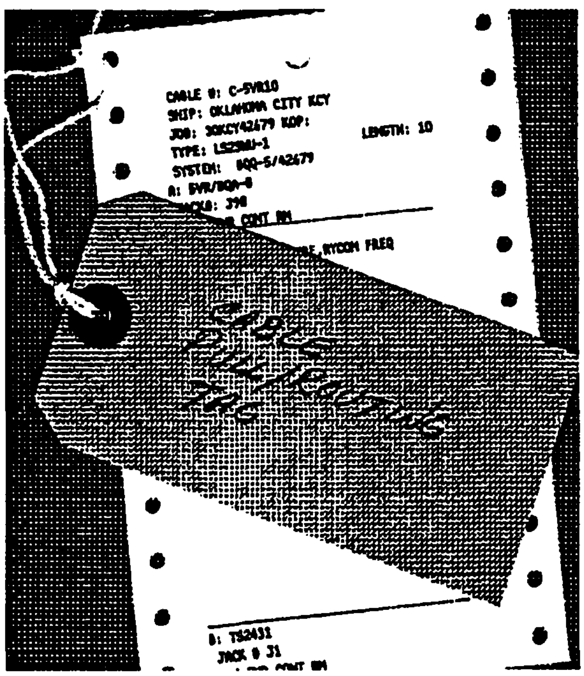

Figure 20. Automated Pull Tag

Then Shop 51PE prepares "pre-kits" jobs for a ship that include all information for hookup: pull tags, cable markers, wire markers, routing tags and temporary wire markers.

Shop 51PE also provides Shop 51P mechanics with reports and fabrication sheets for their jobs, requiring minimum research to complete their pre-kitting of connectors.

Shop 51W/S (Waterfront/Submarine) also receives their pre-kitted package along with the pull tags (Figure 20).

The pull tags provided are two-part tags. When the cable is pulled to the unit, the lower portion is completed and turned in to the lead mechanic or supervisor. This information is input into the computer providing a tracking system for cables pulled. When cables are hooked up, cable markers are placed at the point of termination and the remainder of the tag is removed, completed, and turned in. After this information is entered into the computer, Shop

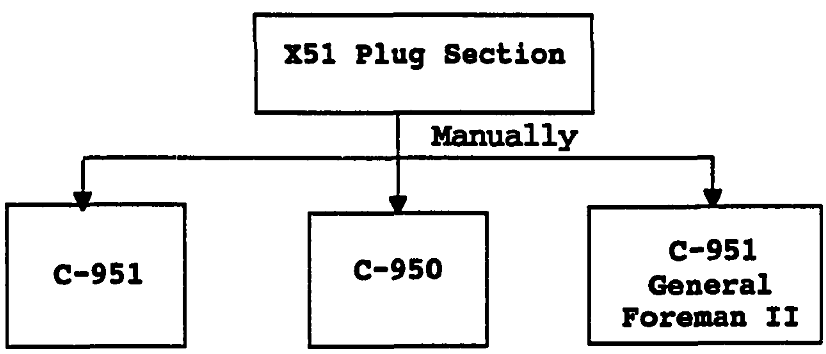

Figure 21. Existing Informational Flow
Shop 51P

51W/S completes the information on cable status for the job. This capability has never before existed for waterfront jobs.

Since many of the manual operations will be replaced by new technology, a graphical representation of the existing operational flow for Shop 51P is depicted in Figure 21.

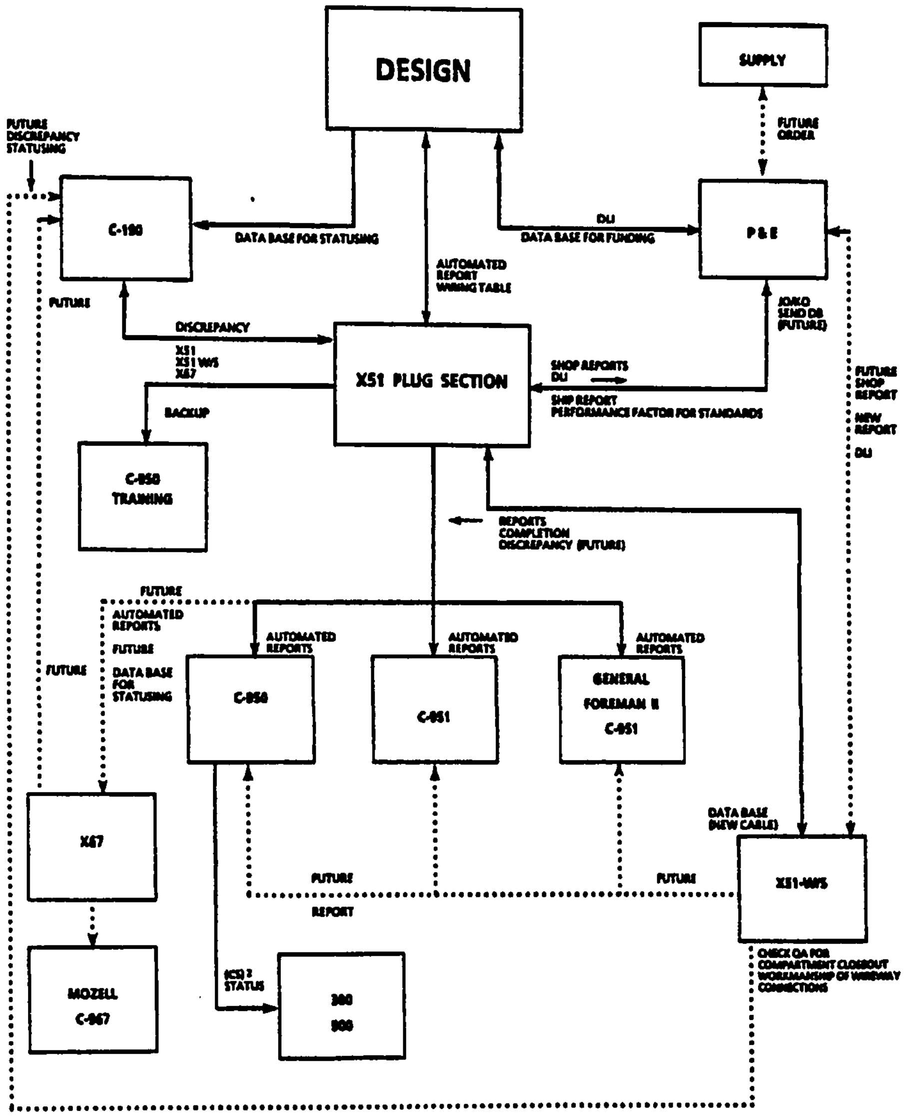

Figure 22. CMS Informational Flow for Shop 51P

The system of informational flow for Cable Management System is shown in Figure 22. This figure should provide a better understanding of the system's effects on the shipyard-wide organization.

Note that the dashed lines are future computer links that will be developed. Following this figure, a data base will be created in the Design Division and sent to Shop 51P. Shop 51P will download the data base into a software program called Cablemark, and use the information as previously described. The Design Division will send updated data base files on a weekly basis, including all EWIs (Engineering Work Instruction). An output of the Shop 51P application will be an updated data base for Shop 51W that will be used in their program under development. This will be sent by modem at the present time and will later use the shipyard LAN (Local Area Network) as it is connected. Presently, the equipment plan for CMS is to use existing terminals/PC's that are in-place for Code 950.

