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SIX SIGMA… THE ROAD TO EXCELLENCE IN ALL WE DO

Introduction

The Air Force is taking a beating. With budget cuts and manpower reductions, we are still expected to perform at previously established levels. This requirement demands that we work more efficiently to cut out waste and reduce the cost of doing business. How do we go about meeting these demands without straining our resources to the breaking point? The answer lies in utilizing those tools which are already in use in the Air Force and combining them to synergistically improve the way in which we do business, that business being national defense. Enter Six Sigma.

What is Six Sigma?

Six Sigma is a system which combines the continuous improvement tools which are on hand to focus on our processes, analyze and compare them, and objectively assign resources to those processes requiring the most attention. The common link between the different processes in an organization is defect. Every process has them and they cause rework, waste, additional man-hours, and increased cost. By focusing on these defects and concentrating our efforts in reducing them, workload as well as cost of the process can be reduced. The Six Sigma system measures defects in a process and normalizes them so that comparisons between processes can be made. Once comparisons between processes are made, objective decisions can be made as to where to place resources for better performance.

Six Sigma is not something new. The concept has been around for more than a decade. The Six Sigma concept was developed by Motorola in the mid-1980s to analyze their manufacturing processes and eliminate defects. It was adopted by Texas instruments in 1991 and given a universal application across the organization, looking not only at manufacturing processes, but all processes within the organization. It was utilized in product production, product development, software, and business processes as well. TI discovered that as well as being a diagnostic system, Six Sigma could provide a predictive measure of short-term process operation.

So, what is Six Sigma?

Is it a Metric?
Is it a Benchmark?
Is it a Vision?
Is it a Philosophy?
Is it a System?
Is it a Tool for
- **Customer Focus?**
- **Continuous Improvement?**
- **People Involvement?**

The answer to all these questions is **YES**. Six Sigma performs all these functions.

Six Sigma is a **metric** in that it measures defects within a process and provides a handy graph by which to display the results and drive action towards improvement. Six Sigma is a **benchmark** in that it normalizes metrics between processes to allow comparison, identifying “best in class.” Six Sigma is a **vision** in that Six Sigma equates to virtually no defects in a process, a desired end state for any organization.

Six Sigma is a **philosophy** of continuous improvement and drive towards “excellence in all we do.” Six Sigma is a **system** used to determine where we are, where we want to be, how we will get there, and how we determine progress along the way. And Six Sigma is a **tool** used to fine tune the process machine through a customer focus, continuous improvement, and involvement of people both within and outside the organization.

In a discussion Six Sigma, there are three main areas in which to place emphasis. The first area is the **philosophy** which determines the drive, the vision, and the direction the organization will take. The second area, **measure**, allows an organization to quantify how a process is actually performing. The third area, **methodology**, is the systematic process for identifying, defining , measuring, analyzing, improving, and standardizing a process.

Of course, there are some things which Six Sigma is not. Six Sigma is...

1. Not A Magic Potion or Silver Bullet - Unlike some tools like Action Work Out, Six Sigma is not a quick fix program. Processes will not magically improve over night. A systematic approach is used to continually improve a process over time

2. Not A Process Only for Industrial Application - Though it was initially designed to improve industrial processes, Six Sigma has been proven to work on all processes within an organization.

3. Not A Tool Requiring a Sample Size of a Million Units to Use - Six Sigma metrics are normalized to one million units, but metrics can be determined using only a few data points.

4. Not A Standard to be Met - Standards tend to drive a reactive response to metrics. No action is taken until a process drops below a standard. Six Sigma is proactive in nature. Measurements are made to determine current process performance, then goals are established to drive towards continuous improvement.

5. Not Another Buzz Word - Six Sigma is a vision towards improving the way we do business in the long term, not a buzz word to be used today and thrown out tomorrow.

6. Not Difficult - People do not need to have a degree in statistics to understand and apply the Six Sigma concept. The focus is on defect reduction, a subject with which everyone is familiar.

7. Not Something New - As has been previously noted, the Six Sigma Concept has been in existence for over a decade and utilizes tools which the Air Force has been using for several years.

8. Not A Zero-Defect Program - Six Sigma strives to reduce defects as much as possible, but, in some cases, there are not enough resources or time to eliminate all defects.

The Language Of Six Sigma

There are a few terms and definitions which must be covered to help in understanding the Six Sigma concept. You may be familiar with some of them. Others may be new. But they all start with the process.

A **Process** is a value-adding activity which takes resources/raw material from a supplier and produces an output which meets the needs of the customer.

A **Unit** of work is the output of a process or particular process step.

