LEADERSHIP WITHIN CONCURRENT ENGINEERING: A DELPHI INQUIRY INTO TRAINING NEEDS FOR THE AEROSPACE INDUSTRY

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CHAPTER I

THE RESEARCH PROBLEM

Introduction

Designing, building and operating aerospace system hardware has always been expensive. Manufacturing small quantities of specialty parts escalate engineering design, production and operation costs. Funding cutbacks and shrinking revenues have prompted drastic cost saving programs that have not always been as effective as intended. The United States government has often encountered criticism for over-inflated budget allocation in selected areas. The current rage in the United States is to balance the federal budget. Any program that receives money from the federal government is under inspection. For example the National Aeronautic and Space Administration (NASA) and the Department of Defense (DOD) are two such areas. Despite NASA's attempts to allocate funding judiciously, it has been unable to contain exorbitant costs such as those connected with launching the space shuttle, the Titan systems rocket program, and the Space Station program (Access to Space Study). Numerous studies have shown that NASA has gone to great lengths to keep production costs minimal. Indeed, one of the highest priorities of NASA as well as the DOD has been to provide relatively economical ground to orbit transport mechanisms (Austin, 1994).

Over the past three decades NASA and DOD have seen technological advances that promoted greater efficiencies in designing, building and operating aerospace and aircraft system hardware. As future NASA/DOD programs like advanced Jet fighters, new launch systems, satellites and manned programs exhibit greater efficiencies, the cost savings should be reflected in the systems overall cost. Joseph Hamaker, of NASA's George C. Marshall Space Flight Center in Huntsville, Alabama, conducted a study that identified newer ways of conducting business that could lead to improved product development strategies and reduced production costs. Examples of such newer approaches of doing business are;

1. More Extensive Pre Project Investment
2. Multi-year Funding Stability
3. Improved Quality And Management Processes
4. Improved Procurement Processes
5. Advanced Design Methods and
6. Advanced Production Methods. (Hamaker,1992).

Implementing these methods can also affect characteristics of an organization's cultural environment. Although Hamaker's research was confined to organizational dynamics at NASA, his findings are potentially applicable to other aerospace organizations. One of his findings identified Concurrent Engineering as a product design system/approach that integrates design personnel, manufacturing personnel and product support within the development phase of a product and transfers ideas throughout the life cycle of the product.

There are several aerospace companies that have been developing the use of Concurrent Engineering in the design, development and production of future space systems. These companies and organizations include, but are not limited to; NASA, DOD, Department of Energy, Boeing, McDonnell-Douglas, General Dynamics Space Systems, Rockwell International, Rocketdyne, Aerojet Propulsion, Martin Martiette Manned Space Systems, and Pratt and Whitney. As the aerospace community begins to embrace the concept of Concurrent Engineering teams, they have faced problems in implementing them into their complex engineering system. "It is not that teams don't work. It's that there are lots of obstacles. People are very naive about how easy it is to create a team (Dumaine, 1994)." Many times a company will form the wrong kind of team. Most team members are trained in the Business As Usual (BAU) approaches to engineering and are reluctant to become involved in the Concurrent Engineering process. Lack of teams empowerment, companies unwilling to let go of control and finally lack of team training or support affect the success of the Concurrent Engineering team.

Description of the Problem

The cost of designing, producing and operating aerospace flight hardware is necessarily more expensive than the same processes to provide equipment for most other human endeavors. Because of the more stringent environments and safety requirements, hardware will probably always be more expensive than similar hardware which is designed for less taxing environments (Hamaker,1992). The implementation and utilization of Concurrent Engineering is one potential method for obtaining low production and life cycle costs without sacrificing reliability (Butler 1993). The implementation, benefits and savings from the use of Concurrent Engineering methods in the designing, production and operations of space systems have been seen to be a tremendous benefit and a cost saving to those companies who have successfully implemented it. Current management is struggling to identify the best methods for successfully converting from business as usual approaches to Concurrent Engineering. It is the thesis of this study that there are identifiable training needs that can facilitate effective implementation and application of Concurrent Engineering work teams in the aerospace community

Statement of the Problem

The implementation of Concurrent Engineering is of great benefit to those companies that successfully adapt and convert from Business As Usual approaches to Concurrent Engineering work teams. A major stumbling block in this conversion is in determining the most appropriate curriculum to be incorporated into a comprehensive Concurrent Engineering training program. This study is a Delphi inquiry of training needs required for effective implementation of Concurrent Engineering work teams within the aerospace community. This study will attempt to answer the following research questions.

1. What is the appropriate training required for a good Concurrent Engineering facilitator?

2. What is the appropriate training required for a good Concurrent Engineering Team Member?

3. What is the appropriate university training needed by a Concurrent Engineering Team Member?

4. What training activities are successful in Concurrent Engineering team?

Significance of the Study

The aerospace industry has utilized Concurrent Engineering with varying degrees of success. The identification of the training needs of individuals in preparation to participate on a Concurrent Engineering team will equip members of the aerospace industry in designing training programs for their employees to be competitive in a global economy. The benefits will be widespread, not only to the aerospace community but to all industries that are in the process of developing new products. As government, corporations and universities begin to utilize work teams to solve complex problems, establishing an effective training program is paramount to continued success.

The utilization of Concurrent Engineering work teams are becoming increasingly more prevalent within American industry. As American aerospace companies face greater competition from the international community as exemplified by the European Space Agency, the Chinese Space Agency, and the Russian Space Agency, increased reliability and cost savings must be obtained.

Brian Dumaine in his article The Trouble with Teams published in the September 1994 issue of *Fortune* explains:

> The center for Effective Organization at the University of Southern California recently conducted a survey of Fortune 1000 companies showing that 68% use self-managed or high performance teams. Sounds like a lot--but the study also shows that only 10% of workers are in such teams, hardly a number betokening a managerial revolution. (p. 130)

Most engineers are not trained with the proper skills to effectively participate in Concurrent Engineering work teams. A comprehensive

Concurrent Engineering training program can help.

Purpose of the Study

The purpose of this study is to identify the areas of training needed to facilitate successful implementation and application of Concurrent Engineering work teams within the aerospace community.

Definitions of Terms

Concurrent Engineering - a product design system/approach that integrates design personnel, manufacturing personnel and product support within the development phase of a product and transfers ideas throughout the products life cycle.

Contractor - A company that is under contract to NASA, DOD, DOE and or any other government agencie or a private company.

Delphi - "a technique of inquiry that is characterized as a method for structuring a group communication process so that the course of action is effective in allowing a group of individuals, as a whole, to deal with a complex problem" (Linstone & Turoff, 1975).

DFM - Design For Manufacturability- facilitates designers, engineers, manufacturing engineers, marketing personnel, and other members of the Concurrent Engineering team by providing a common goal and language with which to communicate.

DOD - The United States Department of Defense

DOE - The United States Department of Energy

Leadership - "The wise use of the capacity to translate intention into reality and sustain it" (Bennis & Namus, 1985).

NASA - The National Aeronautics and Space Administration

Team leader - the individual in the group given the responsibility of coordinating and directing mutually accepted, task-related team activities or who, in the absence of the designated leader, carries out or performs those primary functions in the team (Fiedler, 1967).

TQM - Total Quality Management

SDWT - Self Directed Work Team -These Teams have total control over their jobs in order to optimize their effectiveness of the entire process.

Work Teams - an intact social system consisting of a collection of individuals who;1) are perceived and recognized as a group by both members and nonmembers of the group, 2) have significantly interdependent relations with one another, 3) have separate and distinguishable role within the group and 4) must rely on collaboration if each member is to experience the optimum of success and common goal achievement (Alderfer,1977; Dyer, 1977; Heckman, 1983).

Limitations and Assumptions

The Delphi method of inquiry is assumed to be an acceptable representation of truth. It is possible that some of the members of the Delphi team will have biased responses due to their being from only one areospace company rather than being chosen randomly from a pool of qualified companies. It is also possible that biases could exist due to the shared engineering background that each of them possesses. The Delphi team responded subjectively to the questionnaires and their responses will be affected by the education, nomenclature, cultural background, and aerospace experience. It is assumed that the responses from the Delphi team are characteristic of the aerospace community.

The Lockean Delphi method was chosen to serve the purposes of this study. It appears to be the best method for obtaining the required data. There are limitations inherent in this method and they are assumed. The Delphi method of inquiry is explained fully in Chapter III.

Limitations -- This study is limited to the training and educational needs of the engineers to be involved in Concurrent Engineering, for example, designers, developers, and manufacturing engineers. Because of this limitation, only those individuals who possess a strong engineering background were chosen to be members of the Delphi team.

Organization of the Study

This study is divided into five chapters and the appendices. Chapter I includes an introduction, the description of the problem, statement of the problem, significance of the study, purpose of the study, definition of terms, limitations and assumptions of the study, and organization of the study., Chapter II reviews the research literature regarding Concurrent Engineering. It is divided into seven distinct sections. The first section provides a brief introduction to Concurrent Engineering. It is followed by the second section which defines and explains Concurrent Engineering. The third section provides a historical perspective, briefly outlining the history and precursors of concurrent engineering with brief descriptions of the various engineering areas that can be affected. In section four the concept of team work is discussed and outlined followed by a discussion of team leaders in section five. Section six discusses the necessary training needs that have been identified through the literature and finally, a brief summary is provided in section seven. Chapter III presents the design of the study and procedures employed. The research findings are presented in Chapter IV. Chapter V provides a summary of the research effort, conclusions and recommendations. A list of references follows Chapter V. The appendices contain the questionnaire used in the research study, biographical information, reference and data tables.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

Before the Industrial Revolution, individual craftsmen directed the manufacture of products needed to perform a certain task. From the basic need to conceptualization, design, and manufacturing, the single individual considered all the problems of how the product should be made. The individual selected the type of materials to utilize and chose the process used to manufacture the product. When the product was complete, the same individual then delivered the product to the customer. The final product was often of high quality and performed its function for a long period of time. The individual craftsman depended on the quality of the product for continued business. The individual only received more business based on the quality of the product and its performance.

The Industrial Revolution introduced mass production and standardization. Increased job specialization and reliance on automated machines, as well as the use of a relatively unskilled labor force created barricades to effective communication between the person who designed the product and the consumer. There now existed several levels between the product designer and the consumer. The number of people who had an impact on the quality and production had increased significantly. In many cases, the labor force actually employed in the manufacturing of the product did not possess a clear understanding of the purposes of the product. An increase in the complexity of various parts in the current manufacturing environment, as well as even more job specialization, has caused the distance between the designer, the producer and the consumer to become even greater. These changes have lead to a negative impact on ultimate product quality and cost (Kuo, 1990). A contemporary method for engineering design and manufacturing is intended to reverse the trend in American manufacturing. The method would increase the amount of communication about the development of the product at all levels. This system is intended to create increased integration of product design, product manufacturing, and product reliability. This system is known as Concurrent Engineering.

Several related areas presented themselves as relevant to Concurrent Engineering during the background research. Therefore, the review of literature is divided into seven sections for this chapter. The seven sections are:

1. Introduction
2. What is Concurrent Engineering?
3. Historical Perspective
    A. The Japanese
    B. Concurrent Engineering vs. Serial Engineering
    C. Product Development and Concurrent Engineering
    D. Product Production and Concurrent Engineering
    E. Product Operations and Concurrent Engineering
4. Teamwork

5. Team Leadership
6. Leader Characteristics
7. Training Needs
8. Summary

Concurrent Engineering

There are many names or terms used to describe Concurrent Engineering. These include design build teams, integrated product development teams, platform teams, value engineering, integrated engineering and simultaneous engineering. The fact that so many people use different terminology for the same design process can be confusing. In order to provide a definition suitable for the purposes of this research and to most satisfactorily bring abstraction to understanding, a quest through the literature was fruitful. Concurrent engineering is superiorly defined by L. Ken Keys in his article Concurrent Engineering for Consumer, Industrial Products, and Government Systems published in the June 1992 issue of *IEEE Transactions of Components, Hybrids, and Manufacturing Technology as* "a systematic approach to the integrated simultaneous design of a product and the related processes, including manufacturing and the other support functions." Keys goes on to explain that Concurrent Engineering involves two basic concepts, one being system analysis and the other, team project management. These two concepts provide the basis for "simultaneous product/process development leading to successful concurrent engineering" (Keys, 1992, page 283).

The Industrial Revolution ushered in the era of assembly lines and increased specialization. The results, though not entirely negative, have led to what has become known as the "traditional" manner of conducting business, or in jargonistic terms, Business As Usual. What brought business as usual under scrutiny? Why study Concurrent Engineering? In order to more clearly understand the functionality of Concurrent Engineering in the design process, a brief look at the historical background is warranted.