CMS Components

A LAN within Building 510 will accommodate the sending of updated reports directly to upper management in the shops. A list of the hardware necessary to implement CMS in Shop 51P is shown in Figure 23. The embosser is a machine that fabricates the metal cable tags described earlier. The number of printers facilitates printing more items simultaneously.

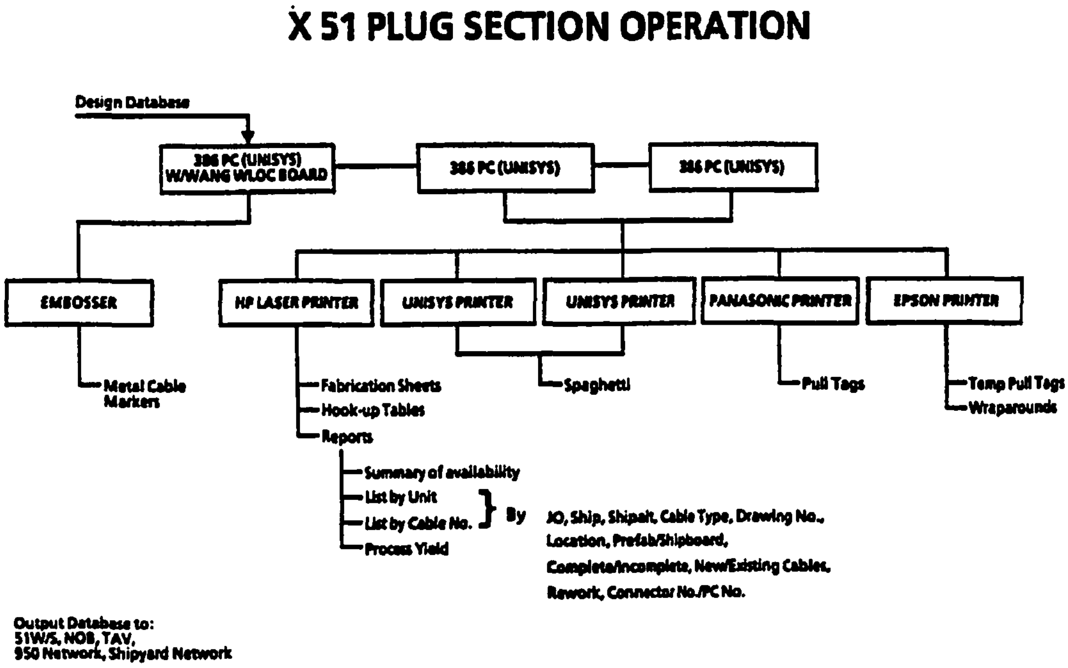

Figure 23. Shop 51P Portion of CMS Hardware Configuration

The imported data base from the Design Division is used to create a variety of items. The system is designed so that one person can operate it at most times. Previously three to four people were necessary. The Design Division's data base, in conjunction with the new application, will allow the mechanic to print all of these items for a single cable at one time. Then the pre-kitting will be a simple job of collecting all the items and placing them in a bag. CMS will also batch items to produce all the items for a single job or system, if requested.

Cost Analysis

The system hardware configuration to metamorphize this perturbation is outlined in Table 8 of Appendix B for a total cost of $22,300. It should be noted that the spaghetti printers are regular dot matrix printers that have had the roller shaved 1/16th of an inch to allow for the bending radius of the spaghetti markers. This has been tested and proven very cost effective.

The total cost of CMS to the shipyard must also chronicle the additional contribution of manpower and materials. Using the old method, an experiment was conducted employing the manual preparation of cable markers. Predicated on a 1991 audit, Norfolk Naval Shipyard produced approximately 204,000 cable makers, 35,000 pull tags, and 720,000 spaghetti markers in different sizes. A sample taken, timed, then extrapolated based on the 1991 production units, shows a manual cost of cable markers preparation to be $471,000. Utilizing CMS new technology of PCs, since most of the manual work will be removed, will cost $26,000. Material contribution, again based on the amounts outlined from the audit, shows status quo costs of $484,000 and using the new system a reduction to $310,000 (Table 9 of Appendix B). Table 5 summarizes the cost comparisons of manpower

TABLE 5

Summary of CMS costs

TOTAL SAVINGS	Manpower	Materials	Total
Old Method	$471,475	$484,510	$955,985
New Method	$26,165	$310,460	$336,625
Total Savings	$445,310	$174,050	$619,360

and material between Cable Management System and the existing shop operation.

Table 5 shows a total cost savings of about $619,000 with the components of manpower and materials. But this cost savings does not correctly reflect the true total cost of Cable Management System to Norfolk Naval Shipyard. Table 10 of Appendix B shows that the cost savings of $619,000 was achieved in year one but one has to back out the cost of hardware ($22,300), software cost ($14,500), and the perturbation has off-loaded some of the personnel costs from Shop 51P and has transferred them on to the Design Division so the savings reflected in the first year are not $619,000, but actually a savings of about $530,000, still an excellent return on investment (ROI) of about 1400 percent.

$$\text{ROI} = \frac{\text{SAVINGS}}{\text{INVESTMENT}} = \frac{\$530{,}000}{\$36{,}800} \times 100\% = 1440\% \qquad (5.1)$$

The Cable Management System was approved in April 1992. With the development of software, interface design for specific equipment (embosser), hardware approvals and purchase, local networking installed, redesign of forms, purchase of different materials (pull tags, spaghetti, cable markers, cable routing tags, fabrication sheets), and reorganization of responsibilities, CMS became operational in November 1992.

Results Of Perturbation

As the Cable Management System was implemented at Shop 51P in November 1992, Norfolk Naval Shipyard (NNSY) initiated a major ship alteration that replaced the existing wire cable with fiber optic (FO) cable. NNSY had some minor exposure in FO installations that requires special training on the handling, bending radius restrictions, polishing and

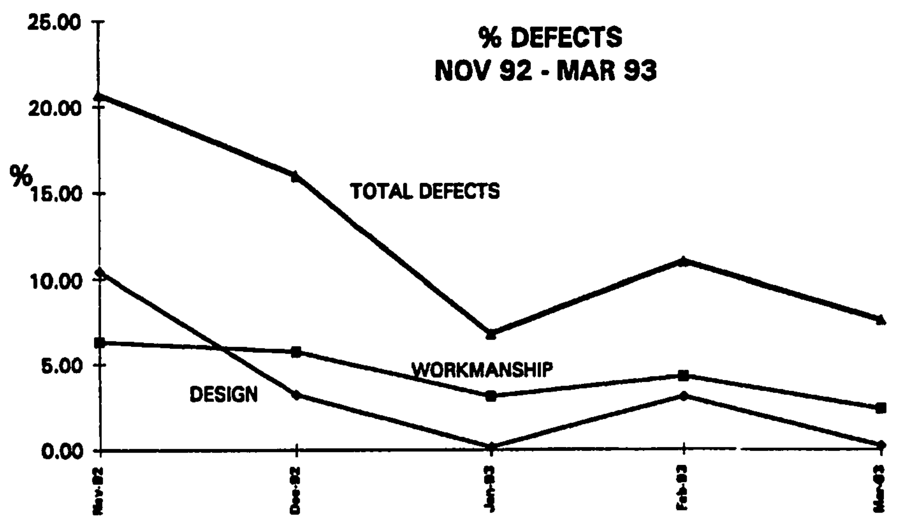

Figure 24. November 1992 - March 1993 Total Defect Rate By Category

splicing connections. Neither the Design Division nor Shop 51P has the wealth of knowledge nor experience with FO that has built over the years in dealing with the media of wire cable. Some problems were anticipated and are reflected in the monthly defect rate for the Shop 51P in Figure 24.