A **Defect** is a mistake or error which is passed on to the customer. It results in customer dissatisfaction and rework.

Opportunities for Error are places/steps in the process where a defect can occur. Opportunities for error defines the complexity of a process. The more complex the process becomes, the more opportunities there are for defects.

To reinforce these definitions, focus on an example: Football.

One **process** in football is that of kicking a field goal. To be a little more specific, the process can be defined as the kick of a field goal from the snap of the ball to the whistle blown by the referee at completion of the play. Each time a field goal is attempted, a **unit** is produced - the attempted goal. There is one type of **defect** which could occur during the process…a missed field goal. Even though there is only one defect which can occur during the process, there are eleven opportunities during the process where an error could result in that defect occurring. There is one opportunity for each member of the team. If someone on the team misses their assignment, the goal could be missed. The **opportunities for error** in the process are therefore eleven (11).

Now a couple of equations should be introduced. The first is **Defects Per Unit,** or **DPU**. DPU is a ratio indicating the quality of the output. The more defects a unit has, the lower the quality. Wouldn't you agree? The equation is:

$$DPU = \frac{\#\text{ of Defects}}{\#\text{ of Units}}$$

The second equation is **Defects Per Million Opportunities**, or **dpmo**. Dpmo provides an equivalent comparison of processes of varying complexity. Say What? Okay. Just look at this equation and it will be explained.

$$dpmo = \frac{\text{DPU x 1,000,000}}{\#\text{ opportunities for error}}$$

There. Does that clear it up? No? Simply stated, dpmo answers the question, "If this process had a million points where a defect could occur, how many defects would actually occur?" Take a look back at the example of the field goal again. Say, during the course of a season, the kicker attempts 27 field goals. Two attempts fail due to one bad snap and one inaccurate kick. What is the DPU?

$$DPU = \frac{\text{\# of Defects}}{\text{\# of Units}} = \frac{2}{27} = 0.074$$

Every time the kicker attempts a field goal, an average of .074 defects occur. This number does not take into account the complexity of the process, though. If there were only 9 players on a football team, there would be less opportunity for error; 9 versus 11 to be exact. How do you account for that? This is where dpmo comes into play. Every time the process is run, there are 11 opportunities for an error to occur (missed assignment) which would result in a defect (missed field goal). So, how many defects occur per opportunity for error? You would have to take the DPU and divide it by the opportunities for error to determine defects per opportunity. The equation?

$$DPO = \frac{\text{DPU}}{\text{O/E}} = \frac{0.074}{11} = 0.00673$$

The problem with this number is that it is pretty small and defects normally don't occur in fractions. They occur in whole numbers, so we need to turn this DPO into a whole number. That's where one million comes into the picture. Why was one million selected? Because one million would drive a whole number on virtually any process, even one that's almost defect-free.

So, how many defects would there be per one million opportunities in this example?

$$dpmo = \frac{\text{DPU x 1,000,000}}{\text{\# opportunities for errors}} = \frac{0.074 \times 1{,}000{,}000}{11} = 6727$$

Now this number seems more realistic! For every million opportunities for error, this process would produce 6,727 errors.

How Is Sigma Level Determined?

Figure 1 - Field Goal Results

Once dpmo is determined, a sigma level can be derived. But how is sigma related to dpmo?

Well, you must first start with an understanding of sigma. So, put on your statistician's hat and get started. **Sigma** is used to designate the distribution or spread about the mean (average) of any process or procedure. Take a look at the field goal example again. Say that each time a field goal was attempted, a mark was made on a diagram of the goal post as to where the ball crossed the plane. The diagram of 27 attempts made by the kicker may look something like that in Figure 1.

The kicker tried to kick the ball through the center of the goal posts each time. Unfortunately, as in every process, there was variation, causing the ball to cross the plane of the posts at various locations. But, notice that those locations are centered on the middle of the goal posts. On average, the balls went through the center of the posts, so that is the mean. The data points (i.e. the footballs) are fairly evenly distributed on either side of the mean. This is known as normal distribution. The left side of the mean looks the same as the right side. This example describes a normally distributed bell-shaped curve. In statistics, this bell-shaped curve looks like the one in Figure 2.