Historical Perspective

In order to gain a better understanding of Concurrent Engineering it is necessary to examine the evolution of this development concept. There are those that refer to Concurrent Engineering as the "new team method". Concurrent Engineering is not new. L. Ken Keys provides a historical look:

> "The underlying concepts of concurrent engineering have been evolving for many years, and are rooted in project management principles which go back several centuries. The fundamental challenges are still the same as those distant builders, i.e., providing the right information personnel, materials, and equipment from the most appropriate sources, to whom , where it is needed, to do the right job, on time, and within cost constraints....In the early centuries and until the last forty or fifty years, the general relative simplicity of the projects made it possible for the most of the important project information to exist in a few "knowledge worker" heads and be relatively easily communicated among these peoples (Keys, 1992, page 282).

The individual craftsmen of the past did not survive the industrial revolution. Those "distant builders" were replaced with assembly lines and automation. Manufacturing companies grew ever larger, with more and more personnel between the designer and the finished product.

> As the products and processes increased in complexity and sophistication, the complex element of designing, developing,

> manufacturing, maintenance and service, etc., were subdivided into smaller more manageable pieces. Over time, a conceptual model of the product/process development process evolved consisting of stages or phases, This sequential process, while important in the development evolution, carried the problem of a lack of coordination, interfacing, and integration of many of the different elements. This led to many product release delays, extra engineering, changes, poor quality, budget and product cost overruns, and high maintenance costs. Increasingly, new products also involved the interfacing and integration of a number of technologies (Keys, 1992).

The volume of products that American industries produced after the World War Two assisted the nation in becoming a superpower. Unfortunately, the quality of products manufactured in the United States was going down while the price of labor was going up. It was not until competition from other parts of the globe began to put a serious dent into the profits being enjoyed by American manufacturers did a serious look at serial engineering become not only desired, but necessary.

The Japanese

During the late seventies and through the early eighties, many companies in the United States were resting on their past laurels and finding themselves falling behind the competition globally. The largest competitive threat came from the Japanese. Product development and production had increased dramatically in Japan. At the same time, costs were soaring in the United States and the quality of the products was rapidly decreasing. In order to remain competitive, the United States companies had to discover Japan's "secret" to time and cost efficiency. In his article published in the *Survey of*

Business in the summer of 1989, Clement C. Wilson explains his company's search for Japan's secret.

> In 1981, my product development engineering team decided to make a direct comparison of our company's ability with that of a much smaller Japanese company by asking the Japanese to manufacture a product that we had also planned to manufacture. The Japanese company demonstrated the ability to convert the product from drawings to a dozen factory prototypes in 50 percent of the time, with 60 percent of the people, and 25 percent of the tooling dollars. When we examined the Japanese methods., we found the techniques to be much like those which had been practiced by the smallest division of our company in the early 1960's. The parts vendors were close (within 20 miles), the engineers knew the manufacturing processes well, and the assembly people knew their product well, so that only a minimum number of support people had to be in the factory. In short, the well-integrated engineering and manufacturing operation of the Japanese was simple and easy to understand. They also had been pursuing a "zero-defects" quality program for 15 years. With the exception of the "zero-defects" program, all the techniques they were using were old rather than new" (Wilson, 1989, p. 36)!

The engineering practices of the Japanese that many American companies were envious of, were the same practices that American companies had practiced before they became sprawling bureaucracies. In the United States, the workers were more and more removed from the consumers and management and designers alike. There was no one to be accountable to other than the line foreman who counted the quota for the day. American industrialization had removed the personal element from the production process. The designers and engineers were not required to sign their products so they remained anonymous to production line workers and customers. American companies seemed to focus primarily on the "bottom line" or short term goals and quick profits. The basic concepts of United States businesses, as reported by Melvin Breuer in the 1990 IEEE International Test Conference paper, went against the aspects of Concurrent Engineering, "such as, (1) use a greedy algorithm in place of Bellman's principle of optimality, (2) design for non-repair, (3) basic research may not pay off, and (4) spend now, save later" (page 86). The Japanese work ethic had not been adjusted to the "bottom line" mentality. This is where the difference had occurred. In America, the ever growing industrialization invested in producing more profit. Wilson tells us that "the Japanese management invests in quality programs of continuing improvement on both product and process which guarantee that they just continue to get better" (page 38) Wilson continued by relating that the United States companies who responded early to the competition of the Japanese made "radical" changes in the organizations of their companies and now compete with the Japanese. He leaves us with the impression that those businesses who did not make changes did not remain competitive. Wilson's comparison between the Japanese and the United States methods of conducting business disclosed three main factors; "1) United States product development and manufacturing systems are antiquated, 2) The Japanese systems are much simpler and need fewer people, and 3) The United States systems are complex due to increasing specialization" (Wilson, 1989, p. 36). The *IEEE Spectrum* agreed in its July 1991 issue by reporting that most companies "fail to set up communication links to notify the design and development departments of deficiencies discovered in the field" (p. 24). Unfortunately, the same *IEEE Spectrum* also tells us that companies are still not employing Concurrent Engineering. They have not learned enough from the Japanese or their own American heritage.

The Japanese government recognized the economic possibilities and the new self regard of their industrial workers. Japanese industries joined in a commitment with the Japanese government to cultivate Concurrent Engineering "by carrying out research on the feasibility of establishing such an engineering design technology" (Kuo and Hsu, 1990, p. 23).

American corporations had to do something to remain competitive or they would be put out of business. In the first stages of comparison and research, it was difficult for Americans to believe that the Japanese could be doing so much better than they. Many still felt the sting of World War II and accused the Japanese of stealing ideas.

> "For years, Japan has been accused of doing cheap imitations of U.S. designs, but nothing could be further from the truth. In fact., the Japanese have been careful not to copy American designs, opting instead to apply DFMA *[Design For Manufacturing and Assembly]* to see how the product can be made better and easier. As a result, Japanese products reflect a high degree of simplicity and quality, while offering an inexpensive alternative" (Otis, 1992, p. 61).

Not all American companies remained blind and immobile to the possibilities and challenges before them. The first American company to radically change its organizational structure was the Xerox corporation (Wilson, 1989, p. 38). The Defense Advanced Research Projects Agency (DARPA) began in 1987 to research product development. "The experts studied successful Japanese product development practices such as the 'tiger team' approach, which entails gathering all the stake holders in one place at the start of a project to hash out a solution that addresses all the participants' individual and the team's global concerns" (Ashley, 1992, p.54).

It was evident that the US companies must closely examine their current engineering and manufacturing practices. The serial engineering that had revolutionized the industries of the United States must be evaluated.

Concurrent Engineering Vs. Serial Engineering

Traditionally, in the Business As Usual (BAU) approach, organizations are segregated according to function (design, manufacturing, test or operations, etc.). This is the typical, historical way of organizing a project, which can be graphically observed in Figure 1 (using a launch vehicle project as an example). In this business as usual approach, the flight hardware is designed and then sequentially passed on to manufacturing, test, and operations. Such a process leads to a high level of change traffic and redesign effort to correct problems associated with design which makes manufacturing, test and operations more difficult. A more efficient way of managing a project is by employing Concurrent Engineering. As seen in Figure 2, a Concurrent Engineering project is divided into design-build or product development teams (PDTs). The Concurrent Engineering approach utilizes product development teams which include representatives from design, manufacturing, test, operations, cost estimating, and all other disciplines required so that the resulting design is capable of being efficiently manufactured, tested, and operated. The Concurrent Engineering process has a foundation of strong design-to-cost and continuous improvement philosophy. As opposed to the BAU approach, Concurrent Engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal including quality, cost, schedule and user requirements.

Figure 1

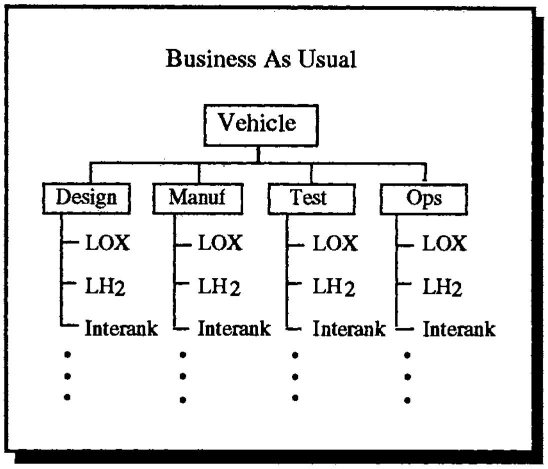
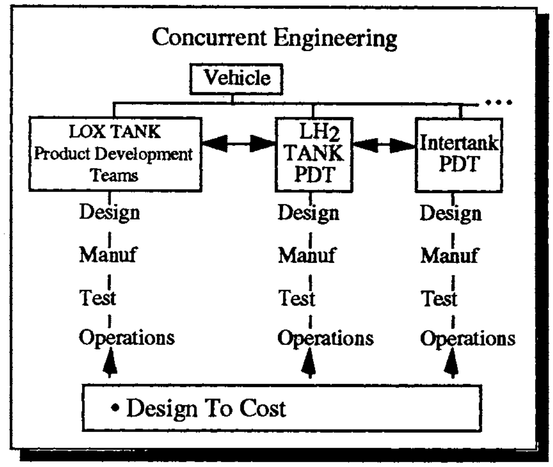


Figure 2



It is assumed that Concurrent Engineering techniques permeate throughout PDTs and serve as a viable foundation for these design-build or product development teams. Concurrent engineering utilizes small hierarchical teams in two areas: a core team comprised of design engineers, manufacturing engineers, quality engineers and procurement specialists, and support teams composed of cost analysts, schedule analysts, systems engineers, tool designers, and suppliers. These design-build teams focus on minimizing life cycle costs, and enhancing risk mitigation (Hamaker,1992).

Product Development and Concurrent Engineering

The days of the individual that designed, produced, and delivered the product to the consumer are from an era long past. The desire for quality products is still with us, now more than ever. In this era of high technology, quality is necessary for the safety, optimum efficiency and performance of space systems. It is in the best interest of the aerospace community to consider the methods that can best utilize the funds made available to them and yet produce the highest possible quality in all of its production endeavors. Concurrent Engineering could be the answer. "Perhaps no other concept in the past decade has so captured the imagination of design engineering as concurrent engineering. The potential benefits of concurrent engineering are by now well known: faster cycle time, better products, and a more responsive organization" (Ulerich, 1992).

Design engineers who are involved in Concurrent Engineering are currently using an emerging discipline called Design for Manufacturability (DFM). DFM is one of the tools utilized by Concurrent Engineering. It facilitates designers, engineers, manufacturing engineers, marketing personnel, and other members of the Concurrent Engineering team by providing a common goal and language with which to communicate. This communication exhibits itself in the computer software that saves costs and development time in the early design cycle. Its primary goal is to help the designer of parts to design for manufacturing processes and assembly.

Companies utilizing DFM within Concurrent Engineering have experienced tremendous savings. General Motors, in its Cadillac division, for example, discovered that their product development time was slashed by 70 percent. They also found that their part assemblies and part counts were down by 73 percent. The General Motors Cadillac Rear Suspension division alone has saved two million dollars in avoidance costs (Dvorak, 1992).

DFM not only provides cost savings in development time and part assembly reduction but it also provides savings through improved product reliability and customer satisfaction. The design engineers employed by NASA and its independent contractors who implement Concurrent Engineering properly will experience cost savings.

A second example is Lamb Technicon of Warren Michigan. They are a major supplier to the automotive industry. They explain that they have been participating in this type of engineering development long before the term Concurrent Engineering had become popular. They find that Concurrent Engineering eliminates wasteful practices like the separation of manufacturing and design engineering department during the crucial early stages of of product design when product changes are relatively easy to implement (Meade, 1989). A major problem that Lamb Technicon first faced was that the habits of the past tended to prevail, "little dialogue took place between the product design and manufacturing people" (Meade, 1989, p. 68). Lamb Technicon's top management stepped in and explained the importance of total cooperation to the success of the project and ultimately to the future success of the entire organization and its suppliers. From that point on, things moved quickly, and past prejudices were forgotten (Meade, 1989).

A third example is provided by Paul Dvorak in his article in *Machine Design.* Dvorak relates the experiences of Allied Signal, a world technology leader in aerospace, electronics, automotive products and engineered materials. A senior staff engineer with Allied-Signal Aerospace states that "few engineers recall when companies were not so large and specialized" DFM and Concurrent Engineering were standard operating procedures. But as departments increased in numbers of employees, so did the isolation of these employees. Now, in a Concurrent Engineering setting, DFM gives everyone the same language, and that helps reduce their isolation. DFM and Concurrent Engineering let people from engineering, manufacturing, quality, and purchasing all speak in terms of dollars and hours, concepts they already understand. He adds they can more easily brainstorm, create products, and solve problems together (Dvorak, 1992, p. 103).