This chart's timeframe covers CMS installation from November 1992 and ends in March 1993. By spanning the fabrication process for this interim of several months, it would give CMS an opportunity to take effect on the shop's operations. Then an evaluation of this snapshot in time would illustrate, at least, a trend line on the effectiveness of CMS even if one could not establish a defect category in statistical control. In November 1992 the total defect rate was over 20%. It should be recalled that Figure 24 only presents two categories, Design and

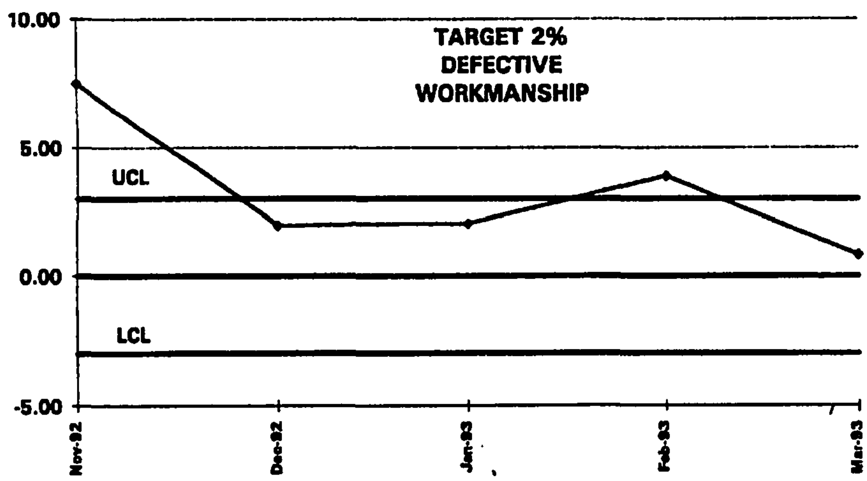

Figure 25. November 1992 - March 1993 Workmanship Target 2%

Workmanship. It has been observed that several things are happening in the plug environment. There is a definite downward trend in the Total Defects category. The Design category shows a drastic reduction to the contribution of the rework rate. The Workmanship category jumped up from an already established rework rate of 1.7% (Figure 14) to over 6% for November 1992. During the next few months, Workmanship also shows a downward trend but in a more stabilized manner. Figure 25 illustrates this point.

Workmanship is not in statistical control with a target of 2% defect rate. Most of this upward movement for Shop 51P was attributed to the FO installation from the ship

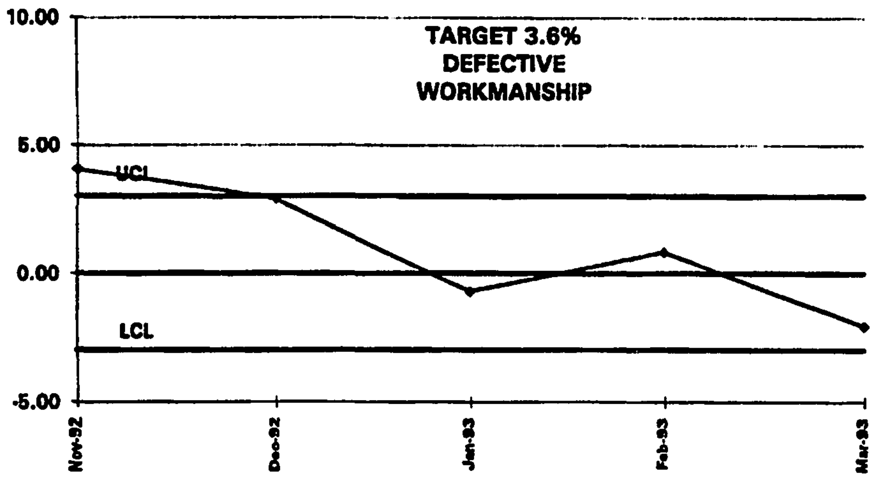

Figure 26. November 1992 - March 1993 Workmanship Target 3.6%

alteration. With all plot points above the average, the chart portrays a system not only out of control but also suggests the target defect rate needs to be recalculated at a higher rate. Figure 26 demonstrates the fabrication process at 3.6% target rework rate.

This chart shows a downward trend that will require a lower target rework rate at a future date. So how would one evaluate the effects of the Cable Management System on the plug fabrication process?

The Shop 51P process was documented to be in statistical control in 1992. The results on the rework rate experienced by Design and Workmanship categories during November 1992 and March 1993 can be attributed to CMS. Considering all indicators on the rework charts show a downward trend, then the perturbation of Cable Management System can be judged as a success. As a reminder, the criteria for positive evaluation of CMS were a perturbation that increased cost savings and reduced rework rate for the defect categories. This system achieved both of these parameters.

Benefits

This system also addressed the concepts of Total Quality Management (TQM): using newer technologies (data bases, networking, automating manual systems); demonstrated an effort that subscribed to continual process improvement; and documented the employees contribution to the manufacturing process. Through this achievement, the benefits to Norfolk Naval Shipyard are as follows:

1. Lowering the rework rate for plug fabrication in the shops.

2. Started a process improvement with an external influence.

3. Introduced new methodology, small run analysis, that was specific to the job shop environment.

4. Brought down cultural and organizational barriers through concurrent engineering strategy.

5. Developed a plug fabrication system that can be exported to both the private and public shipyards.

6. Saved man-hours for:

   a. Shop 51P in creating data base.

   b. Shop 51PE by automating wiring tables for wire markers, cable markers, pull tags, and fabrication sheets.

   c. Shop 51W/S in writing of pull tags and routing tags and wire markers.

   d. Planning and Estimating (P&E) in approximating man-hours for cable pulling and connectorization.

7. The mechanic will have improved information to cable routings and hookup instructions on a cable by cable basis.
8. Timely and efficient incorporation of changes into a data base to avoid rework.

Future

> More than any other time in history, mankind faces a crossroads. One path leads to despair and utter hopelessness. The other, to total extinction. Let us pray we have the wisdom to choose correctly (Allen 1981).

This research on a public shipyard inculcated a manufacturing framework of alternative thinking that bridged the sublime to the pragmatic. It focused the underlying infrastructure that provided a common environment for communications and integration of TQM tools. It additionally provided the framework for success that supported the relentless striving for higher productivity and quality coupled with reduced operational costs in the shipyard repair industry. But there is much more to be accomplished. Future accomplishments should include:

1. As a change to the existing reporting basis, Shop 51P should separate Workmanship category into both wire and fiber optic cables. Presently the information is aggregated and the research has already shown that important information is lost if

grouped and not separated. For example, Shop 51P currently does not know if their wire cable fabrication process is stabilized or how much the wire process is adversely affected by the inclusion of the fiber optics installation.

2. The CMS application should be further developed for the offices that will run any necessary report, thereby, reducing the time a manager must spend trying to get information over the phone or on the ship.