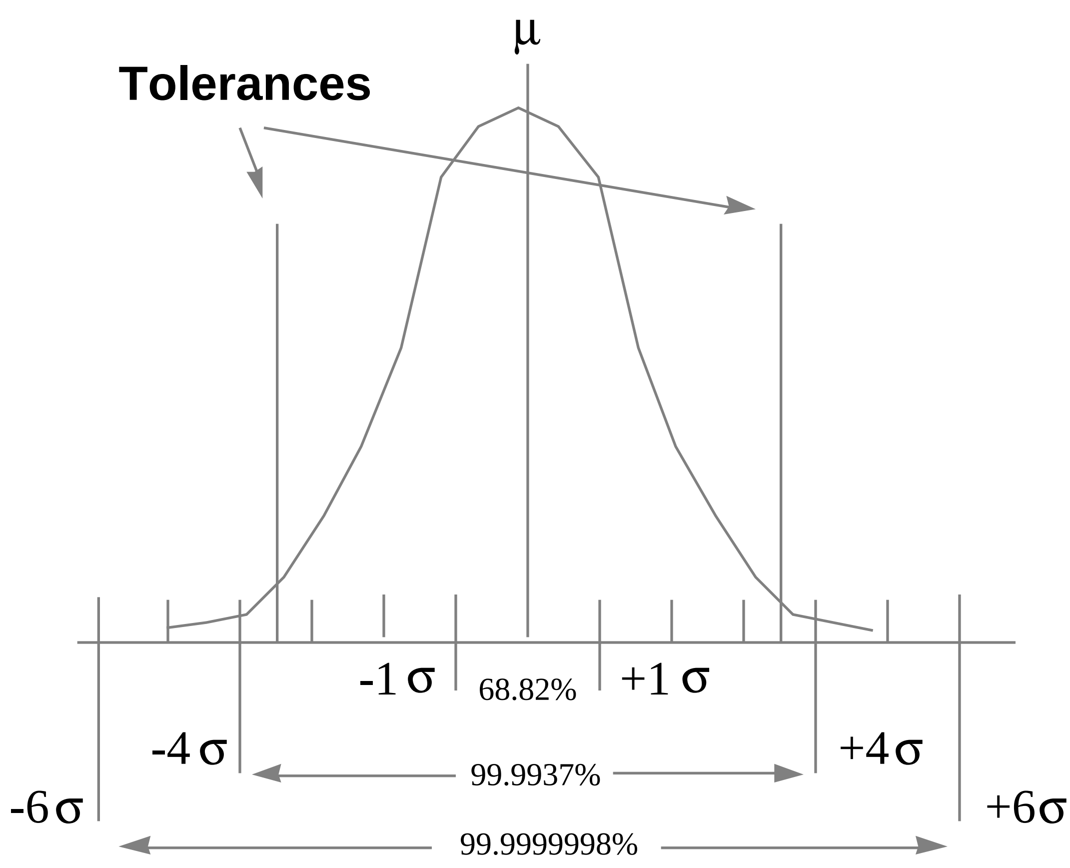

Figure 2 - Normal Distribution with Tolerances

Standard deviation, or sigma (σ), describes the spread of the data about the mean. If you were to move out from the mean in both directions until you reached one (1) sigma, the area between the two points would include approximately 68% of the data points. Two sigma encompasses approximately 95% of the data points. Four sigma encompasses approximately 99.9937% of the data points. When you get to six sigma, you have encompassed 99.9999998% of the data points or, basically, 100%.

There are some limitations which any process must work within. These limitations are called tolerances or specification limits (upper and lower). Any data points which fall outside the specification limits are called defects. For the football example, the specification limits are the goal posts. Anytime the ball passes to the outside of the posts, customer dissatisfaction results. Enough dissatisfaction results in fewer ticket sales, lower revenues, smaller salaries for the coaches and players, and eventually the destruction of college football as we know it.

Standard deviation varies depending on how well the data points are congregated about the mean. If the points are close together, standard deviation (σ) is small. If the points are far apart, standard deviation (σ) is large.

Notice in Figures 3 and 4 that the tolerances remain the same, but the standard deviation changes. The curve with the smaller standard deviation has fewer data points which fall outside the tolerance limits. Sigma level for a process can be determined by locating the intersection of the tolerance limits on the sigma scale. For the small standard deviation process noted above, the sigma level is approximately 4.5. For the larger standard deviation process noted above, the sigma level is approximately 2.5. This sigma value is a metric that indicates how well a process is performing. The higher the value, the better and the less likely a process will produce defects.

