ACE vs. Six Sigma

by

Thomas C. Hutton

B.S. Industrial Technology, Central Connecticut State University, 1989

SUBMITTED TO THE ALFRED P. SLOAN SCHOOL OF MANAGEMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF BUSINESS ADMINISTRATION

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2004

Signature of Author: _____
Alfred P. Sloan School of Management
May 7, 2004

Certified by: _____
Deborah Nightingale, Ph.D.
Professor of Department of Aeronautics and
Astronautics and Engineering Systems Division

Certified by: _____
D. Eleanor Westney
Society of Sloan Fellows and Professor of International Management

Accepted by: _____
Stephen J. Sacca
Director, Sloan Fellows Program

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ABSTRACT

In the early 1980's and 1990's, companies began to build upon the principles of Total Quality Management and developed there own unique quality systems. The most popular and well known of these systems is Six Sigma that was developed by Motorola and successfully adopted by others such as Allied Signal (now Honeywell) and most notably, General Electric. Six Sigma can be characterized as a highly formalized, process oriented improvement tool that is data focused. The Six Sigma process is normally performed by a diverse team, who attack a quality/process problem by analyzing process variation or in statistical terms, sigma. The foundations of Six Sigma are commitment from upper management, detailed training and a regimented diagnostic approach.

Another quality operating system is the less known, but very successful, Achieving Competitive Excellence (ACE) operating system. This system was developed and is practiced by United Technologies Corporation (UTC). The ACE system is broader based than the Six-Sigma approach, however, ACE is not as data oriented as the Six Sigma approach. ACE revolves around the three principle categories of process improvement and waste elimination tools, decision-making tools, and problem solving tools. These tools impact issues as diverse, but not limited to, factory floor cleanliness, market feedback analysis, machine tool preventative maintenance and set up reduction. ACE is a combination of lean manufacturing and quality improvement philosophies.

This paper provides an analysis of both the Six Sigma and ACE Quality Operating Systems. In the paper the systems are compared and contrasted. Further, strengths and weaknesses of each system are discussed. In particular, the analysis focuses on how ACE can leverage elements and aspects of Six Sigma. The analysis concludes that there are elements of Six Sigma that would benefit ACE. The paper identifies that the strength of Six Sigma's statistical approach and its positive impact on process certification could be beneficially applied to the ACE system. Further, there are recommendations for UTC to place more of an emphasis on ACE training and to accelerate its current efforts to better link quality and lean improvement to product engineering and design.

Certified by: Deborah Nightingale, Ph.D.
Title: Professor of Department of Aeronautics and
Astronautics and Engineering Systems Division

Certified by: D. Eleanor Westney
Title: Society of Sloan Fellows and Professor of International Management

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INTRODUCTION

In all sectors of the world economy, quality management and improvement is a central consideration. As quality is an important part of customer satisfaction, it is thereby a critical element of most, if not all, businesses. In some industries, quality goes beyond customer satisfaction and into critical areas such as customer and public safety. Prime examples of these types of industries are the aerospace and building systems industries.

Total quality management, at its most basic level is a philosophy of management. Quality management is not one tool or a grouping of processes or tools, but a focus of the entire organization on the ultimate goal of customer satisfaction (Ovretveit, 2000).

Within quality management resides the major concepts of quality assessment and quality assurance. Quality assessment tends to focus on specific criteria for measuring the quality of a product or service. It is focused on the end result of a total quality management practices. Quality assessment can be defined as the practice of ensuring that products or services that are supplied by an organization meet the quality standards that are determined by that organization (Donabedian, 1992).

Included in quality assessment are the specific tools and processes used by an organization to evaluate if quality standards have been met. Although sometimes quality standards are based on customer feedback or customer specifications, it is rare. Generally, they are based upon internal guidelines or a notion of what is required and desired by the customer (Ovretveit, 2000).

Conversely, in the case of quality assurance, it is the practice of determining if the product or service produced meets the quality specifications. Quality assurance does not necessarily determine specific procedures or processes that are designed to ensure that standards of quality are met (Donabedian, 1992).

Taking into account both quality assessment and quality assurance, many attempts have been made over the years by companies and organizations at developing, deploying, and implementing a sustaining quality management system. There are two quality management systems that this paper will focus on and evaluate. They are Six Sigma, which was originally developed by Motorola in the mid 1980's and later made popular through its adoption by General Electric and Allied Signal (now Honeywell). The second is Achieving Competitive Excellence or ACE that was developed in the 1990's by United Technology Corporation and is used today throughout that company.

Prior to evaluating Six Sigma and ACE, it is beneficial to review Total Quality Management as it is generally accepted to be the underlying foundation from which current day continuous improvement and operating systems have evolved. "TQM as proposed by Deming and Juran, is an all-pervading system of continuous improvement of products (and services) that came to prominence in the United States during World War II. Deming, a statistician, developed monitoring processes that attempted to reduce waste. He persuaded industries to re-examine production processes in order to build in quality and thereby reduce rejection rates. As a result, wartime productivity and quality rose. Later on, Japanese companies eager to enter world markets, enthusiastically embraced

TQM concepts. It has been well documented how, by the 1960's and 1970's, through wholehearted adoption of Total Quality principles, that the reputation of Japanese goods was transformed. TQM has been the root from which numerous offshoots have branched: Total Quality Control (TQC), Statistical Process Control (SPC), and Statistical Quality Control (SQC), being more notable" ("Managing Quality," 2002).

There are many useful summaries that have been produced from the TQM philosophy, most notably Deming's own, "Fourteen Points" and Crosby's re-interpretation of them. A synthesis of the key processes and requirement is as follows:

1. Senior management must embrace the process and take personal charge of quality.
2. Top-down cascade of training from the chief executive through the organization.
3. Effective gathering of statistical data, its correct interpretation and utilization.
4. Clear quality goals must be written into business plans ("Managing Quality," 2002).

Well-known examples of enlightened companies that embraced TQM are Xerox, Hewlett Packard, and Harley Davidson. In these successful companies, TQM led to significant and measurable bottom line benefits. Other organizations followed down the TQM road.

Not all of the companies that followed TQM were successful and pleased with their results. Actually, many were quite disillusioned and unhappy. In some companies, the mention of TQM brought about ill feelings and a sense of frustration. It is commonly believed that companies frustrated and dissatisfied with TQM mismanaged their implementation by choosing to utilize only some of the TQM tools in a "bolt on" type of manner to their existing quality and general management systems and practices. Success was far more likely when companies practiced proper analysis, and as necessary, the appropriate overhaul of existing systems and practices.

Regardless of whether a company's TQM experience was successful or less than successful, the fact remains that many companies and organizations throughout the world gained a general knowledge of and an appreciation for the TQM tools on at least some level. This in my view is critical to the founding, and for that matter, the foundation of the continuous improvement and quality operating systems in use today including Six Sigma and ACE.

Through exposure to TQM programs, both casual and dedicated practitioners learned the value of customer service and continuous improvement residing at the core of their business. Some organizations have the fundamental belief and capability to execute wholesale change and improvement. Others that were less dedicated and committed simply gained familiarity and an appreciation of the magnitude of TQM's potential.

"Customer service is seen as an integral, yet identifiable, part of TQM. In 1950, Deming told his audiences "the customer is the most important part of the production line". Then, as now, the problem is in determining and analyzing customer satisfaction. Should this be a reactive process of response to customer complaints or should it be a pro-active TQM type process that is not content with mere customer satisfaction, but rather strives for customer delight? The data suggests that the latter is the correct approach. Participants in PIMS (Profit Impact of Marketing Strategy) tabulated quality assessments with financial returns analysis showed strong correlation between perceived quality and (a) year-on-year growth in market share; and (b) price margin over competitors" ("Managing Quality," 2002).

As indicated earlier, there are many quality management and continuous improvement programs in the world today. The intent of this paper is to review two of them, ACE and Six Sigma. In the course of doing so, it is the goal to gain a more complete knowledge of both systems. Further, it is my aim to understand the benefits and shortcomings of both systems and to understand how UTC can enhance and improve the ACE operating system.

SIX SIGMA – HISTORY AND BACKGROUND

Six Sigma is a Quality Management Program that strives to improve a company's profitability and customer satisfaction by reducing process errors and variation. The program was developed by Motorola in the early 1990's as the company was challenged by its CEO, Bob Galvin, in the mid 1980's to reduce product failure levels by ten-fold in five years. By implementing the Six Sigma process throughout the company, Motorola improved its quality level from a sigma level of four to a sigma level of six. The company also had unprecedented growth and profitability. Additionally, major gains were made in productivity and cycle-time reduction. Motorola also received significant attention and recognition for the Six Sigma led improvements. Two years after the implementation of Six Sigma, Motorola was honored with the Malcolm Baldridge National Quality Award. In the ten years that followed the launch of Six Sigma, Motorola recorded very impressive business improvements and operating results. These achievements include the company growing sales five-fold, with associated profits rising nearly 20% per year. Additionally, Motorola stock increased 21% annually for the ten-year period. The results that Motorola achieved have been the product of hundreds of individual improvement efforts that effected product design, manufacturing, and services in all its business units. As indicated by Alan Larson, one of the early internal Six Sigma consultants at Motorola who later helped spread the program to other large companies, was that projects effected dozens of administrative and transactional processes. Larson reported that big strides were made by better understanding customer needs and thereby developing new processes that made possible significantly improved services and on-time delivery. As a further testament to Motorola's success, many companies have since

adopted the Six Sigma program, most notably Allied Signal (now Honeywell) and General Electric (Pande, Neuman, & Cavanagh, 2000).

SIX SIGMA - DESCRIPTION

The word sigma takes its origin from the Greek alphabet and is used in statistical distribution equations to represent defect rates. The lower case Greek letter sigma stands for standard deviation. Standard deviation is a statistical way to describe how much variation exists in a set of data, a group of items, or a process (Managing Quality, 2002). A six sigma process is one that is statistically considered near perfect in that it would be expected to yield 99.9997% and produce 3.4 defects per one million observations. Consideration of expected process percent yields and the number of defects per million observations is rather interesting when it comes to the associated sigma of a process. As anticipated, a six sigma process is very difficult to attain. For that matter, so are four and five sigma processes. Upon review of a table in Figure 1 that correlates sigma to percent yield and to the number of defects per million observations, an interesting lesson is learned about the convention of measuring processes in terms of sigma.