3. A program be written for Shop 67 sections that will use the data base from Shop 51P to develop reports on job progress and track their own ringout on jobs. Reports should be generated for transmission by Shop 67 to upper management.

4. The additional linkage between Code 190 and CMS programs for Code 190 to receive updated information from the data base needs to be implemented. A separate program should be written to transmit and track discrepancies written and completed between Code 190 and Shops 51 and 67.

5. As a major organizational change to Norfolk Naval Shipyard, P&E (Planning and Estimating) should be brought on-line in CMS. The new data base received from the Design Division does not have the job

order or key operation (keyop) information, therefore, it would be prudent for the data base to originate through P&E for the additional information. Also a program must be developed that would automate the estimated man-hours necessary for pulling cable and the fabrication of connectors thus saving man-hours for P&E.

6. Shop reports queries/responses should be sent from the host computer via microcomputers, a concept that is not new but not presently on-line.

7. Future plans should accommodate the Supply Department links to P&E for ordering materials from the data base and include production's upper management for CS^2 (Cost Scheduling and Control System) process and DMR (Defective Material Received) tracking information.

8. Two-dimensional bar methodology needs to be integrated into the shop's portion of CMS. It would eliminate manual input of cable information after the bottom portion of the cable pull tag is torn off after installation onboard ship and returned to the shop for status update into the data base. Additionally, the two-dimensional bar code could be installed on the connector backshell providing model, make, manufacturer, pin

configuration, etc. The bar code could be scaled to the size of a postage stamp and would prove it's worth the next time someone needed to know information about the plug. Presently, someone must expend much manual effort looking up drawings, system, equipment, and location for this data. CMS will have this information in its data base but that will not be beneficial to that person if they are in the Persian Gulf or Japan.

9. Since Norfolk Naval Shipyard receives the planning drawings from NNSD, it should be mandatory to include the private shipyard in CMS's requirements. This would address one of the initial comments by the Concurrent Engineering group. They felt there would be a lack of control for the CMS development with an outside private shipyard like Newport News Shipbuilding and Drydock (NNSD). NNSD would provide the information to the Design Division in a digitized format with the data base layout that supports CMS. Details of the data base pertaining to the exact structure in the field lengths would require further definition. The standardization of such a data base throughout Naval shipyards would be a desirable goal furnishing a necessary tool to implement fully the use of these TQM methods.

10. In the near future CMS needs to look into providing production supervisors with on-site status using portable hand-held computers, when available. The Local Area Network (LAN) has been designed and installed for connectivity from the shipyard to the ship. If this suggestion is implemented, then it would eliminate the need for the production supervisor to leave the ship to receive/respond to an inquiry.

Summary

What has been illustrated is that continuous process improvement can be achieved through the adoption and action using multiple disciplines for quality control issues and problems. Such disciplines as the principles of Quality Management based on the Deming approach can be combined with Pareto Analysis. A nontraditional statistical methodology has been developed called Small Run Analysis that can assist the job shop environment. Cultural and personnel barriers can be broken down by understanding and practicing the concepts of Concurrent Engineering. Finally it has been shown that present day technology and automation tools such as relational data bases, LAN (Local Area Networks), computers, can be both cost effective and helpful in identifying variables effecting processes to automating manual processes.

CHAPTER VI

CONTRIBUTIONS

In conclusion through the innovative concepts presented in this research, the quality control literature as well as the shipyard industry will gain leverage and the benefits purported by the electronic and automotive industries, by pursuing synergies for the decade of the 1990's. Synergy makes a business more than just the sum of the parts. "Synergy means you should get a multiplier, an extra benefit, because you get those parts together (Alter 1990)." These and other areas of manufacturing methodologies could prove fertile ground for both future qualitative and quantitative research and posit a separate level of analysis for the quality control literature, particularly in the job shop environment.

The job shop domain requires its own "established" statistical process control methods such as the Small Run "p" chart with features that have proven to be beneficial in this rework example.

First, in Small Run Analysis the traditional sigma has already been set to a unitless ±3. One only needs to evaluate the target rate, which in most cases, will equal $\bar{p}$.

If the process experiences an outlier (out of control condition) during a certain time period, it does not adversely affect the next time period. For some statistical methods, for example, variable data with autocorrelation or lagged regression analysis, one must subtract the outlier data, recalculate the variance, then replot both the control limits and the remaining data from the subgroup ranges. In one particular procedure for control charts of short runs, a two-stage approach is presented that applies a constant factor from a table based on subgroups of five (Hillier 1969) while one develops $\bar{X}$ and R charts and continually drops out subgroup ranges that are out of control. After the run is complete, it combines the raw data from the entire run with the filtered data and repeats this stage until all remaining values are within the control limits. In another small run procedure, the minimum number of subgroups recommended for groups of size two to five was also developed with the assumption that there were no special causes of variation between runs (Proschan and Savage 1960).

Second, the Small Run Analysis allows different part numbers as well as different characteristics to be plotted on the same chart to reduce the burden of traditional Statistical Process Control (SPC) methods. Third, the analysis allows the use of special data transformations to "standardize" subgroup data.

The multidimensional approach utilizes statistical control techniques such as Small Run Analysis and Deming methodologies as problem solving activities that concentrate on continuous improvement to status quo. It is aimed at existing things in situations and changing them for the better. Because this approach consists of analyzing the undesirable aspects of a current situation, feedback is used to ameliorate, through corrective action, those changes necessary to bring about continuous improvement. The things targeted for improvement can be observed and it is often possible to evaluate them scientifically and objectively by compiling the observations as numerical data.

By contrast, innovation is an activity consisting of creating things that do not yet exist and the change it brings about are therefore abrupt and discontinuous. Because innovations have no previous existence, we cannot increase our knowledge of them through observation. Subsequent knowledge; accurate, wide ranging, and in-depth, is important but is often in limited supply and the deciding factors are intuition and insight into the essential nature of the problem. Statistical control techniques, being scientific and analytic, are a universal activity that can be carried out by all; innovation, being intuitive and holistic, is an individualistic activity that depends on the person doing it. Improvement through statistical control techniques and innovation are both activities for changing the status quo. The changes arising from statistical control techniques are quantitative, those resulting from innovation are qualitative.

Statistical control techniques and innovation are therefore different. They must always be borne in mind when promoting a Total Quality Management (TQM) program. A company will not grow if in a situation requiring innovation, management is satisfied with a simplistic approach consisting of inevitable cost reduction activities and activities for improving the immediate situation. The multidimensional approaches and innovation are not mutually exclusive. They are complementary and offer commonalty in practice that management can use to ensure corporate development, whether it be in the public or private sector.

GLOSSARY

backshell - metallic encasement around termination or Radio Frequency Interference (RFI) shield and environment seal

banding - fasten cables to wireways for support

cable clamp - device on back end of backshell to provide a part of the strain relief

cable marker - ID the circuit and system that each cable must connect to

environmental seal - device in backshell seals around the cable to prevent dust or moisture or strain relief

Job Order - A document used to authorize productive work--both shipwork and nonshipwork. Each JO presents a complete Key Operation breakdown, by shop, plus schedules, work instructions, and technical references necessary to accomplish the work.