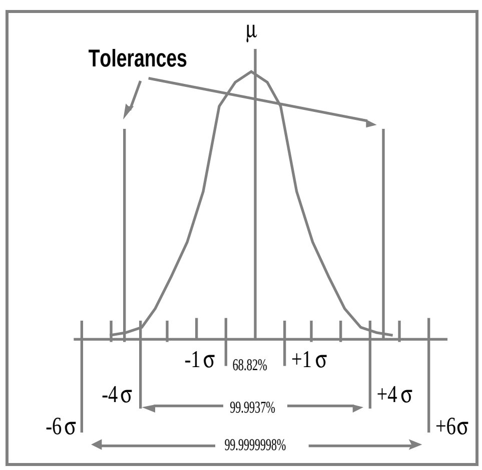

Figure 3 - Small Standard Deviation

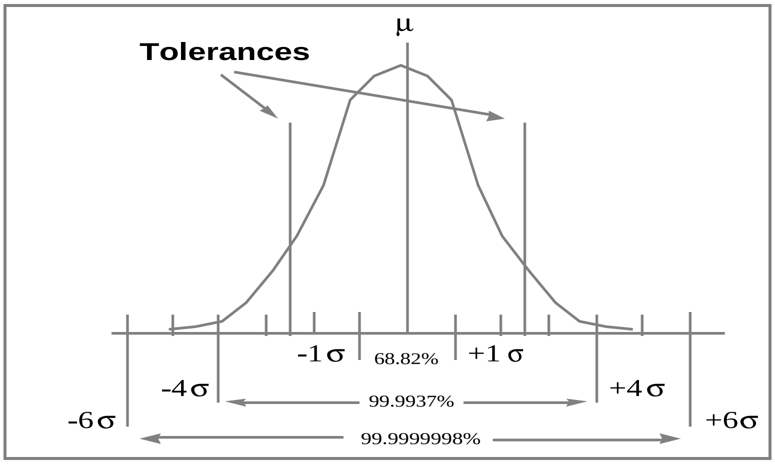

Figure 4 - Large Standard Deviation

So, what's the sigma level of the football example in Figure 5?

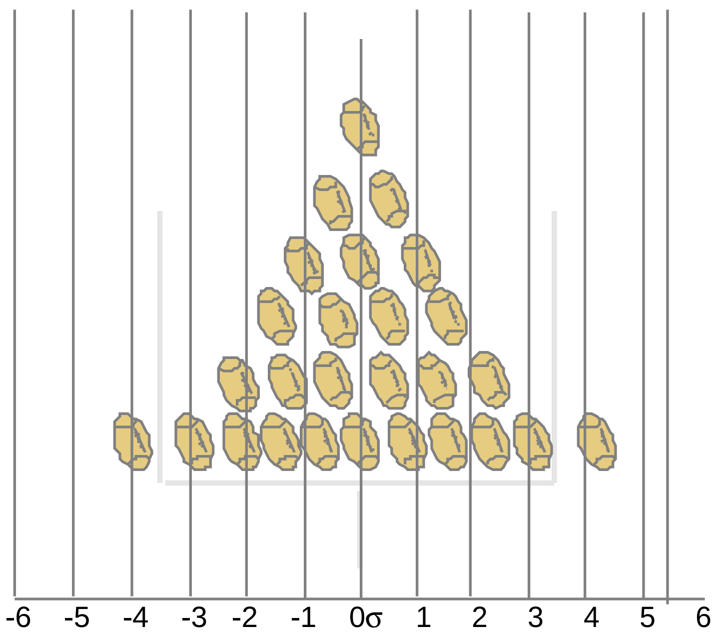

Figure 5 - Pictorial Sigma Determination

Did you say 3.467 sigma? Nice job! Does this mean that you have to draw a bell curve every time you want to determine the sigma level of a process? Fortunately, no. Motorola has developed two charts which can be used to determine sigma level as long as you know dpmo of the process. Large versions of these charts are found in the Appendix. The first chart, depicted in Figure 6, uses a logarithmic scale to determine sigma level. Simply enter the chart on the y-axis with the dpmo, move right until you intersect the arc on the chart, then move down to the x-axis to read sigma level.