Product Production and Concurrent Engineering

There are companies that have learned through experience that Concurrent Engineering not only saves time but can also save them money . The Boeing Company, for example, used its design engineers and manufacturing engineers as part of a Concurrent Engineering team to solve problems in new designs that had been frustrating and troublesome in the manufacture of previous product designs. The design process employed for Boeing's new 777 has become a recognized model for the use of Concurrent Engineering. The results Boeing experienced in improving the manufacturing and production process were outstanding, as reported in *Business Week's* October 28, 1991 issue:

> "For three decades, the skin on Boeing jets has had a bend in it where the top of the wing meets the side of the fuselage. This covers the inside rib of the wing, the structure that attaches the wing to the body. In the assembly process, putting just the right bend in several aluminum body panels that fit side by side has been "like an art form"... difficult, time consuming, and costly. On the 777, ...production engineers suggested redoing the wing-body joint to eliminate the bend. The designers agreed and solved thirty years of manufacturing headaches by altering one line on a computer screen (p 121).

Boeing's experience can be used as a model for other companies, government agencies, and NASA. The problem solving benefits accrued by Boeing in the design and production of the 777 could be realized by other aerospace companies in the production of their aerospace systems and launch vehicles.

The problems that aerospace industries and their contractors face in the design of their systems are the same as those faced by Boeing. When implemented correctly, Concurrent Engineering can produce significant benefits in the production phase of aerospace systems.

Product Operation and Concurrent Engineering

When products are delivered and placed into service, the consumer assumes that the engineers who designed and built the system have created a high quality unit. In the past this was not always true. In the mid 70's and 80's for example, American companies saw their quality begin to drop and their customer base transfer to Japanese and German competition. As corporations saw soaring manufacturing costs and their profits begin to drop they found Concurrent Engineering. Ford motor company, for example, in the late 80's designed and built the Ford Taurus and Mercury Sable models. Concurrent Engineering produced a high quality automobile with excellent customer satisfaction and very few breakdowns. Today the Taurus model is the number one selling car in the United States, according to Dr. L. Keys in his article Concurrent Engineering for Consumer, Industrial Products, and Government System. He states that Concurrent Engineering reported advantages including the reduction of maintainability/serviceability efforts and warranty costs which result in increased customer satisfaction.

Current and future aerospace systems require high levels of reliability. Presently reliability comes at a very high cost. With the implementation of Concurrent Engineering in the development of aerospace systems, reliability will be achieved at a lower cost.

The IDA (Institute for Defense Analysis) report, as well as the studies and efforts of Keys and others, included the following expected benefits (see figure 3).

Figure 3

Reported advantages of Concurrent Engineering

1. Improving the quality of designs which resulted in dramatic reductions of engineering change orders (greater than 50%) in early productions;
2. Product development cycle time reduced by as much as 40-60% through the concurrent, rather than sequential, design of product and processes;
3. Manufacturing costs reduced by as much as 30-40% by having multifunction teams integrate product and process design;
4. Scrap and rework reduced by as much as 75% through product and process design optimization;
5. Reduced maintainability/serviceability efforts and warranty costs (ie., life cycle cost savings).

(Keys, 1992, p 283)

Teamwork

With CE's focus on the product and teamwork, the completed project produces a quality manufactured part at a lower cost. The quality can be compared to the product designed, produced and delivered by the individual. Because of the ownership the Concurrent Engineering process provides for the team involved, pride in the product and process is once again achieved. The saving is achieved through less product change, quickness to market, improved reliability and improved quality. S.G. Shina (1991) explains the importance of teamwork to Concurrent Engineering.

> In concurrent engineering, the key ingredient is teamwork. People from many departments collaborate over the life of a product--from idea to obsolescence--to ensure that it reflects customers' needs and desires. Marketing, design engineering, and manufacturing, for example, work together from the outset to anticipate problems and bottlenecks and to eliminate them early on. In so doing, they avoid delays in bringing the product to market and costly failures in service....With concurrent engineering, no longer does marketing give product specification as a *fait accompli* to engineering. No longer does engineering's designing get "tossed over the wall" to manufacturing. Instead, all work together--in fact, one industry observer likened concurrent engineering to "tossing the engineer over the wall" (Shina, 1991, p.22).

Unfortunately, when a group of people are thrown together and told to work as a team when they have worked independently and competitively throughout their careers, the concept is alien. "One aspect of concurrent engineering that is constantly underemphasized is teamwork. I know of no situation in which a dedicated team has failed, while I have seen the lack of teamwork lead to several disasters" (Cousins, 1991, p. 112). One of the ways that the lack of teamwork manifests itself is by erecting a barrier between members with varying talents and abilities. The various talents and abilities create a "culture" among members who share the same talents and abilities yet create distances between those who have different talents and abilities. Many who have tried putting together Concurrent Engineering teams have been unaware of this culture. "The "wall" separating the functions was made with strong cultural mortar....What we have to do is erase boundary lines within the product development department, to create a true cradle-to-grave team, but it's not going to be easy" (Schamisso, 1992, p. 100). Lamentably, many who do finally choose to implement Concurrent Engineering teams do not realize that "being an effective, contributing team member is very hard work" (Butler, 1993, p. 30). The corporations that are attempting to utilize concurrent engineering teams often find that "there is a constant vacuum pulling things back to business as usual" (Kewley, 1993, p. 36). One factor feeding power to the vacuum is the manner in which individuals within the organization are rewarded. If the reward systems in place in the organization are designed to give individuals additional compensation in the form of monetary or other perquisites, then an imbalance will prevail.

> "To put it simply, you get what you measure, and therefore you must measure what you want. You cannot create an integrated team environment with individual and functional measurement systems alone. Each team must take product ownership, and this can happen only if the team, as a group, is being measured in terms of the overall products cost, quality, and schedule performance, too often companies establish functional measurements that conflict with each other" (Kewley, 1993, p. 36).

It is important to have the proper criterion in place to reward teams that work well together, rather than singling out individuals for reward. An individual will not be motivated to work as well in a team if the rewards are individualistic. The reward systems, as well as creating conflict in the individual team members, can add to the difficulties in interpersonal communications. "When a team is not successful in meeting its objectives, the reasons can usually be traced to poor team interpersonal skills. Each member must give the team 100%" (Butler, 1993, p. 30). It is vital to the success of the team that each of the members have developed good interpersonal skills. Each member of the team needs to be able to be confident that each of the other team members are doing their part of the project. Because of this imposed reliance on other people on the team, trust among members is important. Each Concurrent Engineering team member must feel that all of the other members will "pull their weight" and will not leave a part of the process of development unfinished. Another important aspect of effective teamwork is the ability to equably delegate tasks and responsibilities. Team members need to recognize and accept the strengths and weaknesses of each of the team members. One cannot simply put several people in a room together and expect the trust, confidence and willingness to accept responsibility to spontaneously occur. "This team environment, cannot be mandated, but must be accepted and put into practice by each member of the team" (Butler, 1993, p. 30).

Montebello (1994) in his book *Work Teams That Work*, noted that the difference between effective and ineffective teams is that "effective teams work through the breakdowns" (p. 65). He goes on to list four elements of effective communication in teams; 1) promoting candid communication, 2) probing for information, 3) listening for understanding, and 4) presenting information and ideas (Montebello, 1994, p. 65-9).

In an article for *Personnel Management,* Anderson and West (1994) explain the necessity of individuals feeling as if they are in a "positive and psychologically safe atmosphere" to be effective as a team. They go on to explain that the morale of the team must not have any elements of "threat, insecurity, or political game playing" (p. 81.) They also cite the importance of "task orientation" which contains three components of success in teams. The three components are "appraisal, ideation, and commitment to excellence" (p. 81). Anderson and West (1994) define appraisal as "the time spent critically reflecting on objectives," ideation is defined as "the quantity and quality of new ideas proposed," and commitment to excellence is defined as "achieving first-rate performance through self monitoring and using improved work methods" (p. 81). They also remind us of the importance of the corporation being committed to the success of the work teams. To create an atmosphere that Concurrent Engineering work teams will thrive in, there must exist adequate "support for innovation" (p. 81). There are two ways that a corporation can exhibit this kind of support, "articulated support, both written and verbal, and enacted support, the practical resources actually devoted to innovation, including time, personnel and finances" (Anderson, 1994, p. 81).

Any time that a team is created and the atmosphere is there to support the team, the likelihood that it will be successful increases. Whenever a team is formed, either a leader is designated or one will evolve from the group naturally. Possessing the necessary skills to be an effective Concurrent Engineering team facilitator would be beneficial to any team member, whether or not he or she holds a leadership role.

Team Leadership

Just as many people believe that working in teams should occur naturally without additional training, there are those that believe that team leaders will occur naturally without additional training. There are usually exceptions to the rule but even if this does sometimes occur, it is rare. This section will examine the traits that have been identified to be successful to those who have become Concurrent Engineering team facilitators.

"Although "self-directed work team leader" [SDWT] seems to be an oxymoron, it is a role that is clearly needed" (Lowe, 1994, P. 74). Lowe's use of the term oxymoron does fit the idea of a team leader or Concurrent Engineering facilitator. How can one be "equal but different" and still seen as an integral part of the team? If each of the members of a team are accepting their responsibilities, then why is a leader needed? "In more traditional technically oriented environments, such as engineering, manufacturing and construction, specialists frequently find working in a team to be an unnatural and uncomfortable experience (Kezsbom, 1995, p. 39). Because they are unaccustomed to the concept of working in teams and have been autonomous throughout their careers, it is important that a team leader be present to have a "map" leading the way to reach the stated goal or mission of the team. Even Lowe (1994), who called the team leader an oxymoron, recognized the necessity of having a team leader. "The SDWT leader procures resources, represents the team, problem-solves, and coaches team members" (p. 74). Kewley (1993) also stated the importance of the team leader. "Another critically important factor is the team leader. Each team must have a respected, capable leader who possesses good interpersonal and program management skills, technical cognizance of the project, and an ability to see the "big picture" (p. 37).

The need for a team leader is evident, but what role should the team leader have within the team? Shina (1991) stated that "in forming an interfunctional or interdisciplinary team, the best tactic is to set specific goals as early as possible" (p. 26). Beck and Yeager (1994) in their book, *The Leader's Window,* embrace a four step process in being an effective team leader; 1) identify goals, 2) find out how the member plans to achieve goal, 3) identify best form of leadership style for each member and, 4) set critical checkpoints to assess communication. Kezsbom (1995) agrees with Beck and Yeager. Kezsbom (1995) asserted that "one of the critical first steps...is for the team to collectively develop a clear understanding of the end result or the team's mission" (p. 40). He also stated in concordance with Beck's step two that "determining key tasks and responsibilities" (p.40) was very important. In an article titled Design: The Power behind Concurrent Engineering (1993) that appeared in *Design News* , the author perceived that a "team must have a 'champion' who strives for group consensus, encourages risk-taking, and closes the loop by ensuring action items are resolved quickly (p. 26). Keszbom (1995) introduced the Integrated Planning Process (IPP) which "is directed at creating a complete and integrated plan, schedule and identifying areas of risk and concerns, as well as building a truly cohesive team" (p. 40). (see figure 4) Cousins (1991) reminds us that "the key to having an effective team is to have a supportive atmosphere based on mutual respect and responsibility. Without these, cabinets full of schematics and reams of code will not make a development successful" (p. 136). Isgar (1994) sums up the responsibility of the team leader by stating that "overall, a team leader's main responsibility is to help the team develop a charter of boundaries and out comes (p. 46).

Figure 4

Integrated Planning Process

1. Creating a better understanding of team goals and mission
2. Creating a better understanding of team member roles and their interdependent efforts
3. Increasing communication and creating greating support among team specialist
4. Creating greater collaboration among specialists, and reducing costly competition
5. Developing the ability to use conflict in a productive, constructive manner
6. Creating a true sense of team spirit and fostering greater interdependen

(Kezsbom, 1995, page 41)

Leader Characteristics

There are those that believe that some people are born leaders with an innate talent and that it is impossible to train a leader. There are others who believe that anyone can be trained to be a more effective leader. It is not the purpose of this paper to presume to solve that argument. However, it should be noted that effective leaders share many of the same characteristics, and if those characteristics can be developed in others, it behooves one to be aware of them.

It becomes confusing to some who try to equate the role of manager with the role of team leaders. They are not one and the same. There are managers who may or may not be team leaders and there are team leaders that may or may not be managers. According to Isgar (1994), "the team leader's role differs from that of a traditional supervisor. Team leaders shouldn't conduct performance appraisals or other evaluations, though they can provide input. They should be experts in team dynamics, but they shouldn't serve their own teams as knowledge experts" (p. 45). Keszbom (1995) agrees and provides the very different roles for managers and team leaders. He states that "the project team leader should involve task managers or specialists with the primary responsibility accomplishing project team objectives with in their function and at least one level of management above these tasks" (p. 39). Isgar (1994) continues in this vein by delineating the differences between managers and team leaders even further by illustrating what can happen when a team leader that is technically superior to the other members of a team is put in the leadership role. "A team with a technical expert as team leader is a team with a leader expert and member followers....It's almost impossible for technical experts to be neutral, which is necessary in order for them to be effective team leaders" (p. 46).