Key Operation - A Key Operation (KEYOP) is a logical division of the Job Order which may be scheduled to be performed by a Key Shop Work Center, without significant interruption, and which can be closed out for further charges upon completion; it includes that assist work necessary to support the basic instruction and not chargeable under the established procedures for minor assist work.. The shipyard basic work planning, scheduling, and cost control unit.

plug/connector - type of termination for quick disconnect

prefab - one end of connector made up in the ship prior to ship arriving remake - totally disassembled then reassembled

rework - go back after fabrication to make repairs

ring-out - cable tested to verify connection or check resistance and leakage

spaghetti - piece of sleeving (shrinkable) which ID's each wire or pair for hook-up

Shipalt - A Ship Alteration any change in the hull machinery equipment which involves a change in design, materials, location, number, or relationship of the components parts of an assembly.

strain relief - inner or outer shields to prevent tension at point of termination

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Appendix A

X51P DISCREPANCY CODES

PLANNING ITEMS
P A01 SPARE PINS MISSING
P A02 SEALING PLUG (S) MISSING
P A03 CABLE CLAMP MISSING
P A04 ENVIRONMENTAL SEAL MISSING
P A05 CABLE MARKER MISSING
P A06 SPAGHETTI/SHRINK MISSING
P A07 LOCKRING MISSING
P A09 MISSING COMPONENT
P A10 SHELL NOT ENGRAVED/WRONG
P A11 SPAGHETTI HANDWRITTEN
P A12 CABLE MARKER INCORRECT
P A13 RUN SHEET MISSING
P A14 CABLES PULLED IN/SHOP PREFAB DONE SIMULTANEOUSLY
P A15 WRONG SIZE SPAGHETTI
P A16 IMPROPER PLUG PROVIDED
P A17 PREFABBED WRONG END
P A18 BACKSHELL IMPROPER FIT
P A23 RUBBER SEAL SPLIT OR TORN

SHIP'S FORCE

S C01 CABLE DAMAGED BY SHIPS FORCE
S C02 INSULATION DAMAGE
S C03 BROKEN LEADS
S C04 CONNECTOR DAMAGED BY SHIPS FORCE
S C05 BACKSHELL LOOSE
S C06 CABLE TOO SHORT
S C08 HEAT DAMAGED INSULATION
S C10 COAX CONNECTOR LOOSE
S C11 CONNECTOR OPENED BY PARTIES UNKNOWN
S C12 CONNECTOR LOOSE
S C14 ADAPTER DAMAGED/BROKEN
S C15 BACKSHELL DAMAGED/BROKEN

WORKMANSHIP ITEMS
W B09 NOT HOOKED UP BY RUN SHEET
W B11 ORIGINAL FAB SHEET LOST
W B12 SPAGHETTI INFO WRONG
W B21 BENT PIN (S)W
W B24 INSULATION DAMAGE
W B25 TAPE OR RESIDUE ON LEADS

WORKMANSHIP ITEMS
W B30 EXPOSED SHIELDS
W B31 SHIELD (S) NOT TERMINATED
W B32 INCORRECTLY MADE SHIELD (S)
W B33 GROUND WIRE TOO SHORT
W B34 INCORRECTLY MADE PIGTAILS
W B40 WIRE STRANDS OUTSIDE OF PIN (S)
W B41 WIRE NOT AGAINST BACK OF CUP
W B42 IMPROPER INSULATION GAP
W B44 SHEATH CUT BACK TOO FAR
W B45 SPLICED LEADS
W B46 CABLE TOO SHORT
W B47 CABLE TOO LONG
W B50 PIN (S) UNDERCRIMPED
W B51 EXCESS SOLDER
W B52 GROUND WIRES NOT CONNECTED
W B53 PIN (S) OVER CRIMPED
W B54 INSUFFICIENT SOLDER
W B55 BROKEN LEADS/PINS
W B56 COLD SOLDER
W B57 SPARE LEADS NOT INSULATED
W B58 WICKING
W B59 SLEEVING TOO SHORT
W B60 FLUX ON PIN (S)
W B61 EXTENDED PINS
W B62 RECESSED PINS
W B63 WRONG PINS
W B71 COAX CONNECTOR LOOSE
W B72 LOOSE CABLE CLAMP
W B73 BACKSHELL IMPROPER FIT
W B74 LOOSE CONNECTOR
W B75 SEALING GROMMET NOT SECURE
W B76 IMPROPER PLUG INSTALLED
W B77 ENVIRONMENTAL SEAL UNSAT
W B78 BACKSHELL LOOSE
W B79 SHORT CIRCUIT
W B80 INCORRECT CABLE BUILD-UP
W B81 REVERSAL
W B82 OPEN CIRCUIT
W B83 FAILED ELECTRICAL CHECKS
W B84 CONNECTOR ON WRONG END OF CABLE
W B85 PLUG KEYED WRONG
W B86 BACKSHELL POSITIONED WRONG
W B97 CONN DAMAGED/BROKEN BY 51P
W B98 BURNT LEADS
W B99 HEAT DAMAGED INSULATION

CAUSE CODES

D DESIGN
E EQUIPMENT
I INSTRUCTIONS (P&E)
S SHIP'S FORCE
M MATERIALS (FAULTY)
W WORKMANSHIP
P PLANNING
O OTHER SHOPS AND/OR CODES

X51P DISCREPANCY CODES

OTHER SHOPS AND/OR CODES

O D01 CABLE DAMAGED BY X67
O D02 CABLE DAMAGED BY CODE 190
O D03 CONNECTOR DAMAGED BY X67
O D04 CONNECTOR DAMAGED BY CODE 190
O D05 CABLE DAMAGED BY X51W
O D06 CONNECTOR DAMAGED BY X51W
O D07 CABLE TOO SHORT
O D08 CABLE TOO LONG
O D09 HEAT DAMAGED INSULATION
O D10 CABLE PULLED IN BACKWARDS
O D11 COAX CONNECTOR LOOSE
O D12 CONNECTOR LOOSE
O D13 WRONG CABLE PULLED IN BY X51W
O D14 DEFECTIVE CABLE
O D15 ADAPTER DAMAGED/BROKEN
O D16 BACKSHELL DAMAGED/BROKEN
O D17 INSULATION DAMAGE
O D18 BROKEN LEADS
O D19 BACKSHELL LOOSE
O D20 51W HOOKED UP INTER-CONNECTION BOX WRONG
O D21 CONN DAMAGED/BROKEN BY UNKNOWN
O D22 DISCREPANCY NOT IN PLUG END
O D23 DEFECT FOUND IN EXISTING CONNECTOR
O D24 DEFECT IN CONTRACTOR MADE CONNECTOR
O D25 MATERIAL LOST IN TRANSIT
O D26 NO DISCREPANCY

MATERIAL ITEMS

M G01 DEFECTIVE CABLE
M G02 ADAPTER DAMAGED/BROKEN
M G03 DEFECTIVE LOCKING DEVICE
M G20 PLUG OUT OF ROUND
M G21 CONNECTOR DAMAGED/BROKEN
M G22 BACKSHELL DAMAGED/BROKEN
M G23 INCORRECT MATERIAL (S) RECEIVED

TECHNICAL ITEMS

D H10 DESIGN CHANGE
D H11 PRINT ERROR
D H12 RUN SHEET ERROR
D H13 IMPROPER PLUG INFORMATION
D H14 IMPROPER BACKSHELL INFO
D H15 DWG REVISED AFTER WORK COMP