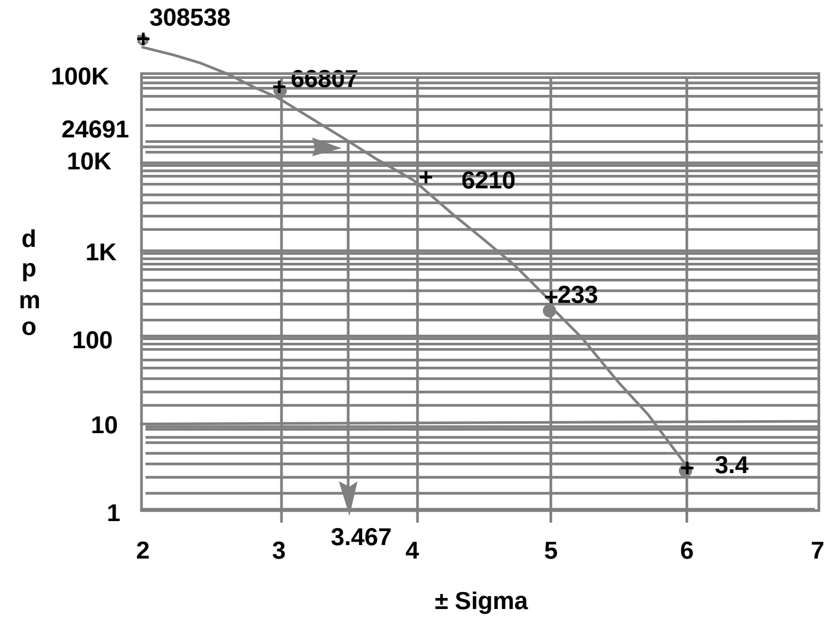

Figure 6 - Graphical Sigma Determination

You must have pretty sharp eyes to be able to measure to the third decimal place. That's where the table (Figure 7) comes in handy. To find sigma level in the table, simply find the dpmo in the table. Look to the left index to find sigma to the first decimal place. Look to the upper index to find sigma to the second decimal place. If your dpmo falls in between two listed on the chart, you can interpolate to determine sigma to the third decimal place. Using an example of 24,691 dpmo, you will find that it falls in between 3.46 and 3.47 sigma. Interpolation gets it to 3.467.

σ	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
							86910			
							72140			
							59380			
							48460			
							39200			
							31440			
3.4	28720	28070	27430	26800	26190	25590	25000	24420	23850	23300
							19700			
							15390			
							11910			
							9137			
							6947			

Figure 7 - Tabular Sigma Determination

Sigma to the third decimal is not necessary. Two decimal places (3.46) will suffice. If dpmo falls between two points on the table, use the smaller of the two levels. That way, you can honestly say that you have reached 3.46 sigma. With this information in hand, what is the sigma level of our football example with 6,727 dpmo? 3.97? Very nice.

What Is Shift In A Process?

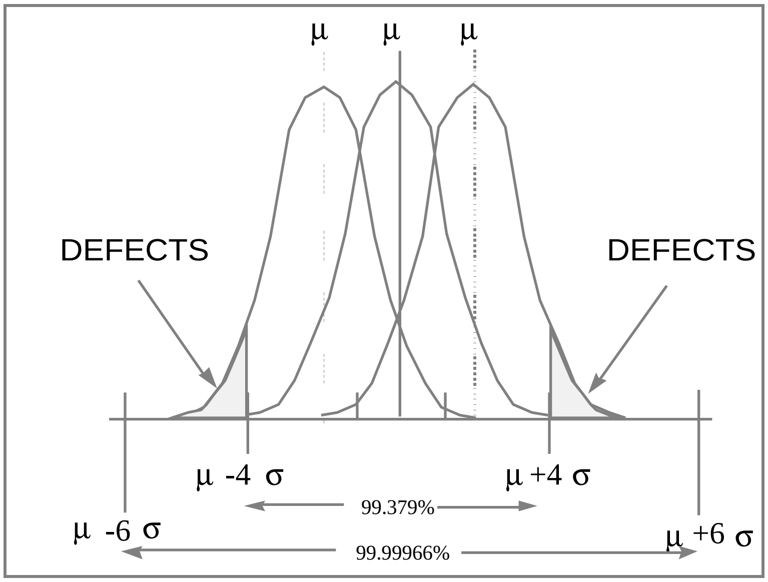

Figure 8 - Process Shift

If you were to pull out your scientific calculator, and I know you have one, you would actually calculate a different sigma level than the one we have just determined. Why? Because **SHIFT HAPPENS**! What is shift? It's the normal wear and tear in a process. When you buy a new automobile, it runs great. But, as time goes by, wear and tear occurs and it doesn't perform as it originally did. You have fallen victim to performance shift. In the football example, shift could occur as a result of a wet field, a change in wind direction, or any one of a number of things. If no change is made to the process, the outcome will shift.

Motorola has found that a process can shift by as much as +/-1.5 sigma as a result of wear and tear, environmental changes, etc. On the bell curve, this shift would look like the one in Figure 8.