> Early on, team leaders need to share information, establish norms and expectations, clarify roles, and build trust among team members. If team leaders do that, even leaders with only average interpersonal skills can be effective. But if they don't they'll need exceptional skills. Team leaders should know how to handle such situations as a lack of participation, disagreements, and disruptive behavior from team members....Team leaders should know how to use their organization's approach to problem solving and how to implement its strategy for improving quality" (Isgar, 1994, p. 47).

This leadership approach is very different from that of simply being a manager and 'overseeing' that tasks are being performed. The 'neutrality' of the team leader is of the utmost importance. By recognizing that Concurrent Engineering is the way to produce and manufacture quality products, and by recognizing that teamwork and team leadership skills are important to future engineers, it is now important to develop a thorough understanding of what kind of training these future concurrent engineers will need to be provided.

Training Needs

As the previous literature confirms, Concurrent Engineering will become the method successful companies will utilize in the future. It is of the utmost importance to learn how educators and human resource personnel must retrain themselves and lead the evolution of the curriculum to reflect the needs of future engineers. Lowenstein (1990) tells us that

> "implementation of 'concurrent engineering' has not proven to be an easy task. It requires adoption of a variety of new methods. tools, and techniques as well as organizational changes that are achieved only when accompanied by comprehensive management commitment. It requires education and training. In summary, it requires a change in industrial culture (p. 258).

Many corporations have not realized that the cultural change is so significant. The culture of the corporation can influence even new engineers once they have been immersed into the culture for a while. Sprague (1991) relates how each department can develop its own form of jargonistic terminology, its own databases, tools, and methods of operation that vary greatly from other departments in the same corporation. He goes on to relate that the differences from one corporation to another are significant impediments to Concurrent Engineering. He also tells us that policies ranging from those of the highest governmental agencies to the managers at the bottom of the hierarchical rung have developed "stereotypes" that act as barriers to "cooperative product development" (p. 8). Erkes (1992) purports that if the "cultural" or "human factors" are not an integral part of the training, the training will fail. "People need to learn to cooperate across disciplines, and the appropriate organizational structure has to be instituted right up front" (p. 56). Sprague (1991) agrees.

> "The only way to achieve these goals is to create an environment in which individuals from all disciplines important to a product's life cycle cooperate interactively in defining, planning and managing the product's requirements, concept, design, manufacture, maintenance, refinement, and disposal as well as any related research and development activities (p. 9).

Keys (1992), possibly in order to induce educators to respond, posited "educational institutions will learn how to take a more active role in training future engineers in the fundamentals and applications of this new approach to engineering" (p. 285). Before Keys provided his inducement, Dwivedi (1990) gave definite suggestions as to what must be provided for Concurrent Engineers.

> "The fundamental requirement for concurrent engineering implementation is the education of the individual. Education which will change the individualistic thinking of the people to one of group thinking. This education has to begin from the highest rungs of the hierarchical ladder in the organization and trickle down *[emphasis added]* to lower levels. Thus, it is the cultural change that will herald the fruition of newer design methodologies like concurrent engineering. The implementation of these approaches in traditional management settings will definitely boomerang. Whatever be the design methodologies which are adopted, in the absence of the accompanying cultural changes,. American industrial productivity can never be enhanced" (p. 148).

In contrast, Erkes (1992) relates that training should happen from the "bottom-up" (p. 56). He tells us that if the Concurrent Engineering initiatives are "top-down oriented" and then "try to come up with a global solution," there will be problems with that approach" (p. 56) He discloses the DICE (DARPA Initiative in Concurrent Engineering) mission in "trying to develop a migration path from the current sequential-engineering environment to improved processes, new standards, and full commercial support down stream" (p. 56). Butler (1993) concurs. "Management commitment is essential to CE's success. All levels of management must support the teams by providing both empowerment and needed resources (p. 30).

Erkes (1992) and Butler's (1993) concepts that training should happen from the "bottom-up" directly contradict the concepts of Keys (1992), Shina(1991), and Dwivedi (1990) that training should occur with a "top-down" approach. As seen in figure 5 Shina (1992) outlines successful implementation of Concurrent Engineering into the corporate structure. His first prerequisite of implementation is to obtain the "commitment of senior level

Figure 5

Ten Prerequisites for Successful Implementation of Concurrent Engineering

1. Obtain the commitment of senior level management to make concurrent engineering work.
2. Diagram your current development process. Diagram how it will work with concurrent engineering. Form a consensus on your concurrent engineering strategy.
3. Review your current technology.
4. Establish a long term objective.
5. Target a pilot project for concurrent engineering.
6. Clearly define the measurement of success.
7. Establish a Concurrent Engineering project team.
8. Empower the Concurrent Engineering team with decision making. Agree that management will attend a minimum of two Concurrent Engineering meetings.
9. Prepare the organization for Concurrent Engineering. Make people want to join.
10. Seek advice from other companies. Utilize available outside resources.

(Shina, 1992, 83)

management" (1992, p. 83). He also states that changes that would occur as a result of Concurrent Engineering implementation "should be aggressive, not evolutionary, and should be based on experience with current products" (Shina, 1991, p. 26). Irwin (1994) offers "six issues for successful implementation of concurrent engineering" (p. 10), within these issues, Irwin advances the concept of organizational realignment (see figure 6). According to Irwin (1994), this organizational realignment must occur throughout the organization. It should become a commitment throughout all levels of the organization, neither focusing on the top level first, nor the bottom level first.

Figure 6

Six Issues Critical for Implementation

1. Planning needs to be driven by a vision
2. Commitment is the key dimension of leadership
3. In structuring work teams, form follows function
4. Team decision-making is at the heart of the transformation
5. Training is a key organizational support
6. Organizational support systems often need realignment

(Irwin,1994, p.10)

One issue that a significant portion of the literature agrees upon is the need for training for individuals to participate effectively on a Concurrent Engineering team. Training should be provided to all individuals in the organization that may participate on a Concurrent Engineering team, irrespective of whether they are positioned at the top of the hierarchical organization or at the bottom. Whether training begins at the top or the bottom levels of the organization Kewley (1993) remind us of imminent pitfalls due to the tradition of business as usual. "To offset this, trained concurrent engineering facilitators should be chartered to keep teams focused on the process" (Kewley, 1993, p. 36). Sorohan (1994) provides noteworthy examples of how a Concurrent Engineering facilitator or Team Leader can more likely be successful (see figure 7).

Figure 7

The DO's of Team Leading

1. Encourage team members to confront their differences constructively
2. Keep the team focused on its goals
3. Stress the need to make decisions as a group
4. Tie the teams activities to the organizations vision
5. Help team members develop professionally
6. Provide fair and honest feedback on how well team members perform
7. Provide team members with opportunities to develop new skills and abilities
8. Give members freedom to determine details of how they do their jobs

(Sorohan, 1994, page 14)

Isgar (1994) agrees with the concept of training team leaders, "many team training programs focus on team building, which shows team members how to work together, develop norms, and resolve interpersonal issues but not how to lead" (p. 45). McKnight (1989) explained the importance of an industrial engineer as a project integrator but pointed out the inconspicuous need for "good communication or 'people' skills (p. 27). He further stated that "university curriculums cover this area to some [emphasis added] degree" (p. 27). He explains how an engineer can become an integral part of the process with the appropriate training background (see figure 8).

Figure 8

The Engineer should position himself or herself to be a successful, integral part of Concurrent Engineering projects

Keys to doing this :

1. Develop and Maintain Engineering Skills
2. Develop and Maintain Communication and People Skills
3. Develop and Maintain Organization Skills

(McKnight, 1989, page 27)

Training Concurrent Engineering facilitators (team leaders) will not be expansive enough to encompass the business as usual culture of an organization. Individuals who are slated to be participants will need training as well. In the December 1994 issue of *Training and Development*, it was reported that guidelines (see figure 9) for effective teams "are often quoted, but they are seldom heeded" (p. 36).

The literature implies that there are many concepts of how Concurrent Engineering should be introduced into an organization. The implications are also present with a predilection toward the development of improved corporate and university training and curricular instruction to cultivate effective concurrent engineers.

Figure 9

Eight Edicts For Effective Teams

1. Have a goal
2. Select members carefully
3. Define success
4. Set a lifespan
5. Know who's doing what
6. Establish accountability
7. Develop a team agenda
8. Make meetings meaningful

(Anonymous, 1994, p.36)

Summary

This chapter provided an introduction to the concept of concurrent engineering and defined it as "a systematic approach to the integrated simultaneous design of a product and the related processes, including manufacturing and the other support functions" (Keys, 1992, p. 283). A historical perspective of the development of Concurrent Engineering, with an examination of the role of Japanese competition delivering the necessity to study United States design and manufacturing processes followed. Serial engineering maintains distance between designers, manufacturers, and customers. Concurrent engineering brings all of these aspects closer together. The development of products using Concurrent Engineering were found to be exceptionally superior in quality to those produced with serial engineering. When manufacturing products use Concurrent Engineering, processing problems are solved before manufacturing begins. When Concurrent Engineering is implemented the final product exhibits increased reliability. Concurrent engineering lowers the cost of a product. Teamwork is important to the success of Concurrent Engineering. An effective team leader may mean the difference between the success and failure of a Concurrent Engineering team. There are few who agree upon the methodology of introducing Concurrent Engineering into the corporate structure, specifically the aerospace community. A significant need exists for identification of the training needs for individuals to effectively participate in, and the aerospace community to utilize the development of Concurrent Engineering teams.

CHAPTER III

METHODOLOGY

Introduction

This chapter includes the conceptual framework as well as the components of the research design through which the purpose and objectives of the study were accomplished. This chapter is divided into the following sections: introduction, conceptual framework, research questions, overview of research design, sampling procedure, and instrument.

Conceptual Framework

The training needs of effective concurrent engineering work teams will be identified through the utilization of the Lockean Delphi method of Inquiry. The Lockean Delphi espouses the experiential theory of truth. A Delphi group will be able to provide empirical referents by simplifying the complex skills of a concurrent engineering team and will provide the basis for truth (Linstone & Turoff, 1975).

Although there are several Delphi models, including the Kantian, Leibnizian, Hegelian, and Singerian, the Lockean model was found to be preferable due to its reliance upon the experience and strong base of knowledge obtained from experts and its recognition of the value of that data. "Delphi has become a multiple-use planning tool. The Delphi can be applied to a wide range of program-planning and administrative concerns" (Delbecq, Van de Ven, Gustafson 1975). The Delphi method presented itself to be the most effective in determining the training needs of concurrent engineering teams as perceived by the current engineering practitioners. The Delphi method of inquiry is a systematic, iterative method of data gathering based on independent inputs from a group of experts. Its objective is to obtain a consensus of opinion from a panel of experts regarding a particular subject. This study is to identify several necessary characteristics for effective participation on concurrent engineering teams to be used in the development of successful training programs.

Research Questions

This study will attempt to answer the following research questions.

1. What is the appropriate training required for a good Concurrent Engineering facilitator.

2. What is the appropriate training required for a good Concurrent Engineering Team Member.

3. What is the appropriate university training needed by a Concurrent Engineering Team Member.

4. What training activities are successful in Concurrent Engineering teams.

Overview of Research

The Delphi participants were chosen by a selection committee consisting of current Program Planning, Engineering Cost and Science & Engineering personnel at the National Aeronautics and Space Administration Agency of the Marshall Space Flight Center in Huntsville, Alabama . The selection committee chose the aerospace contractor who best exemplified the concurrent engineering philosophy within their design, development and production processes. The Delphi participants were then selected by the contractor. Those participants were solicited initially by mail (Appendix A). Participation in the study was completely voluntary.

The Delphi study involved three separate mailings to the participants. The first mailing was a solicitation which was returned in the self addressed stamped envelope. The second contained packet with a cover letter, explanations,instructions and the questionnaire (Appendix A), and a self addressed stamped envelope was included for returning the questionnaire. The compiled responses were then returned in mailing three with instructions to rank each of the responses consecutively in a descending order of importance. The ranking resulted in a hierarchical structure identifying the training needs for concurrent engineering teams. The prioritized ranking were then returned to the Delphi participants for perusal, additional comments or revisions.

Each Delphi participant questionnaire was numbered. This served as a tracking device for the researcher, who was the sole recipient of the information. The compiled results are reported in the study and to the members of the Delphi team; however, no Delphi team member was apprised specifically as to how any other team member has responded, nor was this information be supplied in the study.