INSTRUCTIONS (P&E)

I E02 JO LISTED INCORRECT REF

CAUSE CODES

D DESIGN
E EQUIPMENT
I INSTRUCTION (P&E)
S SHIP'S FORCE/OTHER SHOPS
M MATERIALS (FAULTY)
W WORKMANSHIP
P PLANNING
O OTHER SHOPS AND/OR CODES

CONNECTOR FABRICATION CONTROL
X51RPTO1

CABLE # : R-SK-525
UNIT : 128-1
LOCATION : CSES

SYSTEM: BQQ-5 ! SHIP: BATON ROUGE ! HULL NO.: 689

J.O.: 30DMA42602 ! K.O.: 051 ! CABLE DIAG: 5202730 REV A

PRELIMINARY CHECKS

1._____CABLE CHECK
CABLE NO: R-SK-525
ROTATION: CW
TYPE: 2U-45 LENGTH: 24
CHECK FOR OBVIOUS DAMAGE
2._____ CONNECTOR CHECK
CONNECTOR#:M81511/06EF01S1 PC:
ADAPTER#: PC:
BACKSHELL#: PC:
UNIT: 128-1
PLUG/JACK #: 59
CHECK FOR OBVIOUS DAMAGE

PRODUCTION CHECKS

3._____SEQUENCE/POSITION OF PARTS
4._____WIRE LENGTHS
5._____SHIELD PREPARATION
SHIELD WIRE SOLDERED SECURELY
INSULATION CONDITION
IDENTIFICATION SLEEVING
6._____WIRE PREPARATION
LENGTH STRIPPED
STRAND CONDITION
CRIMPED/SOLDERED SECURELY
7._____PINS
NOT BENT/DAMAGED/BLOCKED
INSERTED SECURELY
INSERTION DEPTH EQUAL
SPARE PINS INSERTED
8._____SPARE CONDUCTORS INSULATED
9._____ASSEMBLY
CABLE GROMMET SECURE
BACKSHELL/KEYWAY POSITION
BACKSHELL/BODY SECURE
LOCKING RING MOVEMENT
GROUND WIRES CONNECTED
10._____CABLE MARKER INSTALLED

PREFAB ! X ! SHIP ! _ !

TIME ! _ ! ___Hrs ___Min

REPAIR ! _ ! ___Hrs ___Min

REMAKE ! _ ! ___Hrs ___Min

VISUAL CHECKS

(TO BE ACCOMPLISHED BY QA PERSON)
11._____KEYWAY CONDITION
12._____LOCKING RING CONDITION
13._____PLUG SHAPE OK (ROUND ETC.)
14._____SECOND-CHECK ITEM NO 7
15._____SECOND-CHECK ITEM NO 9
16._____CABLE CLAMP SECURE

WIRE CHECKS

(TO BE ACCOMPLISHED WITH 2ND PERSON)
17._____CONTINUITY/WIRE POSITION
18._____Megger
19.CABLE RUNNING SHEET NO._____

DISCREPENCY REPORT

DESCRIBE

DISCREPENCY CODE__________

SIGN-OFFS

CONNECTOR FABRICATED BY

Name____________________
CHECK NO.______________DATE________

ELECT./WIRE CHECKS BY (2ND PERSON)

NAME____________________
CHECK NO.______________DATE________

QUALITY ASSURANCE CHECKS

First__________Final__________
NAME____________________
CHECK NO.______________DATE________

REMARKS:

407-2-1601
REVISION

DATA SHEET 1

EQUIPMENT:

AN/UYK-7 FRAME A

CABLE ID	R-003	R-004	R-005	R-006	R-007
PLUG NO.	P65	P66	P41	P42	P61

PRE-CONNECTOR INSTALLATION

1 Qualified Tech					
2 Cable ID					
3 Proper Tools/Doc.					
4 Cable Bend Radius					
5 Cable Type/Damage					
6 Jacket Strip Length					
7 Backshell/Clamp Assy.					
8 Backshell/Clamp Cond.					
*9 Contact Type					
*10 Conductor Strip Lgth/Pos'n					
*11 Crimping					
*12 Pull Test					
*13 Shield/Sheath Term.					
14 Spare Conductor Term.					
15 Twisted-Pair ID					
16 Connector Type					
17 Connector Condition					
18 Connector Mating					

POST-CONNECTOR INSTALLATION

19 Conductor Routing					
20 Conductor Damage					
21 Contact Retension					
*22 Solder-Joint Surfaces					
23 Tape Prohibition					
24 Unused Contact Positions					
25 Environmental Seal					

* Inspected on a sampling basis to the extent that the inspector is satisfied all specifications are being complied with.

407-2-1601
1823.21
1821-2204

DATA SHEET 1 (Cont'd)

EQUIPMENT:

AN/UYK-7 FRAME A

BACKSHELL/CLAMP ASSY.

26 Backshell Position					
27 Backshell Torqued					
28 Lockwire Installed					
29 Deleted	N/A	N/A	N/A	N/A	N/A
30 Strain Relief					
31 Clamp Torqued					

NOTE: Above data blanks should be initialed by shipyard inspector.

NNSY 10380/86 (8-87)

Connector Control Sheet

SHIP	JOB ORDER	KEY OP	SYSTEM	PRINT # AND REV.	LEAD MECHANIC

CABLE NUMBER	UNIT NUMBER	CABLE TYPE	LENGTH	JACK	LOCATION	CONNECTOR NUMBER	PC. NO.	BACKSHELL/ ADAPTER NO.	PC. NO.	N	E	P	S	REMARKS	TIME	MECHANIC