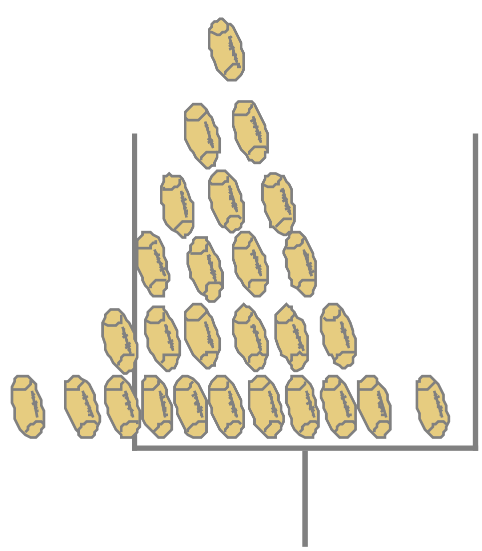

Figure 9 - Toe Kick with 1.5 Sigma Shift

The shift causes more data points to fall outside the process specifications, increasing defects. From the football example, the pattern of kicks attempted may look like Figure 9.

The pattern is still normally distributed, but it has shifted from center. Now there are four (4) defects; 1 for a bad snap, 3 for a bad kick. Calculating DPU and dpmo, you come up with

$$DPU = \frac{4}{27} = 0.148$$

$$dpmo = \frac{0.148 \times 1,000,000}{11} = 13,455$$

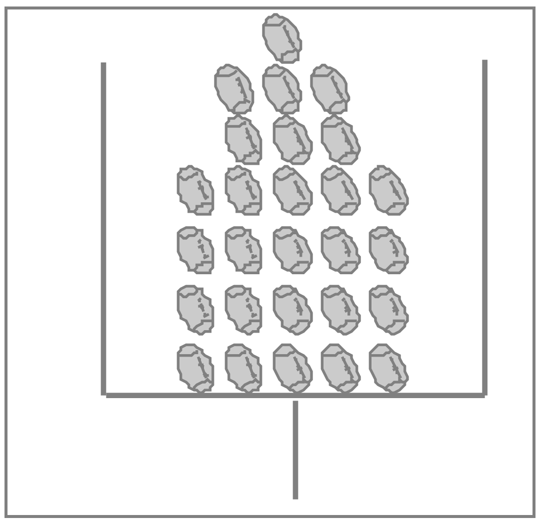

Figure 10 - In-Step Kick Without Shift

Looking up sigma level in the table in the Appendix, you find that your sigma level has just decreased to 3.71. Now the process which used to get you 3.97 sigma, is getting you 3.71 sigma. What happened? Shift happened! How can you adjust for this change in output? Make the process so good that when the shift occurs, it is barely noticeable. Goal kickers found that by using an instep kick instead of a toe kick, they achieved lesser variation in their kicks. The distribution of the kicks looked more like Figure 10. There was smaller deviation from the mean, resulting in fewer defects.

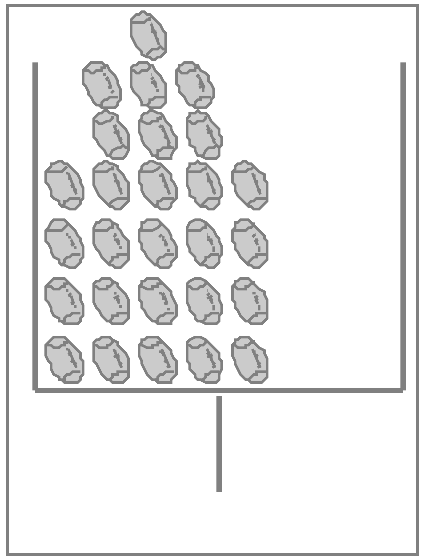

Figure 11 - Sigma Shift Effect on In-Step Kick

When a 1.5 sigma shift occurs in this new process, the results are as shown in Figure 11

The process was good enough that the shift did not affect the output of the process. So how do you change your calculations to take this shift into account? You don't have to. The chart and table in Appendix 1 have already been adjusted for a +/- 1.5 sigma shift. Life is good!

Before you continue, try a couple of sample problems to see if you have a good grasp on what you've read so far.

Exercise 1

Given the following processes, complete the chart, defining defects, units, opportunities for error, and computing DPU, dpmo, and sigma level.

1. Over a one month period, 46 preflight inspections were performed with 26 defects noted by QA. The preflight has 67 items that are checked on each inspection.

2. Over the last year, 1050 injections have been administered by the hospital. In one instance, the incorrect amount was administered and in another, the wrong drug was given. Consider amount and type of drug to be the only opportunities for error.

3. In the transportation section, main tires are checked for proper inflation prior to sending the vehicle (mini-van) out on the road. In the last month, 35 vehicles were sent out and on 3 occasions the pressure was incorrect.