YIELD (%)	DPMO	Sigma
6.68	933200	0
8.455	915450	0.125
10.56	894400	0.25
13.03	869700	0.375
15.87	841300	0.5
19.08	809200	0.625
22.66	773400	0.75
26.595	734050	0.875
30.85	**691500**	**1**
35.435	645650	1.125
40.13	598700	1.25
45.025	549750	1.375
50	500000	1.5
54.975	450250	1.625
59.87	401300	1.75
64.565	354350	1.875
69.15	**308500**	**2**
73.405	265950	2.125
77.34	226600	2.25
80.92	190800	2.375
84.13	158700	2.5
86.97	130300	2.625
89.44	105600	2.75
91.545	84550	2.875
93.32	**66800**	**3**
94.79	52100	3.125
95.99	40100	3.25
96.96	30400	3.375
97.73	22700	3.5
98.32	16800	3.625
98.78	12200	3.75
99.12	8800	3.875
99.38	**6200**	**4**
99.565	4350	4.125
99.7	3000	4.25
99.795	2050	4.375
99.87	1300	4.5
99.91	900	4.625
99.94	600	4.75
99.96	400	4.875
99.977	**230**	**5**
99.982	180	5.125
99.987	130	5.25
99.992	80	5.375
99.997	30	5.5
99.99767	23.35	5.625
99.99833	16.7	5.75
99.999	10.05	5.875
99.99966	**3.4**	**6**

Figure 1. Sigma capability conversion table.

A one sigma process yields 31% and produces 691,500 defects per million observations. A two sigma process correlates to a 69% yield and would be expected to have 308,500 defects per million observations. Note that a three sigma process has a significantly higher yield of 93%, but still produces what would generally be considered a very high number of defects at 66,800 per million observations. A four sigma process is one that has a 99.38% yield and produces what again would be considered to be a high number of defects per million observations at 6,200. A five sigma process yields 99.977% and produces a dramatically reduced number of defects per million observations at 230. Finally, the highly desired and sought after process that has a sigma level of six would allow only 3.4 defects per million observations and would have an associated yield of 99.997%. Clearly, by measuring products and processes against a six sigma standard, the bar is raised. This appears to be particularly appropriate in today's world of very demanding customers.

As depicted by Forrest Breyfogle in Implementing Six Sigma, the "goodness level" of 99% is rather telling. In a world of 99% yield we would experience the following:

- 20,000 lost articles of mail per hour
- Unsafe drinking water almost 15 minutes per day
- 5,000 incorrect surgical operations per week
- 2 short or long landings at most major airports each day
- 200,000 wrong drug prescriptions each year
- No electricity for almost 7 hours per month

Figure 2. Depicts examples of how a 99% yield world is truly subpar and unacceptable (Enck & Breyfogle, 2002).

The overarching goal of Six Sigma is to increase customer satisfaction and to improve company profits by reducing process variation and defects. Defects can be related to most measures of customer satisfaction, including cost, quality and delivery. It can therefore be stated that Six Sigma is based on the general assumption that increased defects lead to increased customer dissatisfaction and a loss in sales. Six Sigma practitioners utilize metrics such as defect rate, sigma level, defects per unit, yield and process capability indices.

Six Sigma is based on what is called the "statistical thinking" paradigm. This means that all processes have inherent variability. Therefore, in developing metrics, customer requirements and needs are first taken into consideration. These customer driven values, for example cost, are utilized as the mean of a normal distribution. Specifications or defects are then placed six standard deviations on either side of the mean. Therefore, the way that Six Sigma works is to first determine the number of defects in a process, and then to determine how to eliminate the defects (Enck & Breyfogle, 2002).

SIX SIGMA – SIX MAJOR THEMES

The critical elements of Six Sigma can be summarized by six major themes. These themes are supported by many six sigma tools.

Theme One: Genuine Focus on the Customer

By every available source and measure, Six Sigma certainly appears to be customer centric. In Six Sigma, customer focus becomes the top priority. Six Sigma performance measures begin with the customer; further, Six Sigma improvements are defined by their impact on customer satisfaction and value.

Theme Two: Data and Fact Driven Management

Contrary to the 'just do it" approach, Six Sigma's approach is more in line with "just the facts". The Six Sigma process begins by clarifying what measures are key to gauging business performance, then it applies data and analysis in order to develop an understanding of key variables in order to understand results.

Theme Three: Process Focus

In Six Sigma, the process and the improvement of it is the key vehicle to success. In focusing on processes, the changes and improvements brought about are more lasting and permanent. Also, that mastering processes is a way to build competitive advantage in delivering value to customers.

Theme Four: Proactive Management

Six Sigma attempts to change the culture of companies from reactivity and fire fighting to proactively. The desired end result is having a dynamic and responsive approach to management. A key objective is to learn to act in advance of events. Too often, managers are given a false sense of security that they are right on top of things due to all of their hard work and efforts. In a Six Sigma world, this is believed to be a sign that a manager or organization has lost control.

Theme Five: Boundaryless Collaboration

Six Sigma tends to create an environment of true teamwork. The process expands opportunities for people from different departments and organizations to collaborate. Activities tend to become measured in the form of an entire process rather than by the parts. This tends to enhance collaboration and cause participants to see more of the big picture. Boundaryless doesn't necessarily promote self-sacrifice; rather it requires an understanding of the real needs of the end users of the supply chain.

Theme Six: Drive for Perfection with Tolerance for Failure

Although the title of this theme may appear to be contradictory in nature, in practice and in Six Sigma it doesn't seem to be. Along with the benefits of new ideas and approaches, unfortunately comes risk. The Six Sigma process and associated education recognizes this and aggressively takes strides to encourage creativity while also including significant risk management training and the utilization of risk management tools.

As indicated in the Six Sigma literature and research and as evident in the real world, people that are severely punished for taking risks in the course of making improvements and bringing about change will tend to become risk adverse and live with status quo. Six Sigma attempts to find the right balance (Pande et al., 2000).

In review of the six themes, none of them appear to be new or truly unique. Six Sigma experts and practitioners readily admit this. The power and effectiveness of Six Sigma is believed to be brought about by the ability to package and use the six themes in totality.

SIX SIGMA - DMAIC

The problem solving process that Six Sigma uses is called DMAIC, (pronounced duh-MAY-ick), it is an acronym for the five phase processes of define, measure, analyze, improve and control. DMAIC is the backbone of Six Sigma and is considered as such because it provides the fundamental structure and processes from which all Six Sigma activity is to emanate and evolve. Like most TQM processes or tools, Six Sigma is practiced typically in teams of diverse backgrounds and different organizational areas. In bringing a diverse team together to work a problem or initiative across a large enterprise, it is critical to have a common process or model that all members can follow. This process for Six Sigma is DMAIC.

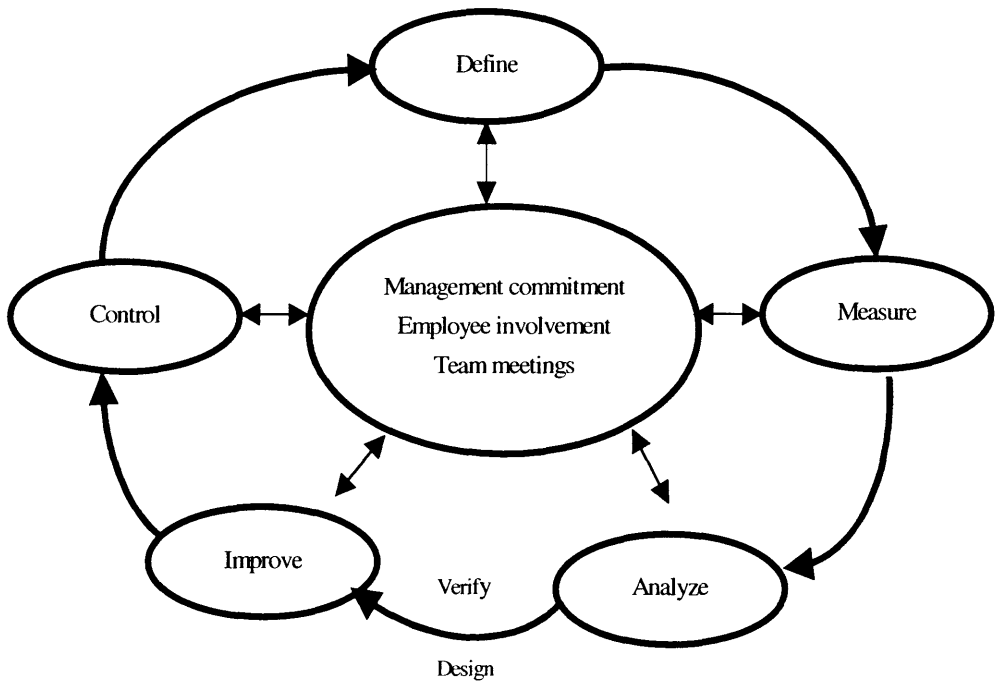

Figure 3. The DMAIC base model.

Define Phase

In the define phase, it is determined that a candidate project will be selected for Six Sigma. The intent of the define phase is to clarify the goals and value of a project. Teams and champions use the appropriate tools necessary to assess the magnitude of the opportunity in a given value stream, the resources required, and an overall design of the problem-solving process. The selected issue will be a clear source of pain for the organization and either currently or potentially for the customer.

This first step is in many ways the most difficult for a team. They must deal with many important questions. Although they may seem like rather basic questions, they are critical to the success of the team and project and must be answered in this early stage. Questions such as, "Who is the customer?", "What are the customers requirements?", and "What are the benefits of making improvement?".

Once a project has been selected, a team will be identified to work the issue. In this phase, the team's job will be to rigorously define the parameters of the project. An important aspect of this phase is for the team to define the scope and goals of the project such that it will be clear to all when success is achieved. A key deliverable for the team in the define phase is for the process that is being evaluated to be flow charted in order to fully understand and define all of the variables associated with the project. The tools used in this phase are not unique to Six Sigma and are typical of many TQM programs. It is fairly typical for teams to use fishbone diagrams in this phase. The define phase is

considered a critical phase in that it is the first and the other four phases of DMAIC build upon it (Munro, 2002).

Measure Phase

The define phase identifies the boundaries for the team to work within, aids in identifying the process variables, as well as guiding the team to develop a means to keep score. In the measure phase the team will assess the amount of variation within the variables. Teams are expected to identify and measure both input and output process variation. The measurement tools used, and in particular the variation associated with them, are considered critical. Therefore, a critical and early step in the measure phase is to determine how much variation exists in the measurement tool. This is commonly referred to as the gage repeatability and reproducibility procedure and its goal is to identify a measurement tool with the least variation.

Once the team has selected a measurement tool with high repeatability and reproducibility, they devote their energy to measuring and charting the variables associated with the process. The typical type of tools used is again found in most TQM programs such as histograms, Pareto charts, and statistical process control charts.