Unit Listing Report
TIGER TEAM
SHOP 51
Monday April 5, 1993 09:52:25 AM

Page: 4

Primary Sort By: JOB ORDER 468G940901

Secondary Sort By: NONE NONE

System

Unit Name / Job Order	Keyop	Location / Jack	Cable Number	Cable Type	Connector Type	New/Exist/Re	Status
COMM DEPT OFFICE		05-83.5-1-C					
468G940901	050	J	R-DR/L W1726	2X0-6	M24308/4-2	N	
COMPUTER		05-67-3-C					
468G940901	050	SWE	SWE	1N5101A		N	
CP-2137 #1		04-69-1-C					
468G940901	050	SER A	R-DR/L W1120	2X0-6	M24308/4-3	N	
468G940901	050	TTY C0	R-DR/L W1121	2X0-6	M24308/4-3	N	
468G940901	050	TTY C1	R-DR/L W1122	2X0-6	M24308/4-3	N	
468G940901	050	TTY C2	R-DR/L W1123	2X0-6	M24308/4-3	N	
468G940901	050	TTY C3	R-DR/L W1124	2X0-6	M24308/4-3	N	
468G940901	050	TTY C4	R-DR/L W1125	2X0-6	M24308/4-3	N	
468G940901	050	TTY C5	R-DR/L W1126	2X0-6	M24308/4-3	N	
468G940901	050	SER C	R-DR/L W1127	2X0-6	M24308/4-3	N	
468G940901	050	SER D	R-DR/L W1128	2X0-6	M24308/4-3	N	
468G940901	050	KBD 1	R-DR/L W1129	LS2U-10	M24308/4-2	N	
468G940901	050	SER B	R-DR/L W1164	2X0-6	M24308/4-3	N	
468G940901	050	KBD	R-DR/L W1165	LS2U-10	M24308/4-2	N	
468G940901	050	J1-R	R-DR/L W21106	RG-59	M39012/16-0015	N	
468G940901	050	J1-G	R-DR/L W21107	RG-59	M39012/16-0015	N	
468G940901	050	J1-B	R-DR/L W21108	RG-59	M39012/16-0015	N	
468G940901	050	J2-R	R-DR/L W21109	RG-59	M39012/16-0015	N	
468G940901	050	J2-G	R-DR/L W21110	RG-59	M39012/16-0015	N	
468G940901	050	J2-B	R-DR/L W21111	RG-59	M39012/16-0015	N	
468G940901	050	T1-(D)	R-DR/L WFP1207	AT&T105-570-162	AT&T 105-753-669	N	
468G940901	050	R1-(D)	R-DR/L WFP1312	AT&T105-570-162	AT&T 105-753-669	N	
468G940901	050	R2-(D)	R-DR/L WFS0712	AT&T105-570-162	AT&T 105-753-669	N	
468G940901	050	T2-(D)	R-DR/L WFS1213	AT&T105-570-162	AT&T 105-753-669	N	
CP-2137 #2		04-69-1-C					
468G940901	050	SER B	R-DR/L W1108	2X0-6	M24308/4-3	N	
468G940901	050	KBD 2	R-DR/L W1109	LS2U-10	M24308/4-2	N	
R-DR 1		05-73-1-C					
468G940901	050	HW	R-DR/L W111	2X0-6		N	
CP-2137 #2		04-69-1-C					
468G940901	050	SER A	R-DR/L W1110	2X0-6	M24308/4-3	N	
468G940901	050	TTY C0	R-DR/L W1111	2X0-6	M24308/4-3	N	
468G940901	050	TTY C1	R-DR/L W1112	2X0-6	M24308/4-3	N	
468G940901	050	TTY C2	R-DR/L W1113	2X0-6	M24308/4-3	N	
468G940901	050	TTY C3	R-DR/L W1114	2X0-6	M24308/4-3	N	
468G940901	050	TTY C4	R-DR/L W1115	2X0-6	M24308/4-3	N	
468G940901	050	TTY C5	R-DR/L W1116	2X0-6	M24308/4-3	N	
468G940901	050	SER C	R-DR/L W1117	2X0-6	M24308/4-3	N	
468G940901	050	SER D	R-DR/L W1118	2X0-6	M24308/4-3	N	
468G940901	050	KBD 1	R-DR/L W1119	LS2U-10	M24308/4-2	N	
468G940901	050	J1-R	R-DR/L W21100	RG-59	M39012/16-0015	N	
468G940901	050	J1-G	R-DR/L W21101	RG-59	M39012/16-0015	N	
468G940901	050	J1-B	R-DR/L W21102	RG-59	M39012/16-0015	N	

Appendix B

TABLE 1

STANDARD TIME ASSOCIATED WITH INSPECTION/REWORK/REMAKE

	QA (51P) (MIN)	MECH (51P) (MIN)	QA (51P) (MIN)	QA (190) (MIN)	MECH (51P) (MIN)	QA (51P) (MIN)	QA (190) (MIN)
NO PROBLEM	10			10			
SHOP 51P REWORK #1	10	60	10	10			
CODE 190 REWORK #2	10			10	60	10	10
SHOP 51P/CODE 190 REWORK #3	10	60	10	10	30	10	10
SHOP 51P REMAKE #4	10	240	10	10			
CODE 190 REMAKE #5	10			10	240	10	10
SHOP 51P/CODE 190 REMAKE #6	10	240	10	10	30	10	10

TABLE 2

STANDARD COST ASSOCIATED WITH INSPECTION/REWORK/REMAKE

	SUB TOTAL SHOP 51P (MIN)	SHOP 51P RATE 34.10 ($/HR)	SUB TOTAL CODE 190 (MIN)	CODE 190 RATE 36.00 ($/HR)	PREFAB TOTAL (MIN)	PREFAB TOTAL ($)
NO PROBLEM	10	5.68	10	6	20	11.68
SHOP 51P REWORK #1	80	45.47	10	6	90	51.47
CODE 190 REWORK #2	80	45.47	20	12	100	57.47
SHOP 51P/CODE 190 REWORK #3	120	68.2	20	12	140	80.2
SHOP 51P REMAKE #4	260	147.77	10	6	270	153.77
CODE 190 REMAKE #5	260	147.77	20	12	280	159.77
SHOP 51P/CODE 190 REMAKE #6	300	170.5	20	12	320	182.5

TABLE 3

UTILIZATION OF STANDARD COSTS OF REWORK AND REMAKE

Inspection by: 51P and 10
Source: 2/29/89
Ship: SHIP B
System: SYSTEM A
Total Plugs: 285

No Problem	51P Rework #1	190 Rework #2	51P/190 Rework #3	51P Remake #4	190 Remake #5	51P/190 Remake #6
12	2	4	3	2	1	1
11	5	4	1	1	1	1
6	6	8	6	2	1	2
19	1	7	2	1	1	3
9	2	9	4	1	1	1
4	8	1	2	6	1	4
18	4	5	6	1		1
7	2	3	3			2
7	5	6	2			
3	2	4	5			
20		1				
12						
128	37	52	33	14	6	15

Rejection rate = 157/285 = 55%

Costs of Inspection w/Rework

(1)	128 x $ 11.68	=	$1,495.04
(2)	37 x $ 51.47	=	$1,903.28
(3)	52 x $ 57.47	=	$2,986.88
(4)	33 x $ 80.20	=	$2,645.28
(5)	14 x $153.77	=	$2,151.52
(6)	6 x $159.77	=	$ 958.08
(7)	15 x $182.50	=	$2,736.00
	Total		$14,876.08

if all plugs were inspected without problems the cost would be:
285 plugs x $11.68/plug = $3,328.80

therefore the cost of rework/remake would be:
$14,876.08 - 3,328.80 = $11.547.28

so cost added to plug because of bad plugs (rework) at 55% rejection rate would be:
$11,547.28 ÷ 157 bad plugs = $73.54/bad plugs

cost added to all plugs because of bad plugs (rework)
$11,547.28 ÷ 285 total plugs = $40.51/plugs

TABLE 4

Cost savings - effect of eliminating Combat Systems inspection
Assumptions

- annual plugs fabricated - 10,000 plugs
- cost added to plug (Table 2) for Combat systems inspection range $6 to $12

annualized effect

minimum savings (10,000 plugs x $6) = $60,000

maximum savings (10,000 plugs X $12) = $120,000

TABLE 5

Cost avoidance - effect of reducing rejection rate
Example taken during interim with no Combat Systems inspection

Ship	System	Plug	Rework
Ship E	UH	67	4
Ship L	WL	14	1
Ship M	CI	63	4
Ship G	WL	15	0
		158	9

Rejection rate = 9/158 = 5.7%

NOTE: Table 3 showed that a previous example with a 55% rejection resulted with an additional cost of $40.51 plug.