Process	Defect	# Defects	Unit	# Units	Opportunities for Error
Preflight Inspection					
Injection					
Vehicle Checkout					

Process	DPU	dpmo	Sigma
Preflight Inspection			
Injection			
Vehicle Checkout			

Comparative Sigma Levels

So, what's a good sigma level? How do you know when your doing a good job? Historically, companies have held three (3) sigma as the standard for industry. Without the +/- 1.5 sigma shift, that means 99.74% defect-free. Pretty good. With the sigma shift, three sigma equates to 93.32% defect-free. Not so pretty good. Currently, industry is running at approximately four (4) sigma without shift, which equates to 99.9937% defect-free processes. With shift, it falls to 99.38%. Sounds pretty good, but think about the results of a four sigma process:

- In the postal service, 2,000 lost articles of mail each hour.
- In public health, 15 minutes of unsafe drinking water each day.
- In the telephone industry, no service for 9 minutes each week.
- In pharmacy, 20,000 wrong drug prescriptions a year.
- In aviation, two short or long landings at Chicago's O'Hare airport every day. This also applies to all airports of comparable size.
- In surgery, 500 incorrect operations per week.

Many companies are realizing that four sigma is no longer good enough. They are now setting their sights on six sigma. *Why six sigma?* Six sigma equates to 3.4 defects per million opportunities, virtually defect free. A company working at a six sigma level is considered to be **Best-In-Class**. The results of a six sigma process are as follows:

- In the postal service, 1.1 lost articles of mail each hour.
- In public health, 3 minutes of unsafe drinking water per year.
- In the telephone industry, no service for 2.6 minutes each decade.
- In pharmacy, 11 wrong drug prescriptions a year.
- In aviation, four short or long landings at Chicago's O'Hare airport every decade. This also applies to all airports of comparable size.
- In surgery, 142 incorrect operations per decade.

Do all processes need to operate at six sigma? Not necessarily. Take a look at a comparison of some of today's common processes in Figure 12 on the next page.

What does the chart tell you? *Don't call the IRS for tax advice*! More importantly, it shows the importance industry has placed on different processes. Flight safety is very important, so industry invests a lot of time, energy, and resources to ensure the flight safety process maintains a level above six sigma. When an accident does occur, investigators are on the scene trying to identify the cause and improve the process so that accident doesn't happen again. Is airline baggage handling so important as to warrant the same attention? Probably not. The cost wouldn't justify the result.

The same is true in the military. Flight and ground safety are very important to national defense, so large amounts of resources are dedicated to safety to keep the sigma level high. Those resources are dedicated at the expense of other programs. More on this topic later.