Sampling Procedure

A committee of individuals from NASA's Marshall Space Flight Center selected the aerospace company at which Delphi study should be done. The Delphi selection committee were individuals from the Marshall office of Program Planning, Engineering Cost and Science & Engineering. Each committee member is a NASA employee trained in Concurrent Engineering or was familiar with the philosophy.

The selection committee utilized a set of criteria as a base for the selection process of the Delphi Group. The participants were selected based on the following criteria.

1. Recognition as an established leader within Concurrent Engineering.
2. Past track record with Concurrent Engineering programs
3. Training Efforts currently in practice.

Instrument

The initial instrument consisted of four open ended, short answer questions. This design reduces the likelihood of bias or limitations associated with the Likert-type questionnaire. The questions were developed from the literature and specifically the training literature dealing with Concurrent Engineering.

The Delphi members, in answering the questions were asked to give a short answers in their responses to specific questions. This form of response helps to provide a more consistent organization of the answers.

CHAPTER IV

PRESENTATION OF FINDINGS

Introduction

The purpose of this study was to identify the areas of training needed to facilitate successful implementation and application of Concurrent Engineering work teams within a broad area of the aerospace manufacturing community. This chapter presents the results of a Delphi team responses to four Delphi research questions. The Delphi team generated a list of training topics for each Delphi question. The team then ranked the compiled responses in hierarchical order creating a prioritized listing of the most important training needed for an individual to successfully participate on a Concurrent Engineering work team.

This chapter presents the findings of the research and analysis of data. The chapter is organized in the following manner. The first section presents the training topics suggested by the Delphi team of Concurrent Engineering experts and describes the process of how the topics were conjoined into a second list which was then returned to the Delphi team for hierarchical ranking. The second section presents the training topics that the Delphi team ranked as most important.

The NASA selection committee (Appendix B) identified one large aerospace company considered to be preponderantly experienced in the utilization of Concurrent Engineering teams. When the company was identified by the NASA selection committee, a manager of manufacturing engineering was approached and the purpose of the research was explained, along with an explanation of how the company had been selected by NASA. Permission to proceed with the research was granted and twenty-two individuals were identified as experts in the use of concurrent engineering within this particular aerospace company. All twenty-two of those selected were sent letters soliciting their participation on the Delphi team. Of the twenty-two who were initially identified, fourteen (Appendix C) agreed to participate as a Delphi team member and eight declined.

Upon completion of a consent form (Appendix A), the fourteen Delphi participants were sent a four question survey (Appendix D) which was developed from the review of literature and the NASA selection committee input. The survey process commenced in January of 1996.

The Delphi team members were asked to answer the survey (Appendix D) and give short answers to the specific training needed for Concurrent Engineering facilitators, Concurrent Engineering team members and for developing corporate and university engineering team training curriculum. The responses varied greatly from each other, yet there were some of the contributions similar enough to compress into the second questionnaire. An analysis of the Delphi teams' first responses compressed all the responses into forty-eight (48) items for the first question, forty-five (45) items for the second question, fifteen (15) items for the third question and twenty-nine (29) items for the fourth question. The conjoined responses were numbered and forwarded to the team for ranking (Appendix E). In a cover letter, (Appendix A) the experts were requested to rank each item listed in the consecutive order of importance from the greatest to the least significant. The Delphi team was instructed that items left blank would receive a zero or no ranking. In actuality the items left blank would receive a score that places them at the end of the ranked list. This, in effect would accomplish the same goal as the zero ranking in the final analysis. When an examination of the ranked responses for each question had been completed, a list of training needs for concurrent engineers was identified.

Responses to Survey Number One Question Number One

What are the appropriate training elements or topics required for a good Concurrent Engineering/Design Build team facilitator? This question was revamped from research question number one. The term "Design Build team" was added due to the knowledge that the company where the research was being conducted used that nomenclature to describe their Concurrent Engineering teams.

Employing the semblance of responses, the eighty-five individual responses were compressed into forty-eight items. Although further compression was possible, it was avoided due to the additional comments provided by team members concerning the confusion they had experienced within the teams of which they had participated. One individual expressed concern over the semantic perplexity of team terminology in describing skills. The conjoined responses of the Delphi team is listed in Table 1. The second questionnaire requested that the experts prioritize the conjoined list.

Table 1

Compiled Responses to Delphi Question Number 1

What are the appropriate training elements or topics required for a good Concurrent Engineering/Design Build team facilitator

1. An Understanding of the Procurement of Outside Production Parts
2. Ability to Communicate Technical Issues to Program Managers
3. Network Communication Skills as Electronic/Communication
4. An Understanding of the Process Flow of Parts Fabrication
5. Knowledge of the Mission and Charter of the Company Knowing the Company Goals and Direction
6. Recording and Documenting Team Resolution Decisions
7. Knowledge of How to Remove Communication Barriers
8. An Understanding of the Process of Major Assembly
9. An Understanding of the Product Definition Process
10. An Understanding of the Process of Sub-assembly
11. Training in Engineering or Technical awareness
12. A Working Knowledge of Systems Engineering
13. Training in the Basics of Project Management
14. Lean Manufacturing and Low Cost Hardware
15. How to Effectively Organize Team Members
16. Training on Keeping the Team on Task Assist (Achieve Its Goals)
17. Interpersonal Management Techniques
18. Training in Quality Improvement Tools, A Clear Understanding of Pareto Charts, Statistical Process Control, Cause and Effect Analysis
19. Ability to Promote Team Activities
20. Ability to Prepare Team Agendas
21. Teaching Skills to Train the Team
22. A Basic Liberal Arts Background
23. Possession of Forecasting Skills
24. Documenting Team Decisions
25. Hardware Variability and Control
26. Archiving a Complex Projects
27. Reaching Team Consensus
28. Being an Organized Person
29. Public Speaking Experience
30. Leading Effective Meetings
31. Ability to Read Blueprints
32. Motivational Techniques
33. Commitment to Process
34. Team Technical Issue

Table 1(continued)

Compiled Responses to Delphi Question Number 1

What are the appropriate training elements or topics required for a good Concurrent Engineering/Design Build team facilitator
35. Computing Packages--Ability to Use Computer Software for Tracking Program Action Items Setting Up Technical Data and Correspondence Files, Knowing How to Use A Computer Scheduling Tool, Knowing How to Use A Word Processor, Knowing How to Use A Chart Maker, Knowing How to Use A Spreadsheet
36. Respect of the Team
37. Resolution Methods
38. Sharing Information
39. Time Management
40. Development Skills
41. Conflict Resolution
42. Negotiation Skills
43. Scheduling Skills
44. Data Gathering
45. Listening Skills
46. Brainstorming
47. Responsibility
48. Prioritizing

Responses to Survey Number One Question Number Two

What are the appropriate training elements or topics required for a good Concurrent Engineering/Design Build Team Member? This question was revamped from research question number two. The term “Design Build team” was added due to the knowledge that the company where the research was being conducted used that terminology to describe their Concurrent Engineering teams.

Employing the semblance of responses, the sixty-five (65) individual responses were compressed into forty-five (45) items. Although further compression was possible, it was avoided due to the confusion expressed by one of the members over the semantic perplexity of team terminology in describing skills. The conjoined responses of the Delphi team is listed in Table 2. The second questionnaire requested that the participants prioritize the conjoined list by ranking them.

Table 2

Compiled Responses to Delphi Question Number 2

What are the appropriate training elements or topics required for a good Concurrent Engineering/Design Build Team Member
1. Knowledge, experience, and background in the field of your specialty
2. Technology training specific to the team company's business
3. Team member training explaining exactly what a team is
4. Team (technical) issue resolution methods and skills
5. How team members interact to reach common goals
6. Ability to simplify concepts for team understanding
7. How individual members contribute to team goals
8. Training in what makes a team meeting effective
9. Training for appreciation of other points of view
10. Psychology of teams or psychology of groups
11. Geometric dimensioning and tolerancing
12. Communications software training
13. Sharing the why of requirements
14. Training in Engineering Software
15. Willingness to Teach and Learn
16. Understanding team pressures
17. Dealing with difficult people
18. Basic project management
19. Hardware Variability Control
20. Lean production techniques
21. Dynamics of group action
22. Responsibility to the team
23. Effects of peer pressure
24. Manufacturing Exposure
25. Low cost manufacturing
26. Machine control basics
27. Commitment to a team

Table 2 (continued)

Compiled Responses to Delphi Question Number 2

What are the appropriate training elements or topics required for a good Concurrent Engineering/Design Build Team Member
28. Basic problem solving
29. Increased Vocabulary
30. Public speaking skills
31. Process engineering
32. Technical excellence
33. Confidence building
34. Interpersonal Skills
35. Negotiation skills
36. Presentation skills
37. Listening Training
38. Conflict resolution
39. Consensus skills
40. Team dynamics
41. Data gathering
42. Quality Control
43. Voice Training
44. Design to Cost
45. Brainstorming

Responses to Survey Number One Question Number Three

What are the appropriate elements or topics needed in a University curriculum to train a Concurrent Engineering/Design Build Team member? This question was revamped from research question number three. The term "Design Build team" was added due to the knowledge that the company where the research was being conducted used that terminology to describe their Concurrent Engineering teams.

Employing the semblance of responses, the thirty-eight (38) individual responses were compressed into fifteen (15) items. The conjoined responses of the Delphi team are listed in Table 3. The second questionnaire requested that the participants prioritize the conjoined list by ranking them.

Table 3 (continued)

Compiled Responses to Delphi Question Number 3

What are the appropriate training elements or topics needed in a university curriculum to train a Concurrent Engineering/Design Build Team Member?

1. A Thorough Technical training, including; math, physics, engineering.
2. Development of Good Presentation skills, including; public speaking,
3. Communication skills, including both written and oral, interpersonal
4. Training in what a Concurrent Engineering/Design Build Team is designed to
5. Development of an understanding that engineering designs drive the total
6. Formation of Process Thinking, including project cost estimates, project
7. Study of successful team efforts, including conflict resolution, group
8. Instruction geared toward the development of PC software skills.
9. Methods to lead toward confidence building
10. Basic problem solving tools
11. Statistical process control, including statistical analysis
12. A Thorough Knowledge of Process Engineering
13 Lean Production Techniques
14. Knowledge of and Ability to Conduct a Tolerance Analysis
15. Study of Total Quality Management

Responses to Survey Number One Question Number Four

In your professional assessment, what training topics work best to result in successful Concurrent Engineering/Design Build teams? This question was revamped from research question number four. The term "Design Build team" was added due to the knowledge that the company where the research was being conducted used that terminology to describe their Concurrent Engineering teams.

Employing the semblance of responses, the forty-seven (47) individual responses were compressed into twenty-nine (29) items. The conjoined responses of the Delphi team are listed in Table 4. The second questionnaire requested that the participants prioritize the conjoined list by ranking them.

Table 4

Compiled Responses to Delphi Question Number 4

What are the appropriate training elements or topics needed in university curriculum to train a Concurrent Engineering/Design Build Team Member

1. Understanding World Competition and the need for team deliverables, reduced cycle time, reduced cost, increased customer satisfaction, and better quality.
2. A Knowledge of the Impact of Computer Aided Design on Customers
3. Excellent Examples of Concurrent Engineering Teams Currently Used
4. A Knowledge of the Impact of Computer Aided Design on Tool Design
5. Automated Data Collection of Statistical Process Control
6. Earning Respect for Doing the Hard Work these Projects Require
7. A Knowledge of the Impact of CAD on Numerical ControlProgramming
8. Self confidence with an appropriate amount of humility
9. A Knowledge of the Impact of Computer Aided Design on QC/QA
10. Awareness of business decisions which will affect projects
11. How to work as A Team Instead of an Organization
12. A Knowledge of the Impact of CAD on Planning Techniques for Interaction between Organizations
13. The ability to use Computer Software
14. Willing to Incorporate New Ideas
15. Sharing a Common Understood Goal
16. Team Dynamics Training Together
17. Techniques for Promoting Brainstorming
18. Respect for the opinion of others
19. Techniques for Problem Resolution
20. Competence in Critical Path Analysis

Table 4 (continued)

Compiled Responses to Delphi Question Number 4

What are the appropriate training elements or topics needed in university curriculum to train a Concurrent Engineering/Design Build Team Member
21. Cross Functional Training
22. Planning Skills & Scheduling Techniques
23. Project Management Basics
24. Interpersonal Management Skills
25. Suitable Vocabulary
26. Costing Proficiency
27. Speaking Skills
28. Listening Skills
29. Organization Skills

Analysis of Ranks

The second round of the Delphi survey (Appendix E) was designed from the conjoined responses of the first survey The purpose of the second questionnaire was to create a hierarchical structure from the responses to the first question. A cover letter (Appendix A) to the Delphi team instructed the team members to identify their choice of the most important training needs for future concurrent engineering/design build teams. As a Delphi team member, they were to rank in an ascending order of importance the listed responses from the first questionnaire. The most important item was to be identified with a number one (1) and the least important item was to be identified with the last number in the series. The ranking resulted in a hierarchical structure identifying the most important training topics The data from the Delphi ranking sheets were entered into a spread sheet program. The Delphi training topics for each Delphi question were ranked by the team members. The ranked values were then totaled. The total sum values for each training topics were then sorted and the numbers placed in an ascending order. The ascending order displays the data so that the lowest number represented the most important training need and the highest number represented the least important training need. This hierarchical structure created an ascending number series and a descending order of importance for the training topics. In this round of the Delphi process, twelve (12) of fourteen (14) team members responded. This Data is presented in tables 5 through 8 and the total from the rankings are under the title score in the tables.