If 55% rejection had continued then the additional cost would have been:
158 plugs x $40.51/plug = $6,400.58
but the additional cost for these four ships with a 5.7% rejection cost (rates taken from Table 2 of appendix (a) with Shop 51P inspectors only)

158 plugs x $5.68/plug	= $ 897.44
9 plugs X $48.47/plug	= $ 408.96
Subtotal	$1,306.40
less 9 plugs without problems	
(9 plugs x $5.68/plug)	- 51.12
Total	$1,255.28
55% rejection rate	$6,400.58
5.7% rejection rate	- $1,255.28
Difference	$5,145.30
Cost Avoidance/Plug	= $5,145.30/158 plugs
	= $ 32.56/plug

annualized effect (cost avoidances)

10,000 plugs x $32.56/plug = $325,600

TABLE 6

Cost savings - effect of reducing paperwork

example: SYSTEM A on SHIP B	
mechanic rate (Table 2)	$34.10/hours
time working up new job order	362 hours
prior to development of computer application	
$34.10/hr x 362 hours =	$12,344

the customer was charged $12,344 for the development of paperwork on the SYSTEM A

NOTE: Even though the SYSTEM A was timed, it was decided that 362 hours was an unusual situation (first ship of the CLASS) and that 150 hours would better reflect the norm.

annualized effect (cost savings)

time working up new job	150 hours
new jobs/year	250 jobs
mechanic rate (Table 2)	$34.10/hr
annual supply cost	$3,000

150 hours/job x $34.10/hours x 250 jobs/year =	$1,278,750
supply costs	3,000
Total	$1,281,750

TABLE 7

Cost savings - effect on computerizing Combat Systems I&V (Inspection and Verification) Form 3 of Appendix A

inspection time for I&V	20 min or 1/3 hr
inspection rate Combat Systems (Table 2)	$36.00/hr
time in signing 31 blocks/plug	10 min or 1/6 hr
number of plugs	10,000 plugs/year

annualized effect (cost savings)

inspection(I&V) 1/3 hr X $36/hr x 10,000 plugs	= $120,000
sign-off 1/6 hr x $36.00/hr x 10,000 plugs	= 60,000
Total	= $180,000

TABLE 8

SYSTEM HARDWARE CONFIGURATION

1	One Embosser	$11,000
2	Two Spaghetti Printers	$ 600
3	One Pull-tag Printer	$ 400
4	One Fabrication Sheet/Report/Hook-up Table Printer	$ 2,000
5	One Temporary Pull-tag - Wraparound	$ 300
6	One 386 PC with One WLOC (Wang) Card for Down Loading Data From Design	$ 2,500
7	Two PCs to Run Printers	$ 4,600
8	One Network	$ 900
	Total	$22,300

TABLE 9

Shop 51P
Cost Analysis

MANPOWER Old Method	Sample Time 32 Units (Minutes)	Sample Time 167 Spaghetti (Minutes)	Unit Time (Minutes)	1991 Annual Production (Units)	Shop Manpower Required (Hours)	Shop Rate Accelerated ($18.68/HR)
A.Cable Markers				204,000		
1. Make List	15		0.47		1,594	$29,771
2.Type Tags	22		0.69		2,338	$43,665
B.Cable Pull Tags				35,000		
1.Hand WriteTags	90		2.81		1,641	$30,647
2.Gather Info From Plans	32		1.00		583	$10,897
3.Temp Tags (Hand Write)	160		5.00		2,917	$54,483
C.Spaghetti				720,000		
1.Make Order List		160	0.96		11,497	$214,764
2.Input Order List		60	0.36		4,311	$80,537
3.Print Spaghetti		5	0.03		359	$6,711
TOTAL					25,240	$471,475
New Method						
A.Cable Markers				204,000		
1.Print	8		0.25		850	$15,878
B.Cable Pull Tags				35,000		
1.Print Tags	5		0.16		91	$1,703
2.Wrap Arounds (Temp)	5.5		0.17		100	$1,873
C.Spaghetti				720,000		
1.Print		5	0.03		359	$6,711
TOTAL					1,401	$26,165

TABLE 9 (CONTINUED)

Material	1991 Annual Production (Units)	Unit Costs ($)	Total Costs ($)
Old Method			
A.Cable Markers	204,000.00	0.24	$48,960
B.Cable Pull Tags	35,000.00	0.17	$5,950
C.Spaghetti (3/8")	400,000.00	0.77	$308,000
C.Spaghetti (3/16")	320,000.00	0.38	$121,600
TOTAL			$484,510
New Method			
A.Cable Markers	204,000.00	0.24	$48,960
B.Cable Pull Tags	35,000.00	0.34	$11,900
C.Spaghetti (3/8")	400,000.00	0.44	$176,000
C.Spaghetti (3/16")	320,000.00	0.23	$73,600
TOTAL			$310,460

TABLE 10

NNSY
Cost Analysis
for
Shop 51P Project

	Year 1 ($)	Year 2 ($)	Year 3 ($)	Year 4 ($)	Year 5 ($)
Shop 51P Savings (Annually)	$619,360	$619,360	$619,360	$619,360	$619,360
System Hardware Cost (One Time)	($22,300)				
System Software Cost (One Time)	($14,500)				
Hardware Maintenance (Annually)	$0	($1,500)	($1,500)	($1,500)	($1,500)
Code 200 Personnel Cost (Annually	($51,813)	($53,886)	($56,041)	($58,283)	($60,614)
NNSY Savings	$530,747	$563,974	$561,819	$559,577	$557,246

AUTOBIOGRAPHICAL STATEMENT

I was christened Paul Ray Hollandsworth on May 2, 1948 in Long Beach, California. I am 5 minutes older than my twin sister, Paula. I grew up in a Navy environment and attended nine schools the first twelve years of school. I graduated from Norview High School in Norfolk, Virginia. I am married to April Sweitzer from Chesapeake Virginia since 1977.

I graduated with a B.S. degree in Civil Engineering, with an option in Architectural Engineering from Virginia Polytechnic Institute and State University (1966-1970) and received my diploma in May 1971. I graduated in June 1975 with Masters of Business Administration degree (MBA) with major emphasis in computer-based modeling and statistics from College of William and Mary. I was recipient of a Graduate Fellowship Scholarship in 1974. I received my Ph.D. with major emphasis in computer integrated manufacturing from the Department of Engineering Management at Old Dominion University in December 1993.

I was a Nuclear Design Engineer at Newport News Shipyard from 1970 to 1974. Following the MBA, I worked for the City of Norfolk for seven years in the Department of

Human Resources, working with the elderly, the handicapped, the child abused, the poor, and juvenile delinquents.

In 1991, I was one of a 10 member group representing the United States at an international conference on federal ADP activities with 21 foreign countries in attendance.

As of 1993, I presently hold the position of Supervisor Industrial Engineer at Norfolk Naval Shipyard (1983-present) and provide research in quality control methodologies, process improvements, policy development on computer aided design/computer assisted manufacturing (CAD/CAM), 3 dimensional parametric modeling, photogrammetry, design and serve as project manager for major computer applications e.g., Engineering Data Management Information and Control System (EDMICS) raster scanning of aperture cards, drawings, sketches, and text.

I sit on the Flexible Computer Integrated Manufacturing (FCIM) Core Group for the Secretary of the Navy, outlining Navy manufacturing strategies for the next 15 years. I am a member of the Federation of Data Processing Specialists that submit policy recommendations to the White House on data processing issues. I also serve as President of the Intergovernmental ADP for city, state, and federal employees for the five state area.