An important milestone in the measurement step is to get an initial sigma measurement of the output of the process under review. This preliminary measure of the process sigma is helpful in the team getting a better handle on the extent of their issue and potential impact on the customer.

Analyze Phase

The goal of the team in this phase is to determine if the processes being studied are capable of obtaining their goals. Teams conduct capability studies to look for causes of why some processes are not obtaining the desired results. In this phase, computer software tools such as Microsoft Excel often aid teams. Tools such as Excel assist teams in reducing and organizing large quantities of data and thereby better understanding trends and relevant factors.

It is in this phase that teams really delve into the details and truly gain an understanding of the process in which they are studying. The end goal of the analyze phase is to identify the root cause of the project. In some projects, root cause is readily evident and teams move quickly through the analyze phase. In other projects, root cause is not immediately visible and the teams are required to do a significant amount of work. This work can last weeks and in some cases even months drawing on a number of tools and testing various ideas before getting to true root cause.

Good DMAIC problem solving generally includes close consideration of the types of causes. Six Sigma practitioners are known to look at common cause categories. These are methods, machines, materials, measures, Mother Nature, and people. The aforementioned categories are commonly referred to as the "4 M's and 1 P" (Pande & Holpp, 2002).

Improve Phase

The improve phase is where many teams are tempted to go right at the very start of the DMAIC process. One of the key attributes and benefits of Six Sigma is the rigor that it employs in keeping teams from rushing immediately to the improve phase. In as much as teams, especially inexperienced ones, are initially frustrated that they cannot move immediately to the improve phase, they generally gain a deep appreciation and respect for Six Sigma once they arrive at this phase. This is due to the recognition of the methodical, and in general, high quality work that they have performed up to this point.

Early on in the improve phase, teams many times go back and modify the scope of their project because they now have a better appreciation and understanding of the problem as well as the subject process. Regardless of a revisit of the project scope or not, the improve phase is where teams are expected to achieve results.

Achieving results, even after completing all of the rigorous work associated with DMAIC thus far, is often not an easy task. It is generally very difficult to identify creative solutions that truly address the root cause of the problem.

Once several potential solutions have been identified, they must be tested. At this point, the team goes back into the analytical phase and collects and analyzes data. In many cases, the team may identify more than one solution to the problem. If this is the case, various proposed solutions are judged against criteria such as cost and timing of implementation as well as likely benefits.

The final solution must be approved by the team champion and generally the cognizant leadership of the subject process. At this point in the DMAIC process, the "I" no longer stands for improve, it now stands for implement (Pande & Holpp, 2002).

Control Phase

The team's objective in the control phase is to identify and implement a control plan that will successfully monitor the process and will readily indicate to the appropriate personnel when the process degrades or goes off track. An appropriate control plan will identify the process owner(s) and will include a flow chart and standard operating procedure that contains the previously determined improvements. An appropriate control plan will also include a response plan for dealing with problems that may arise.

Additional responsibilities of the team in the control phase are to "sell" the project through presentation and demonstrations. Also, to hand off responsibility for the project to the people that use and own the subject process on a day-to-day basis. Finally, it is the team's responsibility to ensure support from management for the long-term goals for the project (Pande & Holpp, 2002).

SIX SIGMA – VARIATION

Variation is an important topic when it comes to Six Sigma. Variation is a basic law that no two things are exactly the same. Usually, there are many reasons that variation exists from one unit to the next. It is difficult to understand the true source or sources of variation. Like with most things, perception is not always reality and Six Sigma causes its users to focus on the facts and data that drive variation. Six Sigma uses the formula $y = f(x)$, or y equals the function of the x's. Simply stated, the effect is the y of the formula and the causes are the x's.

A traditional view of quality that is sometimes called the goal post mentality gives insight into how many people look at variation, especially when it comes to parts that have already been produced. Figure 4 below depicts this quite clearly (Munro, 2002).

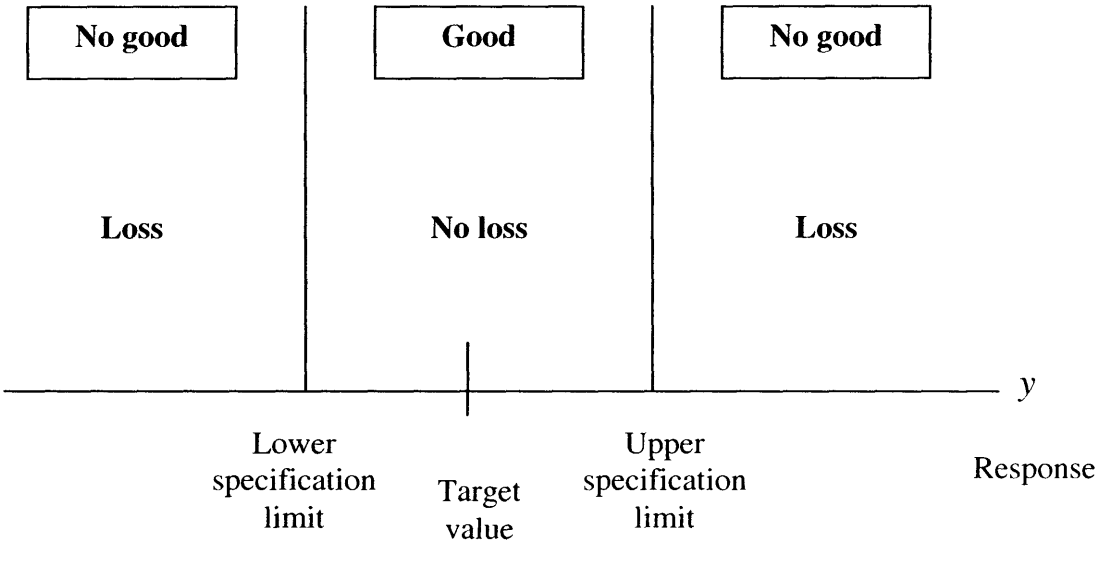

Figure 4. Traditional view of quality.

The traditional view of quality, as depicted in the figure, shows that some parts are produced within the specifications and that some are produced outside of them. The question that should be asked is, "what is the difference between parts produced just inside the specification versus ones that are produced just outside of the specifications"? A comparison of two parts that meet the aforementioned criteria will more than likely show that the two parts are very similar and will probably perform the same when used by the customer. This is one reason that some people use this traditional model as rationale to ship parts that are just outside of the specifications.

Figure 5 shows the Taguchi Loss Function Model, and demonstrates the change associated with its use with regard to product quality and customer satisfaction. This more enlightened view of quality states that all products or services measured by the sum of the x's, should aim for a target value that should be in the middle of the specification limits (Munro, 2002).

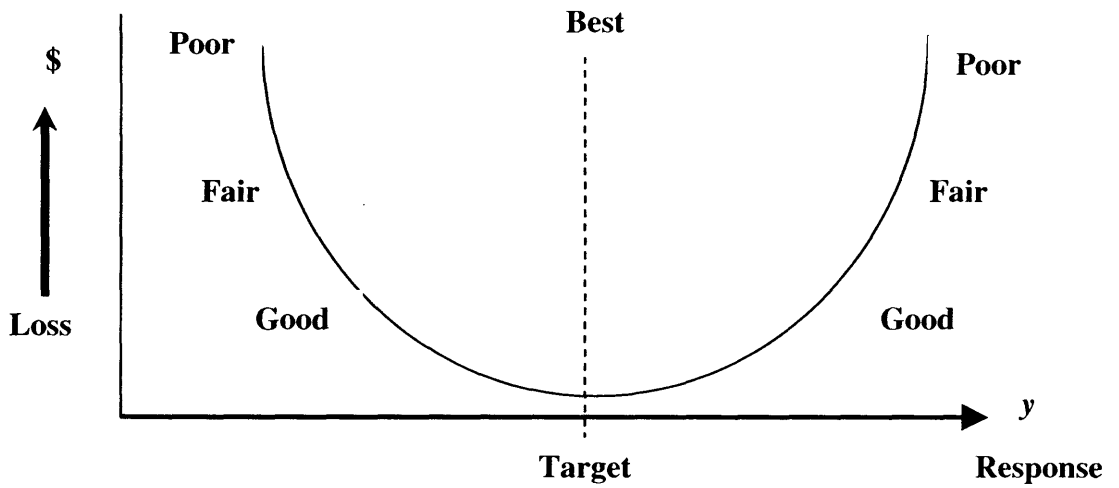

Figure 5. Taguchi loss function.

It is important to note that the specification limits are not shown on the graph. The Taguchi Model clearly shows that parts produced just in or just out of the specification will have the same less than favorable experience by the customer. The model also shows that parts that move away from the target value are of more cost and loss to the customer.

The goal of the Taguchi model and of Six Sigma is to reduce variation and thereby improve customer satisfaction. Improved customer satisfaction manifests itself by the customer experiencing more parts that are closer to the target value. This discipline clearly yields higher customer satisfaction, but also reduces warranty costs and expenses associated with product failures (Munro, 2002).

SIX SIGMA – BELTS AND FORMAL ROLES

Perhaps the most recognizable attribute of Six Sigma is the use of trained personnel and the naming of them in terms of belts associated with martial arts. Even people that have limited familiarity and knowledge of Six Sigma have generally heard of the titles: Black Belt, Green Belt, and Master Black Belt. As with all TQM programs, the success of the program is largely dictated by the people within the organization and the influence and change in the company culture that they in turn are able to bring about. Six Sigma is certainly no different. While organization leadership plays a very critical role, carefully selected and highly trained personnel in the form of Black, Green, and Master Black Belts play a pivotal role. Once the leadership of a company has decided to pursue the use of Six Sigma, it then engages a group of personnel and utilizes them in many different capacities including that of facilitators, team leaders, team members, Black Belts, Green Belts, Master Black Belts, Champions, and Implementation Leaders. The roles of facilitator and team member are well known in the business world and are typically utilized in Six Sigma. The roles of formally trained and tested "belted" personnel are unique to Six Sigma as are the roles of the Champion and Implementation Leader. Therefore, these five critical and unique roles require some explanation and definition.

Black Belt

The role of the Black Belt is central to the activity of Six Sigma and in particular Six Sigma Projects. A Black Belt is a person that is full time dedicated to bringing about change and the results associated with change. Black Belts are typically selected from the ranks of high performing and high potential middle management professionals.

Although it is not essential, it is generally considered an advantage for a candidate to have a technical degree and most Black Belts are selected from the ranks of personnel that have had experience as engineers. Black belts typically have extensive experience in program and project management. Further, it is the norm for a Black Belt to have skills such as data collection, data analysis, leadership, and coaching. Further, it is generally the case that Black Belt candidates possess solid organizational savvy, as they will need to call upon these skills as they guide their associated teams and projects through the rigorous and challenging process of fundamental change and improvement.