Rankings of Survey Number Two Question Number One

Table 5 represents those training topics which are needed to develop the personal and technical skills of a good Concurrent Engineering Facilitator. The Delphi team members ranking exhibits the most important training as number one (1) and the least important training need as forty-eight (48). One of the team members did not send back a ranked list but listed the top four items on a separate page. In that one case, where the expert did not rank the responses, although the expert did not rank the items correctly, the selection of the most important training items was easily identifiable. The unidentified items were treated as if not ranked, and the identified items were counted with the rest of the rankings.

Table 5

Ranking of Training Topics for Delphi Question #1

Rank	Score	Training Topics Required For A Good Concurrent Engineering Facilitator
1	86	Training on Keeping the Team on Task Assist Team to Achieve Its Goal
2	106	Knowledge of How to Remove Communication Barriers
3	114	How to Effectively Organize Team Members
4	131	Interpersonal Management Techniques
5	142	Leading Effective Meetings
6	143	An Understanding of the Product Definition Process
7	143	Listening Skills
8	154	Ability to Prepare Team Agendas
9	164	Ability to Promote Team Activities
10	166	Conflict Resolution
11	168	Resolution Methods
12	170	Reaching Team Consensus
13	182	Recording and Documenting Team Resolution Decisions
14	182	Documenting Team Decisions
15	194	Teaching Skills to Train the Team
16	207	Commitment to Process
17	209	Training in Quality Improvement Tools
18	233	Negotiation Skills
19	239	Knowledge of the Mission and Charter of the Company
20	243	Training in the Basics of Project Management
21	247	Being an Organized Person
22	247	Sharing Information
23	250	Computing Packages
24	256	Public Speaking Experience
25	256	Respect of the Team
26	262	Brainstorming
27	273	Ability to Communicate Technical Issues to Program Mgr.
28	274	Responsibility
29	278	Motivational Techniques
30	286	Network Communication Skills as Electronic and Communication
31	304	Training in Engineering or Technical awareness
32	308	Time Management
33	313	Prioritizing
34	319	Scheduling Skills

Table 5 (continued)

Ranking of Training Topics for Delphi Question #1

Rank	Score	Training Topics Required For A Good Concurrent Engineering Facilitator
35	330	Data Gathering
36	338	Archiving a Complex Projects
37	345	An Understanding of the Process of Major Assembly
38	384	An Understanding of the Process Flow of Parts Fabrication
39	384	An Understanding of the Process of Sub-assembly
40	386	A Working Knowledge of Systems Engineering
41	403	An Understanding of the Procurement of Outside Production Parts
42	405	Team Technical Issue
43	410	Hardware Variability and Control
44	410	Ability to Read Blueprints
45	411	Development Skills
46	427	A Basic Liberal Arts Background
47	440	Possession of Forecasting Skills
48	456	Lean Manufacturing and Low Cost Hardware

Rankings of Survey Number Two Question Number Two

Table 6 represents those training topics which are needed to develop the personal and technical skills of a good Concurrent Engineering Team Member. The Delphi team members ranking show the most important training need as number one (1) and the least important training need as forty-five (45). In that one case, where the expert did not rank the responses, although the expert did not rank the items correctly, the selection of the most important training items was easily identifiable. The unidentified items were treated as if not ranked, and the identified items were counted with the rest of the rankings.

Table 6

Ranking of Training Topics for Delphi Question #2

Rank	Score	Training Topics Required For A Good Concurrent Engineering Team Member
1	24	Knowledge, experience, and background in the field of specialty
2	109	Technology training specific to the team company's business
3	128	Team member training explaining exactly what a team is
4	129	Team (technical) issue resolution methods and skills
5	148	Ability to simplify concepts for team understanding
6	148	How individual members contribute to team goals
7	163	Technical excellence
8	167	Basic problem solving
9	168	Willingness to Teach and Learn
10	171	How team members interact to reach common goals
11	180	Commitment to a team
12	182	Training in what makes a team meeting effective
13	195	Responsibility to the team
14	195	Manufacturing Exposure
15	199	Listening Training
16	205	Interpersonal Skills
17	224	Training for appreciation of other points of view
18	239	Understanding team pressures
19	239	Dynamics of group action
20	251	Quality Control
21	256	Dealing with difficult people
22	256	Consensus skills
23	263	Negotiation skills
24	267	Data gathering
25	274	Lean production techniques
26	275	Conflict resolution
27	276	Psychology of teams or psychology of groups
28	277	Presentation skills
29	282	Design to Cost
30	285	Sharing the why of requirements
31	290	Low cost manufacturing
32	291	Hardware Variability Control
33	296	Process engineering

Table 6 (continues)

Ranking of Training Topics for Delphi Question #2

Rank	Score	Training Topics Required For A Good Concurrent Engineering Team Member
34	296	Brainstorming
35	299	Team dynamics
36	302	Basic project management
37	306	Effects of peer pressure
38	320	Communications software training
39	323	Geometric dimensioning and tolerancing
40	334	Public speaking skills
41	343	Training in Engineering Software
42	398	Machine control basics
43	401	Confidence building
44	452	Increased Vocabulary
45	484	Voice Training

Rankings of Survey Number Two Question Number Three

Table 7 represents those training topics which are needed in a university curriculum to develop the personal and technical skills of an engineering student so that he/she will become a successful Concurrent Engineering Team Member. The Delphi team members ranking show the most important training need as number one (1) and the least important training need as fifteen (15). One of the team members did not send back a ranked list but listed the top four items on a separate page. One of the team members chose not to respond to this question on the second survey. No scores were added or subtracted due to that team members lack of response.

Table 7

Ranking of Training Topics for Delphi Question #3

Rank	Score	Appropriate University Training For Future Concurrent Engineering Members?
1.	18	Training in what a Concurrent Engineering/Design Build Team is designed to accomplish, a knowledge of the need for interaction between organizations and providing excellent examples of successful concurrent engineering teams now in use..
2.	43	A Thorough Technical training, including; math, physics, engineering, chemistry, metallurgy, etc.
3.	47	Development of an understanding that engineering designs drive the total product cost (i.e. procurement cost, manufacturing cost, support costs, market share penetration potential).
4.	47	Study of successful team efforts, including conflict resolution, group dynamics, negotiation skills, team based problem solving, as well as a study of unsuccessful team efforts.
5.	60	Communication skills, including both written and oral, interpersonal management, data gathering and presentation, and negotiation skills.
6.	70	Formation of Process Thinking, including project cost estimates, project scheduling, and project management.
7.	83	Basic problem solving tools
8.	92	Development of Good Presentation skills, including; public speaking, computer software programs for designing project presentations, psychology, and business management.
9.	97	Study of Total Quality Management
10.	104	Statistical process control, including statistical analysis
11.	117	A Thorough Knowledge of Process Engineering
12.	118	Instruction geared toward the development of PC software skills, including; CAD/CAM solid modeling and associated analysis tools, factory simulation, machine control basics.
13.	126	Lean Production Techniques
14.	128	Knowledge of and Ability to Conduct a Tolerance Analysis
15.	157	Methods to lead toward confidence building

Rankings of Survey Number Two Question Number Four

Table 8 represents those training activities which are most successful in the personal and technical development of an individual to become a viable member of a Concurrent Engineering Team. These items would be important whether the training would be in the role of facilitator, member, or college student. The Delphi team members ranking show the most important training need as number one (1) and the least important training need as number twenty-nine (29). One of the team members chose not to respond to this question on the second survey. No scores were added or subtracted due to that team members lack of response.

Table 8

Ranking of Training Topics for Delphi Question #4

Rank	Score	What training activities are successful in Concurrent Engineering teams?
1.	42	Understanding World Competition and the need for team deliverables, reduced cycle time, reduced cost, increased customer satisfaction, and better quality.
2.	80	How to work as A Team Instead of an Organization
3.	90	Techniques for Problem Resolution
4.	102	Team Dynamics Training Together
5.	103	Sharing a Common Understood Goal
6.	106	Cross Functional Training
7.	111	Willing to Incorporate New Ideas
8.	135	Awareness of business decisions which will affect projects
9.	137	Excellent Examples of Concurrent Engineering Teams Currently in Use
10.	142	Interpersonal Management Skills
11.	152	Respect for the opinion of others
12.	154	Listening Skills

Table 8 (continued)

Ranking of Training Topics for Delphi Question #4

Rank	Score	What training activities are successful in Concurrent Engineering teams?
13.	164	Organization Skills
14.	165	Project Management Basics
15.	173	A Knowledge of the Impact of CAD on Customers
16.	179	Competence in Critical Path Analysis
17.	180	The ability to use Computer Software
18.	181	A Knowledge of the Impact of CAD on Planning Techniques for Interaction between Organizations
19.	181	Techniques for Promoting Brainstorming
20.	190	Planning Skills & Scheduling Techniques
21.	196	Speaking Skills
22.	203	A Knowledge of the Impact of Computer Aided Design on Tool Design
23.	216	Automated Data Collection of Statistical Process Control
24.	216	Costing Proficiency
25.	227	A Knowledge of the Impact of Computer Aided Design on Quality Assurance
26.	231	A Knowledge of the Impact of CAD on Numerical Control Programming
27.	238	Earning Respect for Doing the Hard Work these Projects Require
28.	238	Self confidence with an appropriate amount of humility
29.	259	Suitable Vocabulary

Summary

This chapter presented the results of the data collected from a Delphi survey process. The process was conducted in two stages. In the first stage, survey one requested the fourteen Delphi team members to respond to four open-ended questions. All fourteen members responded to the first survey. In the second stage, the responses from survey one were conjoined into lists that were returned to the Delphi team for rank-ordering. Twelve of the fourteen Delphi team members responded to survey number two. Although one of the respondents to survey number two did not rank the lists correctly, their selection of the most important training items for the facilitator and the team member were correct and counted with the other rankings. The same team member chose not to respond to question three and four of survey two. The lack of response from that particular team member was not counted on questions three and four. The response rate for survey number two represented eighty-six percent (86%) of the original Delphi team. The hierarchical ranks from survey number two were presented in tables five thorough eight. Chapter 5 will discuss the conclusions and recommendations from this study.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

The purpose of this study was to identify the areas of training needed to develop personnel and help facilitate successful implementation and application of Concurrent Engineering work teams within a broad area of the aerospace manufacturing community. This final chapter presents a summary of the findings, furnishes conclusions and provides a few recommendations for further investigation.

Concurrent Engineering is continuing to evolve in large companies toward the goal of providing products of the quality provided by the individual who once singularly designed, manufactured, and delivered to the customer. Japanese competition prompted American companies to evaluate their process of conducting business as usual. This competition can be met by “designing a better mouse trap”. This new mouse trap for many aerospace companies is concurrent engineering. Too much distance was found to exist between designers, manufacturers, and customers in serial engineering. The superior quality, increased reliability, fewer processing problems and lower costs of products manufactured under the utilization of Concurrent Engineering compel the existing training structures in both the corporate and higher education settings to prepare their engineers to participate successfully in order to harvest the obvious benefits. An effective team leader with a prepared team cooperating on all levels will most likely be successful. A major stumbling block in the conversion from business as usual to concurrent engineering is in determining the most appropriate curriculum to be provided by universities training future engineers as well as the appropriate curriculum to be incorporated into a comprehensive Concurrent Engineering training program for engineers, technicians and business managers already in the field. A significant need exists for identification of the training needs for individuals to effectively participate in, and the aerospace community to utilize the development of concurrent engineering teams.

Research Methodology

The purpose of this study was to identify the training topics needed to develop personnel and facilitate successful implementation of concurrent engineering. A Delphi study was conducted in January 1996. The Delphi study involved three separate mailings to the participants; 1) solicitation, 2) survey question one, and 3) survey question two. Survey number one asked the Delphi team members to specifically answer four open-ended questions. Survey number two compiled the responses from survey number one and returned them to the Delphi participants with instructions to rank each of the responses consecutively in a descending order of importance. The ranking resulted in a hierarchical structure which identified the training topics needed for successful implementation of concurrent engineering teams.