Black Belts are not intended to stay in their role for more than 2-4 years. They correspondingly handle 4-6 projects. Although an organization makes a considerable investment in time and training of Black Belts, the intent is not for them to remain in these positions for the long term. Rather, in a Six Sigma environment, as with most TQM environments, it is senior management's intent to move Black Belts into more senior and influential roles in order to perpetuate a company culture of continuous improvement on a broad scale.

Typically a Black Belt works along side and guides a Six Sigma team through a specific project. The Black Belt is the person responsible for the team attaining successful results. The Black Belt does this by possessing a strong background and experience in Six Sigma and TQM problem solving techniques and tools. The Black Belt gains this knowledge through extensive classroom training as well as hands on and practical training. In most

Six Sigma companies, there are specific and rigorous criteria associated with achieving the title and status of a Black Belt that include a formal examination.

Master Black Belt

Master Black Belts or MBB (pronounced em-bee-bee) act as a coach and mentor to Black Belts. MBB's are selected from the ranks of Black Belts and many times have traditional quality department experience. As with Black Belts, the most successful Six Sigma companies have rigorous criteria for and carefully select Master Black Belts. MBB's primary job function is to train and mentor several Black Belts at a time. In the spirit of continuous improvement and leading by example, it is also common for a Master Black Belt to take a hands on approach with Black Belts and their associated teams, especially when it comes to data collection and in particular data analysis.

It is typical for Master Black Belts to spend a significant amount of his or her time facilitating formal training of various members of the organization. Additionally, it is typical for an MBB to personally take on special Six Sigma projects. These are generally ones that are related to customer requirements and the development of measures for key processes.

Green Belt

A Green Belt is person that has received the same training and for the most part has the same Six Sigma experience as a Black Belt. The difference is that a Green Belt has a full time leadership role in the organization. The intent of these business leaders to also

possess the same skills set as a Black Belt is to imbed Six Sigma and the proper utilization of it within the organization on a day-to-day basis.

Champion

The title of Champion as used in the Six Sigma vernacular is an executive or key leader in the organization that initiates and supports a team project and its corresponding Black Belt. The Champion is truly the individual accountable for the project as it is the practice of Six Sigma for results not to be delegated down several levels in the organization. Rather, it is the practice for accountability for results to be held at the level of executive or middle management.

There are five key roles of the Champion in a Six Sigma world. The first is to ensure that projects are initially aligned and remain aligned with the overarching goals of the business. The second key role of a champion is to keep other members of the company leadership team abreast of project status and progress. The third is to acquire resources required for the team to fulfill its objectives. Fourth, a Champion is expected to conduct appropriate tollgate reviews. The fifth key role of the Six Sigma Champion is to negotiate conflicts, overlaps, and linkages associated with other Six Sigma project teams.

Implementation Leader

The implementation Leader is the person at the highest level of the corporation that is accountable for the orchestration of the entire Six Sigma effort. This person is generally a direct report to the President or CEO. The highest-level goal of the Implementation

Leader is to drive Six Sigma across the organization while simultaneously ensuring that projects yield appropriate financial and customer satisfaction goals. As it is the case with the Black Belt position, the Implementation Leader role is typically not one that an individual holds for a long period of time. This position, like that of the Black Belt, is rigorous and demanding. It is preferable for Implementation Leaders to perform the role for 2-4 years and then to move onto another executive or leadership role (Munro, 2002).

SIX SIGMA – IN THE SUPPLY BASE

Extending Six Sigma to the supply base is a key initiative for most companies as today more and more of an enterprise's work is performed by their supply base. Implementation of Six Sigma throughout a company's supply chain potentially offers many benefits. An enterprise has the opportunity to reduce lead-time and procurement costs as well as improve customer satisfaction through a successful extension of Six Sigma to its suppliers. Because most companies rely on their supply chain, it can be argued that if a company does not extend its Six Sigma effort to its suppliers then the company's internal implementation will suffer greatly.

The first thing that companies are advised to keep in mind upon Six Sigma implementation in the supply base is that more than likely, many of the problems thought to belong to the supplier, actually take their root in the company doing the outsourcing. Therefore, a patient no blame type approach is recommended. There are two major opportunities for working with suppliers in a Six Sigma environment. The first is to implement a pull system, thereby reducing inventory carrying costs and more closely linking the supply chain. The second is working with the suppliers to eliminate waste and improve yields, thereby improving product quality and on-time delivery.

It is generally recommended to Six Sigma companies wanting to engage their supply chains, to not take the big leap by attempting to implement with all suppliers at once. Rather, it is recommended to start first with a few key suppliers and to put a focused effort on them with the companies Black Belts and Master Black Belts. Then, once

significant progress has been made with these few key suppliers, it's recommended to advertise this success and encourage the remaining suppliers to join.

When it comes to engaging the supply chain in Six Sigma, other recommended best practices are in the areas of finance and leadership. With regard to finance, it is recommended for the company doing the sourcing and initiating the Six Sigma implementation to pay for the up front training costs. Also, it strongly suggested separating Six Sigma implementation and progress from supplier pricing negotiations. Therefore, a non-adversarial and teaming approach is best where the sourcing company takes on the role of the host. Therefore, recuperation of investment by the sourcing company is left to more of a market forces type of pricing negotiation. Also, the sourcing company must be sure to be mindful of the benefits in inventory carry costs, supply chain management, and customer satisfaction that they will gain over the long term.

SIX SIGMA - DESIGN

In most TQM programs, the emphasis tends to be on the shop floor. Six Sigma takes measures to "move quality to the left" through DFSS which stands for Design for Six Sigma. DFSS appears to set Six Sigma apart from other TQM programs in this respect. Although there is one school of thought that utilizing Six Sigma tools in the research and development arena could kill creativity, there is significant evidence that suggests that a company can actually remain quite creative while simultaneously improving costs and customer's satisfaction.

Although not all of the Six Sigma tools and processes are directly applicable to R&D, it does provide a mindset that provides a measurable and goal-oriented context for working on quality improvement. DMAIC is generally thought of as a means to improve an existing product or process. DFSS is, therefore, for the development of new products or processes. DFSS is also thought to be effective in situations where existing products and processes can no longer be improved enough to reach the levels of desired improvement through DMAIC methods. There are two acronyms generally associated with DFSS. They are DCOV, which stands for Design, Characterize, Optimize, and Verify. The second is DMEDI, which stands for Define, Measure, Explore, Develop, and Implement. Many users of DFSS like it particularly because it, like its parent Six Sigma, is customer centric. In an R&D environment, DFSS can be used as an effective means of driving top line growth through customer satisfaction (Johnson, 2002)

SIX SIGMA – LEADERSHIP

Very visible and demonstrative leadership engagement is a very consistent theme with all aspects of Six Sigma as well as all Six Sigma implementations. Successful work with suppliers is no different. In this case, senior leadership from both the suppliers and the sourcing companies is paramount. One very key message and learning from Six Sigma is that it is truly a top down initiative (George, 2002).

While it is the case that Six Sigma is customer centric, and has well designed and proven tools and methodology, what makes Six Sigma work is the commitment of leadership and management. A common and consistent theme in studying about Six Sigma is that every source, be it literature reviews or personal interviews, all indicate this.

Leadership involvement starts at the very beginning. Regardless of where the idea to initiate a Six Sigma program comes from, it is essentially always the case that the top executive in the company embrace the program or it will fail. Involvement on the part of top leadership is not only necessary and significant at the launch of the initiative, but is required continuously on an on-going basis throughout the life of it. The Six Sigma implementation process in which top company leadership is squarely engaged in can be summarized into three streams of activity. The first is initiation, which describes the stream where the CEO and his or her direct reports start to become educated on the process and benefits of Six Sigma. The second stream is resource and project selection. This involves selecting the right people to lead the right projects. The third stream is Implementation, Sustainability, and Evolution. In this stream, Six Sigma is converted

from an initiative or program to a way of life that works to continuously improve a company's performance (George, 2002).

Leaders should not and generally do not support Six Sigma just because it looks or sounds good. There is a real opportunity for leaders and organizations to derive significant benefits from Six Sigma. These benefits can be summed up into five major categories. The first is that of clear priorities. In companies both big and small, there are always more things to do and fix then there are resources. Six Sigma and the DMAIC process help to identify the key few initiatives that an organization should focus on in order to deliver the highest customer satisfaction and shareholder value. The second benefit to leaders of Six Sigma is fewer conflicts. The Six Sigma process, by its nature, provides a forum for conflict to be resolved. Further, it helps to delineate and clarify handoffs by focusing the organization on the big picture. Thirdly, Six Sigma benefits leaders by providing the organization with better and more useful data. A fourth way that leaders and therefore organizations benefit by Six Sigma is by providing a means to develop people at all levels of the organization. Finally, the fifth way that Six Sigma benefits leaders is through improved resources, energy, and results. Although in many ways Six Sigma increases people's workload and challenges an organization, it has the potential to energize it. It can be understood that in a successful Six Sigma environment, performance improvement can be fun and addicting and that "success can breed success" (Pande & Holpe, 2002).

SIX SIGMA - SUMMARY

Six Sigma is a very powerful tool that has certainly left its mark on the world. Bill Wiggenhorn in the foreword of Forest Breyfogle's, *Implementing Six Sigma*, said it well when it came to Six Sigma at Motorola. "Whether it was French, Arabic, or Texan, everyone understood the six steps, defect measurement and elimination, and parts per million. The training and concepts were not limited to the factory floor. Every single person was expected to understand the process and apply it to everything that they did." Wiggenhorn further stated that, "some shied away, saying they were exempt from manufacturing processes. Some challenged the soundness of the statistics. Even so, the company stood behind the commitment and the mandate. The rest, as they say, is history. Today, Six Sigma tools, research, training, and consulting have proliferated throughout business, industry, and education."

It is commonly accepted that the existence today of Motorola is tied directly to Six Sigma. Six Sigma for Motorola directly answered the question, "how do we stay in business". In review of interviews of current and former Motorola Six Sigma practitioners, it is a common theme that Six Sigma offered a simple and consistent way to measure performance to customer requirements. Further, it made clear a target for essentially perfect product for all to see.

It is clear to me that Six Sigma has lived up to its reputation in companies that embraced it and followed the Motorola model the closest. While it has evolved over the years, and has consequently become more complex, it is my belief that Six Sigma has succeeded for

three main reasons. First, its fundamental mathematical and statistical foundation is not only difficult to disagree with, but that it does not require a significant leap of faith. Second, in every successful implementation when the program was embraced, rolled out and continuously supported by the most senior leadership in the organization, that it succeeds. Third, and perhaps where Six Sigma sets itself apart from TQM and other continuous improvement programs in which I am familiar, is training. Without a doubt, Six Sigma depends upon and truly embraces the training of all personnel in the organization. Most, if not all other programs, at best, train just the people directly associated with the program. In my view, especially after researching and studying Six Sigma, I believe insufficient training to be a real issue for some quality improvement programs.

ACE – HISTORY AND BACKGROUND

"We have such a wonderful situation of an amazingly powerful business base with defined methodologies to make it better. We know how to do it, we believe it, and now we have to go out and do it ...", stated George David, UTC, CEO in the foreword of the UTC website, (www.utc.com). The "defined methodologies" that David was referring to are encompassed in UTC's Achieving Competitive Excellence or ACE program. UTC states that, "quality and process improvement are an integral part of everything we do. Management and empowered employees need to work together to remove barriers that hinder improvements in order to provide our customers with the highest quality products and services." The UTC ACE Mission Statement states to "Achieve a level of quality and productivity improvement that will delight our customers and allow us to satisfy increased workloads more efficiently. This will be accomplished through the implementation of Achieving Competitive Excellence (ACE) process."

ACE takes its roots from both the lean methodologies of the Toyota Production System and the quality improvement teachings of Dr. W. Edwards Deming. UTC's motivation for creating the ACE Operating System originated from both internal and external sources. As the timeline in Figure 6 shows, the external motivation and feedback came primarily from Yoshiki Iwata, Yuzuru Ito, and James Womack. While these three each had a unique perspective, and in the case of Iwata (see Figure 7) and Ito (see Figure 8), had different tools to offer, all supported the same conclusion that UTC, and in particular Pratt & Whitney, had significant opportunity for improvement in the area of manufacturing operations. These three people exercised their influence upon UTC in the

early to mid 1990's and did so to a significant extent at one of the UTC divisions, Pratt & Whitney. It is also important to note that from an internal perspective, at the same time, two of the top UTC executives, George David, CEO, UTC, and Karl Krapek, President, Pratt & Whitney, were both new to their respective roles and also fairly critical of the current state of UTC operations, particularly of Pratt & Whitney's. David and Krapek engaged the consulting services of Iwata and Ito and made P&W operations assessable to Womack, who later included his observations in his very successful book, Lean Thinking. It is therefore believed that the culmination of this external influence, coupled with the internal drive and appetite for improvement of manufacturing operations within UTC, lead to the ultimate creation of an operating system that would ultimately be named ACE, which stands for Achieving Competitive Excellence.

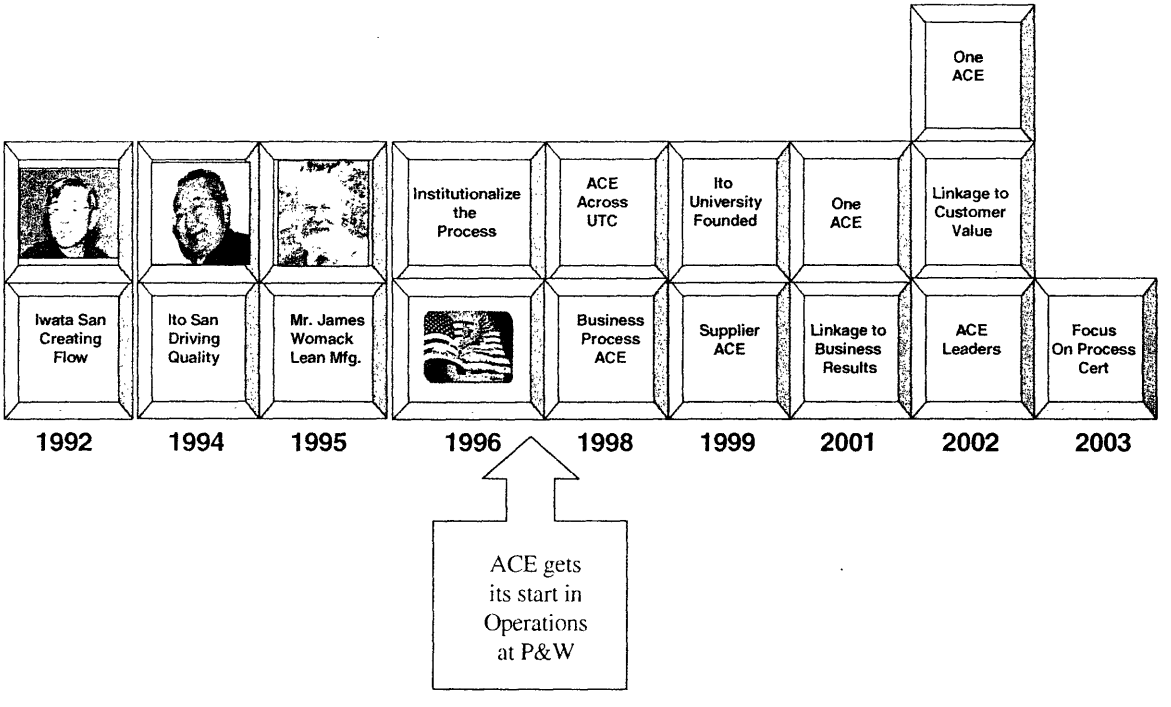

Figure 6. ACE at UTC (Source retrieved from UTC Customer ACE Overview).

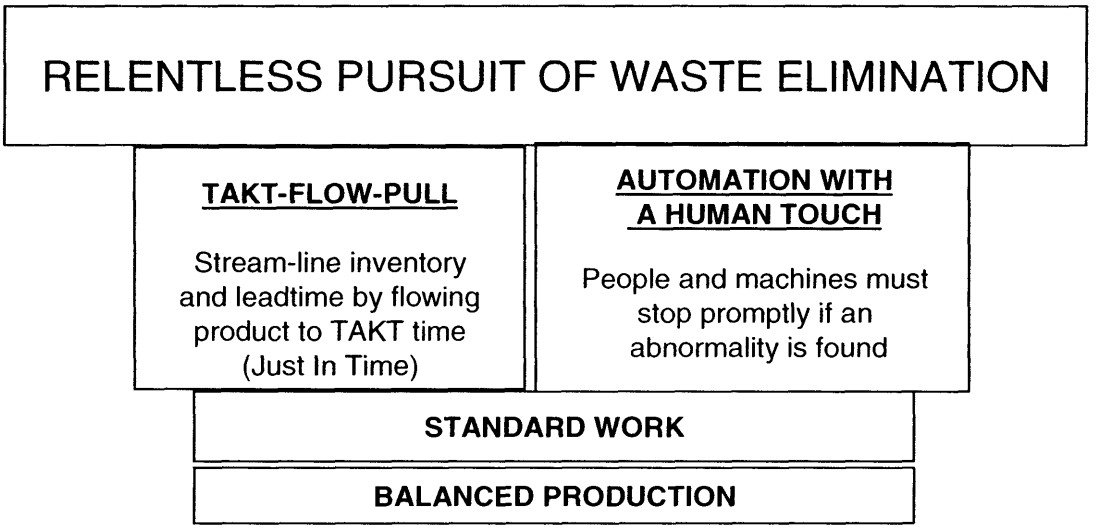

Figure 7. What is Kaizen? (Source retrieved from UTC Customer ACE Overview).

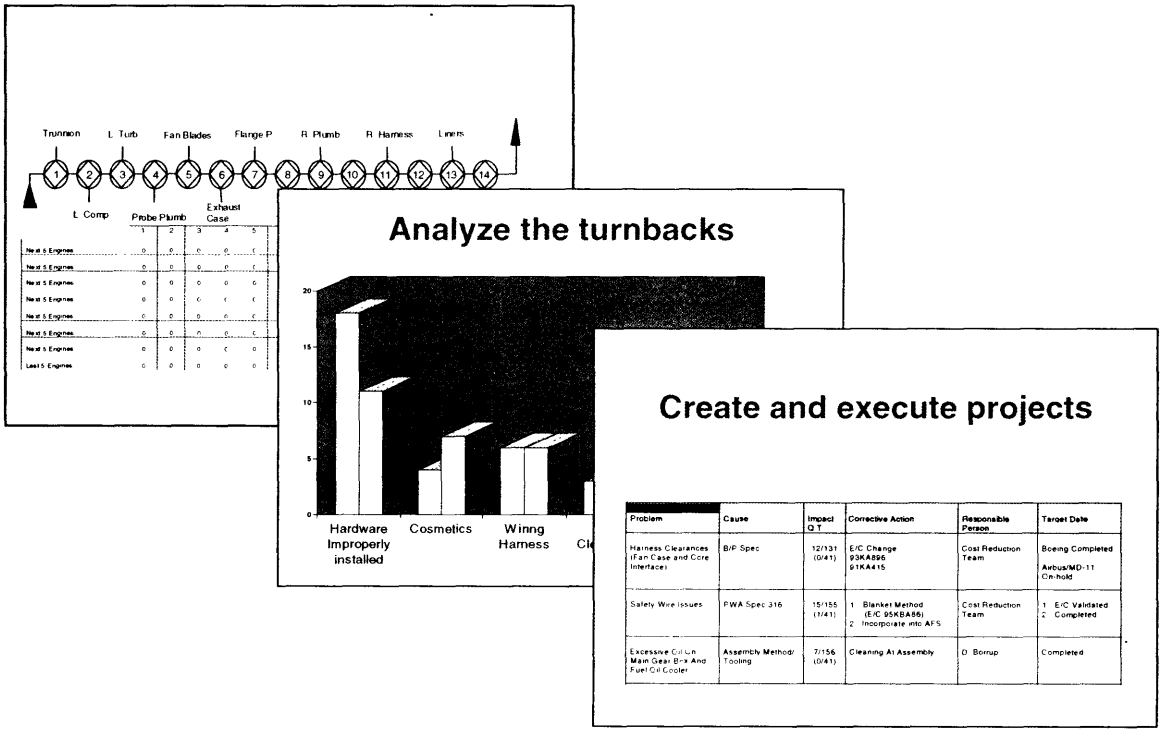

Figure 8. Mr. Ito's Teachings (Source retrieved from UTC Customer ACE Overview).

ACE – THE TEN TOOLS

As indicated in the UTC Website (www.utc.com), the ACE Operating System consists of ten tools that are encompassed in the three categories of Process Improvement and Waste Elimination, Problem Solving, and Decision Making. These tools help a UTC organization identify and solve problems, improve its processes, eliminate waste, and make effective strategic decisions. Through the repeated application of these tools, the organization drives the ACE operating system to close gaps between actual and business goals, and to eliminate waste through lean process flow.