Conclusions

The survey responses accomplished two purposes, one, to identify the training topic needed and, two, to rank the identified topics in descending order of importance for each of the research questions. This section delineates the results of the Delphi teams responses to the final round of the survey.

What is the appropriate training required for a good Concurrent Engineering facilitator?

The final ranked responses provided by the Delphi team concerning question number one are listed below. The listing is by order of importance with number one being the most important training needed for a good Concurrent Engineering facilitator. The list gives the top ten most important training needs.

1 Training on Keeping the Team on Task and to Assist Team to Achieve Its Goal
2 Knowledge of How to Remove Communication Barriers
3 How to Effectively Organize Team Members
4 Interpersonal Management Techniques
5 Leading Effective Meetings
6 An Understanding of the Product Definition Process
7 Listening Skills
8 Ability to Prepare Team Agendas
9 Ability to Promote Team Activities
10 Conflict Resolution

During phase one of the Delphi responses, one of the participants, in response to training needed by a good Concurrent Engineering facilitator, felt it necessary to add that

"It is my experience that in the current industrial environment,

> management rarely provides a full-time, independent facilitator. The task of performing the facilitator function usually falls upon a team member. This can have catastrophic effects upon team performance if that individual is not an extraordinary person".

This would indicate that all individuals should have the appropriate training to be a good Concurrent Engineering facilitator due to the fact that anytime they are requested to be a part of a team, they may find themselves in the facilitator role. Another team member felt that in addition to the items above,

> "The facilitator should also have some training in setting up technical data and correspondence files, and archives for a complex project. This is something that we have usually learned by trial and error,...mostly error. I am sure that a course could be set up that could communicate "proper" ways of cataloging, filing, and archiving project materials".

<u>What is the appropriate training required for a good Concurrent Engineering Team Member?</u>

The final ranked responses provided by the Delphi team concerning question number two are listed below. The listing is by order of importance with number one being the most important training need for a good Concurrent Engineering Team Member. The list gives the top ten most important training needs.

1 Knowledge, experience, and background in the field of specialty
2 training specific to the team company's business
3 Team member training explaining exactly what a team is
4 Team (technical) issue resolution methods and skills
5 Ability to simplify concepts for team understanding
6 How individual members contribute to team goals
7 Technical excellence
8 Basic problem solving
9 Willingness to Teach and Learn
10 How team members interact to reach common goals

In the responses from survey number one, a Delphi participant stressed the importance of knowledge, experience and background in the field of specialty by stating that "Those who speak without a solid background waste the team's time as we try to educate them." Another Delphi participant stated that the production of a good team member would be achieved through:

> "The training that yields the best results is the training that team members receive together. This training is focused on the processes the team will use to identify problems, the tools they will use to solve the problem and the methods to be employed to reach consensus....When team members are identified and assigned, the success of the team effort is greatly enhanced if the team members have already received the basic training [to be a good team member".

Although team training together was not identified as one of the top ten items, this quote appeared profound and merited mention in the conclusions.

What is the appropriate university training needed by a Concurrent Engineering Team Member?

The final ranked responses provided by the Delphi team concerning question number three are listed below. The listing is by order of importance with number one being the most important training needs for an appropriate university curriculum. The list gives the top ten most important training needs.

1. Training in what a Concurrent Engineering/Design Build Team is designed to accomplish, a knowledge of the need for interaction between organizations and providing excellent examples of successful concurrent engineering teams now in use..
2. A Thorough Technical training, including; math, physics, engineering, chemistry, metallurgy, etc.
3. Development of an understanding that engineering designs drive the

total product cost (i.e. procurement cost,manufacturing cost, support costs, market share penetration potential).

4. Study of successful team efforts, including conflict resolution, group dynamics, negotiation skills, team based problem solving, as well as a study of unsuccessful team efforts.
5. Communication skills, including both written and oral, interpersonal management, data gathering and presentation, and negotiation skills.
6. Formation of Process Thinking, including project cost estimates, project scheduling, and project management.
7. Basic problem solving tools
8. Development of Good Presentation skills, including; public speaking, computer software programs for designing project presentations, psychology, and business management.
9. Study of Total Quality Management
10. Statistical process control, including statistical analysis

In response to appropriate university training needed, one Delphi participant stated that "One of the more difficult tasks in adding something to a curriculum is making the class broad enough that what is learned can be used in a broad range of industries". Even though the Delphi team did delineate the most appropriate items needed in a university curriculum, this sage advice should not go unheeded. Another Delphi team member stressed the importance of the study of successful team efforts by stating that:

> "Nothing beats experience. The best way to achieve that in a university setting is via team projects with on-going assessment of team progress The teams should be established with members with different technical knowledge to best simulate a cross-functional team environment".

<u>What training activities are successful in Concurrent Engineering teams?</u>

The final ranked responses provided by the Delphi team concerning question number four are listed below. The listing is by order of importance with number one being the most important training activities believed to be successful are listed below. The list gives the top ten most important training needed as identified by the Delphi team.

1. Understanding World Competition and the need for team deliverables, reduced cycle time, reduced cost, increased customer satisfaction, and better quality.
2. How to work as A Team Instead of an Organization
3. Techniques for Problem Resolution
4. Team Dynamics Training Together
5. Sharing a Common Understood Goal
6. Cross Functional Training
7. Willing to Incorporate New Ideas
8. Awareness of business decisions which will affect projects
9. Excellent Examples of Concurrent Engineering Teams Currently in Use
10. Interpersonal Management Skills

As suggested by the review of literature in chapter two, more and more aerospace corporations will begin to shift from Business As Usual (BAU) to Concurrent Engineering. The shift will be necessary for the aerospace industry to remain competitive in the global market place.

In order to smooth the transition toward a universal use of concurrent engineering, the identification of appropriate training needs was paramount. This study can aid in the transition by providing the topics that the expertise of the Delphi team have indicated. These topics can be used by the aerospace industries in training their employees as well as by university administrators in developing curriculum for future engineers. These lists were provided within four broad areas that were identified as necessary to the future development of concurrent engineering. These areas were:

Appropriate training required for a good Concurrent Engineering facilitator.

Appropriate training required for a good Concurrent Engineering Team Member

Appropriate university training needed by a Concurrent Engineering Team Member.

Training activities are successful in Concurrent Engineering team.

Recommendations

There exists several areas concerning concurrent engineering that yet need to be investigated. There are aerospace companies other than the one selected by the NASA selection committee that have successfully implemented concurrent engineering. A comparison study with one or more of those companies would provide additional support or refutation to the findings of this study. It would be recommended that definitions of terms be provided during the second phase of the Delphi process to eliminate the semantic perplexity encountered during this study.

A team training program could be developed using the topics identified by this study and the results evaluated and quantified. This could provide additional support or refutation to the findings of this study. An experimental training program developed from the topics identified by this study could also identify the feasibility of incorporating these types of training programs for all entering personnel in an aerospace industry.

An Engineering department in an institution of higher education could use these topics to develop curriculum and design follow-up studies of the graduates to evaluate the effectiveness of providing concurrent engineering team training.

It would also be advantageous to discover the correlation of the level of effectiveness when a team facilitator is appointed in the concurrent engineering atmosphere as opposed to when no facilitator is provided.

The concluding thought to be remembered from this study was best stated by one of the Delphi experts "In the future, a lack of effective team work skills will be a handicap almost as great as a lack of computing skills".

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APPENDIX A

Consent Form, Letters, and Solicitation

Pittsburg State University
Department of Engineering Technology•200 Whitesitt Hall•Pittsburg Kansas 66762-7565

PLEASE RETURN BY JANUARY 17th, 1996

Concurrent Engineering Training Needs

DBTs (Design Build Teams)
PDTs (Product Development Teams)

Delphi Member Consent Form

I agree to participate as a Delphi Team Member for Russell Rosmait's research on Training Needs for Concurrent Engineering.

I understand that my name will be listed in the final published paper as a member of the team, but that none of my individual responses from the questionnaires will be directly quoted.

For my participation I will be provided a copy of the research paper when it is completed.

Signed: ____
«fname» «lname»

Date: ____________________________

Pittsburg State University
Department of Engineering Technology•200 Whitesitt Hall•Pittsburg Kansas 66762-7565

January 15, 1996

«mr.» «fname» «lname»
«title»
«company»
«p.o.» «mail code»
«city» «state» «zip»

Dear «mr.» «lname»:

I appreciate your involvement as a member of the Delphi Team on Training Needs for Concurrent Engineering/Design Build Teams. You are one of twenty-two professionals selected and your expertise is vital to the success of this study.

The Delphi study involves three separate mailings to you.

1. This mailing contains explanations and instructions, the first questionnaire, and a self-addressed stamped envelope for the return of the questionnaire. Your response as a study team member is extremely important. Please make your answers short and specific and return the questionnaire by February 1, 1996

2. The next mailing will be in early February. The responses to the first questionnaire will be tabulated by me and returned to you. As a team member you will be given instructions to rank the responses in descending order of importance. The ranking will result in a hierarchical structure identifying the most important training needed for Concurrent Engineering/Design Build Team members and leaders.

3. The prioritized rankings will then be returned to you by mid February for your general perusal and any additional comments you would like to share concerning the ranking. Comments should be returned as soon as possible to be included in the study.

If you have any questions about the time line or the process, call me at (316) 235-4375. Once again, my sincere thanks for your professional participation. I trust we will all benefit from the results of this study.

Sincerely,

Russell L. Rosmait,
Associate Professor

Pittsburg State University

Department of Engineering Technology•200 Whitesitt Hall•Pittsburg Kansas 66762-7565

April 10, 1996

«mr.» «fname» «lname»
«title»
«company»
«p.o.» «mail code»
«city» «state» «zip»

Dear «mr.» «lname»:

Thank you once again for being part of this Delphi Team. Your responses to the Delphi questions were outstanding. I have compiled each of your responses, conjoined duplications and have designed a comprehensive list for each of the Delphi questions.

Your involvement in this section of the Delphi study is to identify your choice of the most important training needs for future concurrent engineering/design build teams. As a Delphi team member, I am asking you to rank in a descending order of importance the listed items for each question. Rank the most important item with a one (1) and what you consider the least important with the last number in the series. The ranking will result in a hierarchical structure identifying the most important training needed for future concurrent engineering/design build team members and facilitators.

You are one of fifteen professionals selected and your expertise is, **vital** to the success of this study. Please take a few minutes of your busy schedule to rank the items in the order of importance as you perceive them. When you have concluded the ranking, return it to me in the enclosed self-addressed stamped envelope as soon as possible. If possible, **please FAX** your rankings to **316-235-4004.** I have enclosed a FAX cover sheet for your convenience.

The prioritized rankings will be returned to you as soon as all Delphi members have responded for your general perusal and additional comments.

If you have any questions about the time line or the process, call me at (316) 235-4375. Once again, I must express my sincere gratitude to you for taking the time to assist me in this important academic endeavor. Your professional opinion is vital to the study. Have a pleasant spring.

Sincerely,

Russell L. Rosmait
Associate Professor

Pittsburg State University

Department of Engineering Technology•200 Whitesitt Hall•Pittsburg Kansas 66762-7565

April 10, 1996

«mr.» «fname» «lname»
«title»
«company»
«p.o.» «mail code»
«city» «state» «zip»

Dear «mr.» «lname»:

My name is Russell Rosmait, a graduate student in the Department of Aviation and Space Education at Oklahoma State University and a full time faculty member in the Department of Engineering Technology at Pittsburg State University in Pittsburg, Kansas.

I am currently in my final semester working on my dissertation to complete my doctoral degree. The topic of my dissertation is "Training Needs for Concurrent Engineering."

For the last few years, I have been involved with summer projects at NASA's Marshall Space flight center. While working at NASA I asked a group of engineers to identify several companies and leaders in industry who have been involved with the successful implementation of concurrent engineering practices. The Boeing Company and your name was recommended by several people. As part of my dissertation, I am conducting a Delphi Inquiry and would like you to participate as a member of the panel. Your involvement would include answering a short list of open ended questions and ranking compiled responses. As an expert, your participation will improve the quality of my research.

You will be listed in the final paper as a participant on the Delphi Team. Your individual responses would be kept confidential, but the consensual responses of the entire team would be published.