The tools supporting the ACE operating system are shown in Figure 9 below. All of the tools have training modules and qualified instructors to teach them. UTC states that in keeping with the ACE philosophy, the ACE tools are relatively easy to learn and use. Further, that the tools are accessible to everyone in the corporation. It is also particularly the case that in Relentless Root Cause Analysis, Mistake Proofing, Process Management, and the Passport Process, the ACE practitioner may desire to supplement the ACE tools with other tools that are described in textbooks and workbooks on quality and process management.

Process Improvement and Waste Elimination Tools

- 5S (visual workplace)
- Process Management and Standard Work
- Process Certification
- Set Up Reduction
- Total Productive Maintenance

Decision Making Tool

- Passport Process

Problem Solving Tools (DIVE process)

- Market Feedback Analysis
- QCPC (Quality Clinic Process Charts)
- Relentless Root Cause Analysis
- Mistake Proofing

Figure 9. How does the ACE Operating System work? (www.utc.com).

1. 5S or Visual Workplace

The category of "Process Improvement and Waste Elimination Tools" includes five elements. The first is 5S or Visual Workplace. 5S stands for Sort, Straighten, Shine, Standardize, and Sustain. This tool and its corresponding methodology comes from the Toyota Production System, UTC's lean manufacturing benchmarking, and the Iwata lead Shingijutsu learning in the early 1990's. 5S as defined by UTC, is a state where anyone can walk into a workplace and visually understand the current situation. One should be able to tell: workplace organization, work process, schedule condition, and abnormalities.

Figure 10. New 5S (Source retrieved from UTC ACE Overview).

2. Standard Work

The second tool in the category of Process Improvement and Waste Elimination is Standard Work. It is defined as the method by which work is simplified and structured to ensure maximum quality, consistence, and repeatability over time. The components of Standard Work are: Defined Standards, Defined Processes and Systems, Simplified Work Instructions/Procedures, and Documentation Lessons Learned. Standard Work is broken down into two categories, manufacturing and business process. In the case of manufacturing standard work, it details the motion of the operator and the sequence of the movement of material through the work area.

3. Process Certification

The third of the Process and Improvement and Waste Elimination tools is Process Certification. This tool is defined as a disciplined approach to achieve business process effectiveness, efficiency, and agility. Process Certification is defined as having four stages. Stage I is used to set the direction. Stage II is used to conduct assessments. Stage III is where vital opportunities are selected. Stage IV is used to improve the process. UTC uses a six step Process Certification Process as shown below in Figure 11.

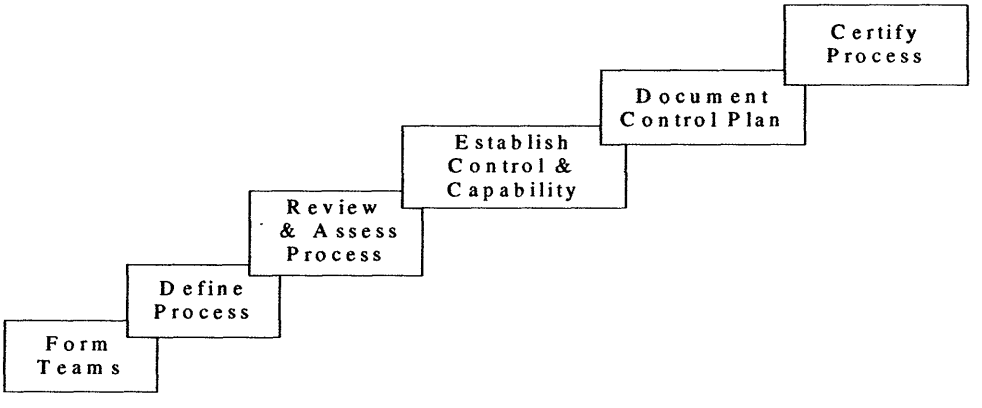

Figure 11. Process management and certification (Source retrieved from UTC ACE Overview).

4. Set Up Reduction

The fourth of the five tools associated with the Process Improvement and Waste Elimination section of ACE tools is Setup Reduction. This tool is defined as, reducing the total time required to change over a machine or process from the last good produced through acceptance of the next good part. The key to setup reduction is to move internal setup tasks to external. Internal tasks are defined as, setup activities that are carried out while the machine is shut down. External tasks are defined as, activities performed while the machine is running.

5. Total Productive Maintenance

The fifth of the five Process Improvement and Waste Elimination Tools is TPM or Total Productive Maintenance. TPM is another UTC tool thats heritage can be traced back to the influence of the Toyota Production System and the Iwata lead Shingijutsu consultants on UTC in the early 1990's. TPM is defined as a method to achieve maximum equipment effectiveness through employee involvement. Successful implementation of TPM creates a culture that raises equipment reliability and accuracy to a level where machine down time and inaccuracies are essentially eliminated as a cause to product quality and overall operational effectiveness. An effective TPM program has many facets and includes expanding the traditional roles of both machine operator and maintenance personnel. In a TPM environment, the machine operator takes on the responsibilities of machine cleanliness as well as most aspects of routine equipment maintenance. The maintenance personnel expand their role by teaching and training the equipment operators in the aforementioned duties.

As shown earlier in Figure 4, of the remaining five ACE tools, four reside in the Problem Solving category and one, the Passport Process, is in the Decision Making category.

6. Market Feedback Analysis

One of the four Problem Solving Tools is Market Feedback Analysis or MFA. Market Feedback Analysis is the use of unemotional market data to focus on the issues causing customers the most pain and frustration. This tool is typically the first one used by an organization in order to determine what processes it needs to improve. MFA methods and tools come in many forms. They range from structured UTC forms and charts to freeform customer surveys consisting of behaviorally anchored response (1-7 scale preferred) with areas for written responses.

7. Quality Clinic Process Charts

Problem Solving Tools were introduced to UTC by Yuzuru Ito. They are activities of problem identification, prioritization, and selection. With the fundamental assumption that all processes must deliver first pass through yield, without delays or in-process rework, and do so in the shortest amount of time possible. Exceptions are considered turnbacks. Each turnback is considered, as Ito called them, a golden nugget or treasure, because it tells a story about why and how it occurred. The overarching belief is that there are no isolated incidents. All turnbacks must be documented, prioritized, and eliminated using the UTC Problem Solving Process. Solving turnbacks requires a mindset that is alert, open-minded, patient, tenacious, and persistent. Figure 12 shows a flow diagram of the UTC Problem Solving Process.

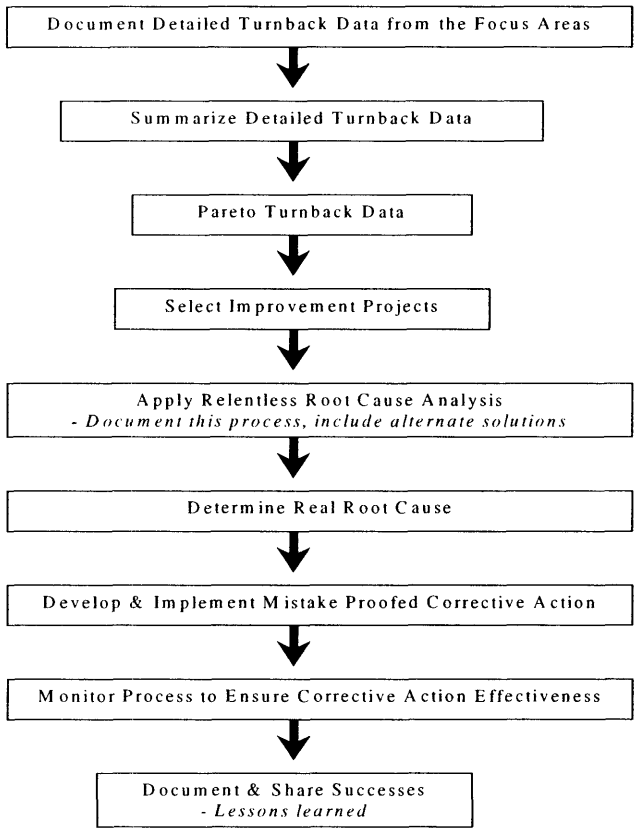

Figure 12. The UTC problem solving process (Source retrieved from UTC ACE Overview).

As shown in Figure 9, one of the four Problem Solving Tools is QCPC, which stands for Quality Control Process Charting. QCPC is a simple tool to identify defects, waste, and inefficiencies for mistake proofing and continuous improvement. As defined by UTC, QCPC's are maps of the sequence of operations or activities in a process where turnbacks are recorded. Turnbacks stop or slow the flow of work through the process. Over time, problem areas can be identified for corrective action. Figure 13 shows an example of a QCPC map. It is rather self-explanatory, considering that the large numbers at the top of the map are operation numbers representing steps in the process. Further, there are

several specific TQM tools associated with QCPC. The first tool used immediately to aid in interpreting QCPC data are Pareto charts. Other commonly used tools are scatter diagrams.

W/E	10			20			30			40			T/B RATIO
11/14/98	PCS. PRODUCED 20			PCS. PRODUCED 25			PCS. PRODUCED 10			PCS. PRODUCED 12			158%
	T/B RATIO 40%			T/B RATIO 60%			T/B RATIO 50%			T/B RATIO 8%			
	T/B	SCRAP	T D	T/B	SCRAP	T D	T/B	SCRAP	T D	T/B	SCRAP	T D	
	8			15			5			1			

Figure 13. The UTC problem solving process: Step 1 (Source retrieved from UTC ACE Overview).

8. Relentless Root Cause Analysis

Relentless Root Cause Analysis resides in the Problem Solving family of ACE tools, and is defined as the rapid and persistent pursuit of the fundamental breakdown or failure of the process that, when resolved, prevents recurrence of the problem. This tool is unmistakably akin to Six Sigma and its DMAIC process. UTC's ACE operating system's root cause and resolution methodology is called DIVE. It is an acronym that stands for a four-stepped process of Define, Investigate, Verify, and Ensure. The first step, Define, is very much like the first step in Six Sigma DMAIC, and is intended to define the problem. The second step of the DIVE methodology is called Investigate. In the Investigate step of the process, one does just that, he or she investigates the root cause of the problem. In this step it is intended to identify the true root cause of the problem. This works much

like the Six Sigma DMAIC process and measures the problem. Verify, is the third step in the DIVE process, and requires the user to validate the problem's root cause. The fourth and final step in DIVE is Ensure. This step is like Six Sigma DMAIC in that its intent is to ensure a mistake proof solution is achieved and implemented.

9. Mistake Proofing

The last of the four ACE Problem Solving Tools is Mistake Proofing. UTC defines Mistake Proofing as, "using the wisdom and ingenuity to create devices which allow you to do your job 100% defect free, 100% of the time". It is UTC's belief that when properly implementing mistake proof devices, one should be able to answer "yes" to all seven of the below attributes:

- Irreversible Corrective Action
- Minimal Cost
- Simple to Use
- Easy to Install
- Durable
- Easy to Maintain
- Does Not Hinder the Operator or User

Mistake proofing was clearly not developed at UTC, but rather adopted from its study and benchmarking of TQM tools. As defined in its web site and in interviews with UTC practitioners, it is clear that UTC has embraced some of the better and more popular mistake proofing tools throughout the world.

10. Passport Process

As previously indicated, the ten ACE tools reside in three categories, (see Figure 4). The aforementioned nine tools reside in the categories of Process Improvement, Waste Elimination, and Problem Solving. The tenth tool, Passport Process, is the sole tool in the Decision Making category. Passport is a management tool that integrates structured checkpoints for program review within the business Integrated Program Deployment Process. The Passport process intends to ensure the following deliverables:

- Ensure products meet all targets
- Make decisions at appropriate levels of management
- Achieve quality, reliability, and cost targets
- Guarantee that no product goes to market before it is ready
- Ensure that current product field failures are not designed into new products

As shown below in Figure 14, the Passport Process is a stage-gated process that encompasses the entire product life cycle.

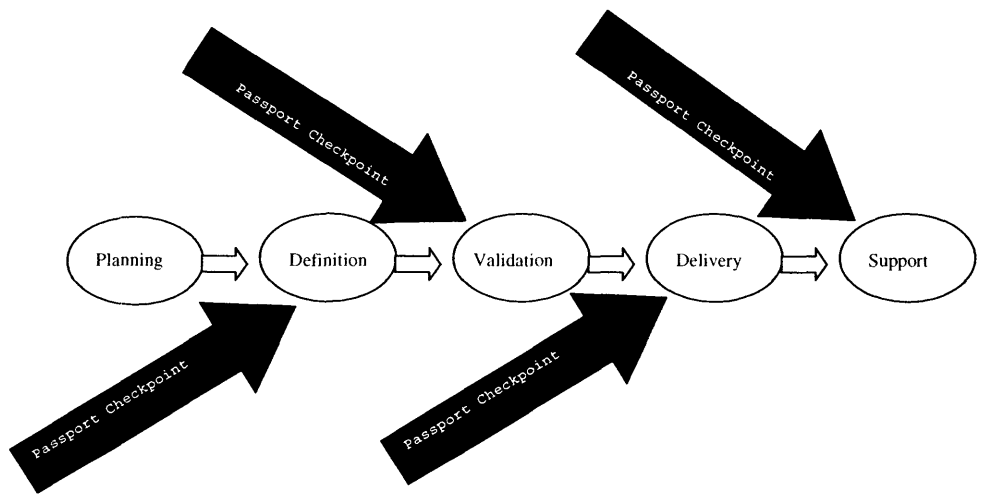

Figure 14. Passport system (Source retrieved from UTC ACE Overview).

Although the current ACE operating system consists of the ten tools enumerated in this chapter, UTC is also extensively using the tool of value stream mapping. Upon review of the UTC Web Site (www.UTC.com), and in interviews with numerous ACE leaders and practitioners, UTC has identified that Value Stream Mapping will be formally added to the ACE Operating System. Although it appears to be the case that Value Stream Mapping (VSM) will be added as an eleventh element of ACE, it is not perfectly clear how UTC will formally incorporate it into its ACE documentation. It is clear however, that UTC is currently using VSM and plans to extensively deploy it across that corporation. UTC formally defines and explains Value Stream Mapping and its utilization of it as follows:

The next evolution of competency in ACE will be the Gold Value Stream, *"an organized group of processes that work together to provide value to customers."* A Value Stream begins and ends with its customers. By its integration of cells and workgroups into a coordinated, end-to-end process, a Value Stream assures that the focus of activity is the customer and that the performance of the whole organization is optimized. Gold Value Stream achievement means:

- best-in-class customer satisfaction and business performance delivered by the organization
- coordinated Gold cells/workgroups in the value stream integrated with Gold support organizations
- constantly increasing effectiveness (quality) and efficiency (flow)
- recognized best practices

ACE – THE FOUR LEVELS

As indicated in the UTC Website (www.utc.com), UTC's method of measuring the progress of its businesses toward ACE implementation and continuous improvement is through auditing them at the cell or department level against reestablished criteria. Progress against this criterion is arranged such that it is measurable at the level of a department, cell, site, or for that matter, an entire UTC division. A business entity can be scored and identified as having attained a certain level of improvement and therefore capability. UTC has four levels in which they assign to a business entity with regard to ACE. The levels are named after the Olympic medals and are Qualifying, Bronze, Silver, and Gold. UTC states that their unique ACE protocol is a time-proven method for the progressive implementation of continuous improvement tools throughout the company. The basic premise behind the protocol is a system of levels that measure each cell's competency in the ACE methodology.

Qualifying – general ACE awareness education exists in this area of the company, local process identification and prioritization, waste elimination and cell organization

Bronze – advanced ACE training, full application of ACE tools to a limited number of key processes, 60% of the cell or department's workgroup is involved

Silver – demonstration of improved customer and business performance, documentation and streamlining of all key processes, defined employee satisfaction target, 80% of the cell or department workgroup is involved

Gold – is considered best-in-class in local customer satisfaction and local business performance, also that there is total cell/work group involvement

ACE - SUMMARY

UTC states that the competency in ACE resides in empowered associates and in committed and involved leadership. ACE competency is believed to be built through many means. Listed below are the more prominent means in which UTC believes that they build competency.

- Awareness education
- Supervised action learning engagements
- Coaching, mentoring, and teaching by expert ACE pilots
- Doing and gaining experience in many different improvement projects
- Sharing of best practices
- Teaching and training others
- Quality Clinics

The tracking of financial results in applying ACE to improve business performance are recorded in a master database that is named QSTARS, which is an acronym that stands for Quality Savings Tracking and Reporting System. UTC states in their website that, "the cumulative financial impact of ACE is the ultimate measure of competency".

CONCLUSION AND RECOMMENDATIONS

As discussed in the introduction of this paper, quality is critical in the world economy in that it is a key element of customer satisfaction and therefore the growth, if not the very existence of an organization. Quality management and improvement therefore take on a critical role in any forward thinking and successful organization.

Whether it is UTC and the ACE Operating System, Motorola, Honeywell, or General Electric and others, in the utilization of Six Sigma, one cannot dispute that both of the subject quality management and improvement systems have benefited their users tremendously.

It was not the intent of this paper to criticize or condemn either of these systems, as both are very successful. The aim of this paper was two fold. First, to learn more about both ACE and Six Sigma. Second, in the spirit of continuous improvement, to understand how UTC can learn from Six Sigma.

Although both systems are very successful, Six Sigma is far more popular. A search of the World Wide Web on March 15, 2004, showed that when searching for the key words "ACE, Quality", there were 1,470 hits. This versus a search of the key words " Six Sigma Quality", which resulted in 46,700 hits. The World Wide Web search data tends to correlate to the views of business and industry people around the world. Six Sigma is clearly the more popular and recognized of the two operating systems, but not necessarily, in my view, the best.

When comparing what are very successful programs, I have found there to be six major items with regard to Six Sigma, that really standout and differentiate that program from others and I believe make it the success that it is. Similarly, I have identified four major points about ACE, that in my view, not only differentiate it from Six Sigma, but cause the program to have an edge and position it to be more successful than Six Sigma.

The six major items that in my view make Six Sigma successful are:

- It is truly customer centric.
- It provides a common language for the entire value chain to speak (employees, customers, suppliers).
- The use of math and statistics that previously existed and are very difficult to dispute.
- The program has a real strength in the area of process certification and control.
- A genuine focus and a significant commitment to the training of all employees.
- A means of aligning Product Design with Quality Improvement.

The six major Six Sigma success items that I have identified do not all necessarily carry the same weight, but are in my view the backbone of the program and distinguishes it from other quality management programs in which I am familiar, including ACE.

The first point, that the program is truly customer centric, stands out for me in that Six Sigma intentionally and rigorously takes measures in order to ensure that all improvement activities and projects selected link back to satisfying the customer. Further,

that unlike other programs, while Six Sigma recognizes the existence of internal customers and hand offs in the value chain, it very effectively in my view, ties all activity to the end external customer. This is very important in that it focuses the organization's resources on what are truly the improvement opportunities with the greatest leverage.

The second point, that the program provides a common language for the entire value chain to speak, is in my view, the most powerful element of Six Sigma. While the ACE operating system assesses and labels business entities with the levels of qualifying, bronze, silver, and gold and provides some means of common measurement and the ability to compare various elements of the business to one another, it is not nearly as precise and succinct as the utilization of the sigma measurement in the Six Sigma world. I believe that it is incredibly powerful to have the ability to communicate with all people in the value chain whether they are customers, employees, or suppliers. Through the utilization of the sigma measurement, a common and consistent means of judging the credibility of all processes is available for all value stream participants to use including management. This is very powerful.

The third of my six major items that really make Six Sigma work is the utilization of math and statistics that previously existed. This item is akin to sigma measurement that was just explained and goes beyond the merits identified. I believe this to be the case as it is very difficult, if not impossible, to dispute commonly accepted math and statistics. There is no appearance on the part of practitioners, customers, or even competitors that the measurement tool is flawed or in any way designed in a self-serving or gratuitous

manner. Further, it is easier to teach and spread knowledge of the measurement tool when it so widely known throughout the world.

The fourth of the six major elements of the success of Six Sigma that have identified the program's strength is in the area of process certification and control. This is linked to the aforementioned math and statistics. In my view, Six Sigma has an ideal means of measuring process robustness. The sigma measurement and the associated statistics tie very nicely to process capability and CPK measurement and evaluation. From my perspective, the one element of the ACE operating system that is the least robust is process certification. Six Sigma appears to provide major insight as to how ACE can be improved in this area. There is significant opportunity for UTC to improve its ACE system by using the sigma measurement tool in Steps 2, 3, and 4 of the ACE 6 Step Process Management and Certification Model. I believe that if UTC decided to adopt sigma process measurement that they could do so very quickly and efficiently by inserting it into the existing process certification tool as a bolt on type module.