I encourage you to please sign the enclosed consent form and return it in the postage paid envelope. Should you have any questions about this research project please feel free to call me at (316)235-4375. I appreciate your time and cooperation. Please return the enclosed form by **January 17, 1996**

Sincerely,

Russell L. Rosmait
Associate Professor

APPENDIX B

Selection Committee

Delphi
Selection Committee

Joseph W. Hamaker, Manager
Engineering Cost Group
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

Dave Taylor
Engineering Cost Group
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

Hugh Brady
Preliminary Design Office
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

John Mac Pherson
Program Review
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

APPENDIX C

The Delphi Team

Fourteen Member
Delphi Team

Mr. Geoff Harrison
Boeing Commercial Airplane Group
Wichita, KS 67277-7730

Mr. Steve Wheeler
Boeing Commercial Airplane Group
Wichita, KS 67277-7730

Mr. Dave Marshall
Boeing Commercial Airplane Group
Wichita, KS 67277-7730

Mr. John Bloom
Boeing Commercial Airplane Group
Wichita, KS 67277-7730

Mr. Harold Albright
Boeing Commercial Airplane Group
Wichita, KS 67277-7730

Mr. Brian Riedel
Boeing Commercial Airplane Group
Wichita, KS 67277-7730

Mr. Tim Garton
Boeing Commercial Airplane Group
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Ms. Angie Wright
Boeing Commercial Airplane Group
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Mr. Tom McDavitt
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Mr. Jack Gucker
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Mr. Harry Arnold
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Mr. Mark Sanders
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Seattle, WA 98124-2207

Mr. Dave Evans
Boeing Commercial Airplane Group
Seattle, WA 98124-2207

Mr. Jag Hajari
Boeing Commercial Airplane Group
Seattle, WA 98124-2207

APPENDIX D

Delphi Survey Round One

Delphi Team Members

Questionnaire on Training Needs for
Concurrent Engineering/ Design Build Teams
Please return in the postage paid envelope
by **February 5, 1996**

Please answer the following Delphi questions. The Delphi method is used to find solutions by using professional or expert opinion. In your answers to the questions please be specific. It is understood that basic communication, math and science skills are a given for this training. You may use additional space or pages if you would like.

Thanks again for your help

1. What are the appropriate training elements or topics required for a good Concurrent Engineering/Design Build Team facilitator?

2. What are the appropriate training elements or topics required for a good Concurrent Engineering/Design Build Team Member?

3. What are the appropriate elements or topics needed in a University curriculum to train a Concurrent Engineering/Design Build Team Member?

4. In your professional assessment, what training topics work best to result in successful Concurrent Engineering/Design Build Teams?

APPENDIX E

Delphi Survey Round Two Rankings

Compiled Responses to Delphi Question Number 1

What are the appropriate training elements or topics required for a good Concurrent Engineering/Design Build team facilitator?

1. ____ An Understanding of the Procurement of Outside Production Parts
2. ____ Ability to Communicate Technical Issues to Program Managers
3. ____ Network Communication Skills as Electronic/Communication
4. ____ An Understanding of the Process Flow of Parts Fabrication
5. ____ Knowledge of the Mission and Charter of the Company
   Knowing the Company Goals and Direction
6. ____ Recording and Documenting Team Resolution Decisions
7. ____ Knowledge of How to Remove Communication Barriers
8. ____ An Understanding of the Process of Major Assembly
9. ____ An Understanding of the Product Definition Process
10. ____ An Understanding of the Process of Sub-assembly
11. ____ Training in Engineering or Technical awareness
12. ____ A Working Knowledge of Systems Engineering
13. ____ Training in the Basics of Project Management
14. ____ Lean Manufacturing and Low Cost Hardware
15. ____ How to Effectively Organize Team Members
16. ____ Training on Keeping the Team on Task Assist Team to Achieve Its Goal
17. ____ Interpersonal Management Techniques
18. ____ Training in Quality Improvement Tools, A Clear Understanding of Pareto Charts Statistical Process Control Cause and Effect Analysis
19. ____ Ability to Promote Team Activities
20. ____ Ability to Prepare Team Agendas
21. ____ Teaching Skills to Train the Team
22. ____ A Basic Liberal Arts Background

23. ____ Possession of Forecasting Skills
24. ____ Documenting Team Decisions
25. ____ Hardware Variability and Control
26. ____ Archiving a Complex Projects
27. ____ Reaching Team Consensus
28. ____ Being an Organized Person
29. ____ Public Speaking Experience
30. ____ Leading Effective Meetings
31. ____ Ability to Read Blueprints
32. ____ Motivational Techniques
33. ____ Commitment to Process
34. ____ Team Technical Issue
35. ____ Computing Packages
    Ability to Use Computer Software for Tracking Action Items
    Setting Up Technical Data and Correspondence Files
    Knowing How to Use A Computer Scheduling Tool, Word Processor, Chart Maker, Spreadsheet programs
36. ____ Respect of the Team
37. ____ Resolution Methods
38. ____ Sharing Information
39. ____ Time Management
40. ____ Development Skills
41. ____ Conflict Resolution
42. ____ Negotiation Skills
43. ____ Scheduling Skills
44. ____ Data Gathering
45. ____ Listening Skills
46. ____ Brainstorming
47. ____ Responsibility
48. ____ Prioritizing

Compiled Responses to Delphi Question Number 2

What are the appropriate training elements or topics required for a good Concurrent Engineering/Design Built team member?

1. ___ Knowledge, experience, and background in the field of your specialty
2. ___ Technology training specific to the team company's business Awareness of company goals
3. ___ Team member training explaining exactly what a team is
4. ___ Team (technical) issue resolution methods and skills
5. ___ How team members interact to reach common goals
6. ___ Ability to simplify concepts for team understanding
7. ___ How individual members contribute to team goals
8. ___ Training in what makes a team meeting effective
9. ___ Training for appreciation of other points of view
10. ___ Psychology of teams or psychology of groups
11. ___ Geometric dimensioning and tolerancing
12. ___ Communications software training Word processing Spreadsheet Scheduling and Presentation slides/overheads software
13. ___ Sharing the why of requirements
14. ___ Training in Engineering Software CAD/CAM solid modeling and associated analysis tools and factory simulation
15. ___ Willingness to Teach and Learn
16. ___ Understanding team pressures
17. ___ Dealing with difficult people
18. ___ Basic project management
19. ___ Hardware Variability Control
20. ___ Lean production techniques
21. ___ Dynamics of group action
22. ___ Responsibility to the team
23. ___ Effects of peer pressure

24. ___ Manufacturing Exposure
25. ___ Low cost manufacturing
26. ___ Machine control basics
27. ___ Commitment to a team
28. ___ Basic problem solving
29. ___ Increased Vocabulary
30. ___ Public speaking skills
31. ___ Process engineering
32. ___ Technical excellence
33. ___ Confidence building
34. ___ Interpersonal Skills
35. ___ Negotiation skills
36. ___ Presentation skills
37. ___ Listening Training
38. ___ Conflict resolution
39. ___ Consensus skills
40. ___ Team dynamics
41. ___ Data gathering
42. ___ Quality Control--Tolerance analysis, Statistical analysis Statistical process control, Statistical processing,Design of Experiments and Continuous quality improvement
43. ___ Voice Training
44. ___ Design to Cost
45. ___ Brainstorming

Compiled Responses to Delphi Question Number 3

What are the appropriate elements or topics needed in a University curriculum to train a Concurrent Engineering/Design Build Team Member?

1. ____ A Thorough Technical training, including; math, physics, engineering, chemistry, metallurgy, etc.

2. ____ Development of Good Presentation skills, including; public speaking, computer software programs for designing project presentations, psychology, and business management.

3. ____ Communication skills, including both written and oral, interpersonal management, data gathering and presentation, and negotiation skills.

4. ____ Training in what a Concurrent Engineering/Design Build Team is designed to accomplish, a knowledge of the need for interaction between organizations and providing excellent examples of successful concurrent engineering teams now in use.

5. ____ Development of an understanding that engineering designs drive the total product cost (i.e. procurement cost, manufacturing cost, support costs, market share penetration potential).

6. ____ Formation of Process Thinking, including project cost estimates, project scheduling, and project management.

7. ____ Study of successful team efforts, including conflict resolution, group dynamics, negotiation skills, team based problem solving, as well as a study of unsuccessful team efforts.

8. ____ Instruction geared toward the development of PC software skills, including; CAD/CAM solid modeling and associated analysis tools, factory simulation, machine control basics.

9. ____ Methods to lead toward confidence building

10. ____ Basic problem solving tools

11. ____ Statistical process control, including statistical analysis

12. ____ A Thorough Knowledge of Process Engineering

13. ____ Lean Production Techniques

14. ____ Knowledge of and Ability to Conduct a Tolerance Analysis

15. ____ Study of Total Quality Management

Compiled Responses to Delphi Question Number 4

In your professional assessment, what training topics work best to result in successful Concurrent Engineering/Design Build Teams?

1. ____ Understanding World Competition and the need for team deliverables, reduced cycle time, reduced cost, increased customer satisfaction, and better quality.
2. ____ A Knowledge of the Impact of Computer Aided Design on Customers
3. ____ Excellent Examples of Concurrent Engineering Teams Currently in Use
4. ____ A Knowledge of the Impact of Computer Aided Design on Tool Design
5. ____ Automated Data Collection of Statistical Process Control
6. ____ Earning Respect for Doing the Hard Work these Projects Require
7. ____ A Knowledge of the Impact of CAD on Numerical Control Programming
8. ____ Self confidence with an appropriate amount of humility
9. ____ A Knowledge of the Impact of Computer Aided Design on Quality Assurance
10. ____ Awareness of business decisions which will affect projects
11. ____ How to work as A Team Instead of an Organization
12. ____ A Knowledge of the Impact of CAD on Planning Techniques for Interaction between Organizations
13. ____ The ability to use Computer Software
14. ____ Willing to Incorporate New Ideas
15. ____ Sharing a Common Understood Goal
16. ____ Team Dynamics Training Together
17. ____ Techniques for Promoting Brainstorming
18. ____ Respect for the opinion of others
19. ____ Techniques for Problem Resolution
20. ____ Competence in Critical Path Analysis
21. ____ Cross Functional Training

22. ____ Planning Skills & Scheduling Techniques
23. ____ Project Management Basics
24. ____ Interpersonal Management Skills
25. ____ Suitable Vocabulary
26. ____ Costing Proficiency
27. ____ Speaking Skills
28. ____ Listening Skills
29. ____ Organization Skills

VITA

Russell L. Rosmait

Candidate for the degree of

Doctor of Education

Dissertation: LEADERSHIP WITHIN CONCURRENT ENGINEERING: A DELPHI INQUIRY INTO TRAINING NEEDS FOR THE AEROSPACE INDUSTRY

Major Field: Higher Education

Biographical:

Personal Data: Born in Milwaukee, Wisconsin, February 23, 1959, the son of Theodore J. and Arlene C. Rosmait

Education: Graduated from Milwaukee Trade and Technical High School, Milwaukee, Wisconsin, June, 1977; received a Bachelor of Science degree from The University of Wisconsin-Stout, Menomonie, Wisconsin, in December, 1981; received a Master of Science degree from The University of Wisconsin-Stout, Menomonie, Wisconsin, in May, 1985; received a Specialist in Education degree, Pittsburg State University, Pittsburg, Kansas; Completed requirements for the Doctor of Education degree at Oklahoma State University, in May 1996.

Professional Experience: Assistant Director, AFS Cast Metals Institute, Des Plaines, Illinois, 1982-86; Process Engineer, Marathon Electric Manufacturing Corporation, Wausau, Wisconsin, 1986-87; Assistant Professor, Pittsburg State University, Pittsburg,Kansas, 1987-Present.

Honors and Achievements: NASA Summer fellowship to Marshall Space Flight Center, Huntsville, Alabama, 1991,1992 & 1995; Phi Kappa Phi 1992; FEF Professor Scholarship for graduate study, 1989,1990 & 1991.

OKLAHOMA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD
HUMAN SUBJECTS REVIEW

Date: 12-05-95 **IRB#:** ED-96-052

Proposal Title: LEADERSHIP WITHIN CONCURRENT ENGINEERING: A DELPHI INQUIRY INTO TRAINING NEEDS FOR THE AEROSPACE INDUSTRY

Principal Investigator(s): Kenneth Wiggins, Russell L. Rosmait

Reviewed and Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved

ALL APPROVALS MAY BE SUBJECT TO REVIEW BY FULL INSTITUTIONAL REVIEW BOARD AT NEXT MEETING.
APPROVAL STATUS PERIOD VALID FOR ONE CALENDAR YEAR AFTER WHICH A CONTINUATION OR RENEWAL REQUEST IS REQUIRED TO BE SUBMITTED FOR BOARD APPROVAL.
ANY MODIFICATIONS TO APPROVED PROJECT MUST ALSO BE SUBMITTED FOR APPROVAL.

Comments, Modifications/Conditions for Approval or Reasons for Deferral or Disapproval are as follows:

Signature: John H. Wycoff
Chair of Institutional Review Board

Date: December 7, 1995