The fifth major element of success that I have identified of Six Sigma is a genuine focus and a significant commitment to training of all employees in its operating system. In reviewing a broad spectrum of published material and in interviewing practitioners of both systems, Six Sigma companies stand out as providing more comprehensive and in-depth training to all members of their value stream on an on-going basis, unlike UTC with regard to the ACE operating system. This includes the training of formally identified associates in both programs such as Black Belts and Pilots, as well as

associates in the organization that do not fulfill formal quality system roles. It is my understanding that Six Sigma companies require some level of training for all of their associates in Six Sigma on an annual basis and then depending upon both individual and job function needs, more specialized and in-depth training is mandated for some associates. This does not appear to be the case with UTC and the ACE operating system. It is clear that at UTC, the majority of associates in the management and executive ranks do go to formal training on ACE. However, it is not clear that these leaders receive sufficient training on an annual or regular basis. Further, it appears that UTC does not rely much at all on ACE training in a comprehensive manner for its work force. In other words, it does not appear to be the case that all associates in the UTC organization are required to have some level of operating system training on a regular basis. This is contrary to the approach taken by Six Sigma companies.

While comprehensive and in-depth training does not insure success of a quality management program, it is, in my view, a major benefit to the success and speed of progress of a program in both a direct and indirect manner. Therefore, in order to maximize the potential benefits of an operating system, I advocate a position that all associates in an organization attend at least some type of annual operating system training. At an absolute minimum, this training, although not without cost and burden to an organization, will send a very positive message to its associates. The message at a minimum, will be that the entire enterprise is committed to practicing the operating system and that there is at least some minimal expectation for all to participate and support improvement and waste elimination. This training can take on many different

forms and can be done, especially today, in many different venues, including via the Internet or company intranet. Also, this recommended training can and in my view should be done in an exciting and motivating way where corporate wide success stories can be shared on a broad scale. This will improve employee morale and enhance the view of the organization's associates toward the future of the corporation and business. It is also, with almost absolute certainty, that I submit that this comprehensive organization wide training will motivate associates and stimulate participation in and passion for the operating system, thereby improvement in the business.

The sixth and final element of success that I have identified of Six Sigma is the recently developed applicability of it to product design and engineering. As previously outlined, Design for Six Sigma or DFSS, has huge potential to move product quality upstream. The opportunity to leverage quality improvement is at its greatest in the product creation phase of the product life cycle. Some believe that less than 10% of product cost is spent on design, yet design dictates nearly 80% of product cost. Further, it stands to reason that a product designed in conjunction with manufacturing and maintenance process capability, has the greatest chance to yield the highest product quality and in turn the highest customer satisfaction.

The UTC ACE Operating System has recently begun to focus on a similar initiative to DFSS that is called Design for Manufacturability. The focus on "moving quality to the left" is a critically important next step for ACE, and for that matter, most quality improvement systems. In my view, UTC ACE, and for that matter most quality

improvement systems have a great deal to learn and leverage from DFSS. In the spirit of continuous improvement, resources and energy should be devoted to developing a clear linkage between ACE and product design at UTC.

As previously indicated, in addition to the six items that I have identified and discussed that make Six Sigma successful, there are four items, in which I believe make ACE unique and successful.

The four major items that I believe make the ACE Operating System successful are:

- The ACE tools and philosophy is a blend of lean manufacturing and quality improvement tools.
- ACE Pilots are selected from a broad range of skill types and job functions.
- The utilization of capability levels of prerequisite, bronze, silver, and gold.
- ACE was developed at UTC, and therefore, is a custom fit for that organization.

The fact that the ACE tools and philosophy are a blend of lean manufacturing and quality improvement, truly differentiate it from Six Sigma and most other quality improvement systems. As indicated earlier in this paper, ACE is a blend of both lean manufacturing and TQM tools. Of the ten ACE tools, four of them, 5S Visual Workplace, Process Management and Standard Work, Set Up Reduction, and Total Productive Maintenance originate from the Toyota Production System or lean manufacturing. Five tools, Process Certification, Passport Process, Market Feedback Analysis, and QCPC come from the Deming/TQM teachings. One tool, Mistake Proofing, is difficult to assign in its entirety

to either lean or TQM. Combining of both lean and TQM tools into one operating system in a corporation that has such diverse product offerings as UTC, is not only unique, but demonstrates high effectivity of the ACE operating system. This ability also demonstrates the opportunity for ACE to aid the UTC supply chain and value stream partners as well as most other companies. It is of great value to practitioners of ACE to be able to have one operating system, versus multiple ones, in order to drive improvement across their business. Most companies today require both cost reduction and productivity type of internal operating improvements as well as improved customer satisfaction and top line growth. ACE has the ability to deliver both in one system whereas Six Sigma falls short from a lean manufacturing and operating results perspective. Although Six Sigma is somewhat complimentary and compatible with lean manufacturing, there is tremendous value in UTC having both combined and practiced under one system.

The second major item that I believe makes ACE unique and successful is the type of people that are selected to act as experts in guiding the organization in their learning and use of the operating system tools. ACE names these individuals Pilots. Six Sigma names these types of associates Black Belts. While it is noteworthy and admirable that Six Sigma utilizes Green Belts in addition to Black Belts, and that these personnel are extremely well trained, it is concerning that the vast majority of Six Sigma Black Belts are chosen from associates that have the singular background of engineers or leaders that were previously engineers. From a contrary perspective, the ACE operating system tends to select and utilize Pilots that come diverse educational and experiential backgrounds.

Most ACE Pilots are selected from their immediate work groups and have backgrounds that are representative of their peers. Further, as UTC, like many companies, performs some portion of its manufacturing in-house, many of its ACE Pilots are hourly shop floor associates. It is also the case that unions represent many of these pilots. This type of selection of pilots, in my view, has the tendency and capability to be far more successful, especially in the long term. Although it is perhaps difficult to directly measure, I believe that the ACE pilot selection methodology, versus the Six Sigma Black Belt one, provides opportunity for improvements in organizational learning, employee involvement, and the creation of common ground between unions and management. These outcomes are potentially enormously beneficial to an organization.

The utilization of the capability levels of Prerequisite, Bronze, Silver, and Gold are another of the four significant items of success for ACE that I have identified. As I previously indicated in this conclusion section of this paper, I believe strongly that ACE can benefit significantly by adopting the sigma measurement methodology in its Process Certification element. While this is the case, the utilization of the ACE capability levels at the cell, site, and ultimately the value stream level is an excellent practice. In doing so, UTC not only established a means to assess and measure its entities on a global scale, it also created a very constructive and collaborative method of accelerating improvement of its businesses globally. Throughout the organization, various cells, sites, and divisions observe and track the progress of business measures and ACE levels. Monitoring the success of peers tends to be natural and common in most organizations. Large multi-national corporations are certainly no exception. A benefit of the ACE capability levels

is the leveraging of this natural tendency. When properly managed, this can clearly accelerate the rate of progress in ACE implementation, and more importantly, can improve the overall business objectives.

The fourth and final major element of success of the ACE operating system in which I have identified is that ACE was developed internal to UTC by its associates. Therefore, it is a custom fit for that corporation. It is very much the case that UTC has demonstrated that ACE successfully applies to all of its varied divisions and product offerings. It is also the case that ACE has the real potential to be adopted and utilized by other companies. It is, however, a distinct advantage for UTC that the ACE program was internally developed. Like all other organizations, UTC possesses unique measurements, goals, approaches and a culture that can dramatically influence the degree in which a comprehensive quality management program is accepted. There is little doubt in my mind that while ACE can work well for other companies, that it works best for UTC.

Given the strengths of Six Sigma previously indicated in this paper, and the fact that ACE is now quite mature, as it is in its eighth year as the official UTC operating system, I, therefore, recommend that the following four initiatives be integrated into ACE in order to improve its effectiveness.

First, that sigma measurement should be used in the evaluation and measurement of all processes. Sigma measurement offers a universal language for communication within the entire value stream. This includes customers, employees, suppliers, and partners. This

will substantially improve the effectivity of both the Process Certification and Relentless Root Cause Analysis elements of ACE.

My second recommendation is that the formal organizational roles of ACE be more clearly defined. In doing so, that the roles have associated with them, required classroom training, practical hands on experience requirements, as well as a formal examination prior to the individual being considered capable in that respective function in the organization. As identified in the "Six Sigma-Belts and Formal Roles" chapter of this paper, Six Sigma clearly identifies and defines these type of roles for the key functions and personnel within the organization that are relied upon to facilitate improvement. ACE Pilots should, in my view, be required to receive more training and to demonstrate a level of competency prior to being assigned that job title and being allowed to perform in that job function. Also, that ACE needs additional formal organizational roles other than just Pilots. Like the roles of the Six Sigma Master Black Belt and Six Sigma Green Belt, ACE should have one to two additional formal organizational roles, where personnel that possess more experience and higher capability lead and guide Pilots and complex enterprise level change. These roles need to be identified and formalized along with specified levels of competencies and associated training and testing.

My third recommendation is one that UTC is currently working to develop and plans to spread across its enterprise. Although this is the case, I believe that it so fundamentally critical to the long term success of ACE and therefore UTC that I find it necessary to comment on it as one of my recommended elements of Six Sigma that should be

integrated into ACE. This initiative is Design for Six Sigma (DFSS). As indicated earlier in this conclusion chapter, the UTC solution for "moving quality to the left" and aligning product design with quality improvement is called Design for Manufacturability and is a parallel effort to DFSS. Design for Manufacturability, like the Six Sigma DFSS, is not easy to develop. Linkages to and from manufacturing and product design don't come easy, they also tend not to occur quickly and many times take much of the product life cycle to incorporate. The fundamental elements of Design for Six Sigma that were enumerated in Chapter 9 of this paper are essential to the long term success of both Six Sigma and ACE. Therefore, I recommend that UTC very aggressively pursues the complete development and deployment of a DFSS based initiative.

With regard to my recommendations of Six Sigma aspects that should be incorporated into ACE, training is my fourth and final item. As indicated many times in this paper, training, both formal classroom and practical hands on training, are critical to the success of an initiative as complex and comprehensive as ACE. In my view, every UTC associate should annually receive formal ACE training and communication. It should be a requirement that all new associates receive the Ito University ACE training within their first 90 days of employment with UTC. Further, in order to ensure that ACE is fully embedded in the organization and is completely understood and leveraged to the maximum extent possible, all employees and critical members of the value stream, such as suppliers and partners, should be assessed annually as to their respective proficiency level of ACE as compared to the proficiency level required for them to function

successfully in the value stream. Proficiency gaps should be identified along with the development and execution of associated training and development plans.

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