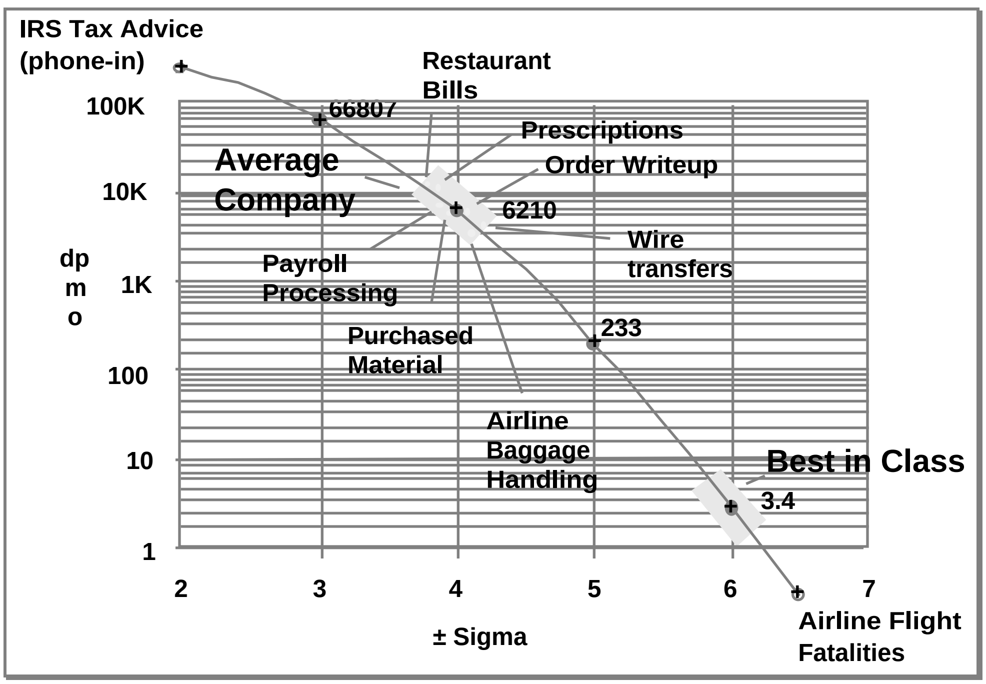

Figure 12 - Deriving Sigma Level

Process Perspective

When converting a process to a sigma metric, care must be taken to ensure you properly define units, defects, and opportunities for error in the process. These definitions could change depending on your perspective of the process. In the football example, the perspective was from the point of view of the special teams coach. He is responsible for players on his special team, and sees eleven (11) opportunities for error when handling the ball. But what about the perspective of the football fan? She only sees one opportunity for error. The ball either goes through the uprights or it doesn't. This different perspective generates a different sigma level. Let's compare the two in Figure 13:

Perspective	**Special Teams Coach**	**Fan**
Unit	Field Goal Attempt	Field Goal Attempt
Defects	Missed Field Goal	Missed Field Goal
Opportunities for Error	11	1
Units	27	27
Defects	2	2
DPU	2 / 27 = .074	2 / 27 = .074
dpmo	(.074 x 1,000,000) / 11 = 6,727	(.074 x 1,000,000) / 1 = 74,074
Sigma	3.97	2.94

Figure 13 - Process Perspective

Notice that only one number is different - opportunities for error. The defect remains the same because a missed field goal results in customer dissatisfaction, the customer in both cases being the fan. Notice also that the DPU is the same in both cases because units and defects are the same. Opportunities for error is not directly related to defects. One opportunity does not equate to one defect. Opportunities for error only measures the complexity of the process, not the defects per unit of output. This is a very important concept to understand. Opportunities for error is used to normalize a process so it can be compared to a similar process of different complexity. DPU measures output quality and is the best indicator of process/product quality.

So which sigma level is the right one? In this case, 3.97 is correct. *Why?* Remember that dpmo measures process complexity. The fan's perspective is flawed since she doesn't know the complexity of the process. Therefore, 2.94 sigma is incorrect. *Does this mean we should ignore the customer perspective?* NO! The customer's perspective is taken into account when you define the defects which measure customer dissatisfaction. The one thing DPU doesn't tell you is the severity of the defect. For example, there are two cars for sale. One has a scratch in the fender. The other won't start. They both have one DPU, but only one will be sold without a major reduction in price.

Another good example of perspective is a computer. To the manufacturer, there may be 50,000 parts, or opportunities for error. The good news is….out of the 50,000 parts, there is only one (1) defect per unit. This equates to a dpmo of 20, or 5.61 sigma. WOW! What a great job! The bad news is….the defect is the power switch. It doesn't work. Every time the customer tries to turn on the computer, nothing happens. That equates to a dpmo of 1,000,000, or 0 sigma. WOW! You're about to go out of business!

So, what should I do? Do I use the process metric and disregard the customer perspective? No. Identify defects as defined by the customer. Then, determine the impact of defects on customer satisfaction and tackle those defects which result in greatest dissatisfaction. There's more discussion about this concept later.

The Philosophy Of Six Sigma

What is the utility of Six Sigma? What does it do for the organization? What's the applicability to the way we do business in the military? These are a few of the many questions people have when a discussion of Six Sigma begins. This section addresses some of these questions and concerns people have when implementing the concept.

There are six basic benefits to the Six Sigma concept. Some of them many have been identified or discovered earlier in this guide. They are as follows:

1. A Common Goal - With defects as the common link between processes and the basic element in computing sigma, we now have a common goal of reducing those defects. Reducing the defects progresses the philosophy of continuous improvement, which in turn perpetuates our core value of excellence in all we do.

2. Teamwork Promotion - Teamwork is required between several individuals when implementing the Six Sigma concept:

A. Among Process Workers - Many operations are task-oriented; based on an individual performing just that portion of the process for which they are responsible without regard for other tasks or individuals in the process. Six Sigma drives a process focus requiring individuals to team together to improve the overall process.

B. With Customers - How do you know you're providing a defect-free product to the customer unless you determine their requirements? What do customers consider to be defects? Teaming with the customer to identify customer needs, as well as communicate process limitations, is essential to properly concentrating unit resources in areas which will provide maximum benefit to the customer.

C. With Suppliers - You are someone else's customer. How are they supposed to provide you with a defect-free product if they don't know your requirements? Also, by understanding the limitations to your supplier's process, you can better prepare your organization to deal with those limitations.

D. Between Units - Six Sigma allows comparison between processes. How can the Air Force benefit as a whole if units don't team together to ensure the practices of best-in-class processes are communicated throughout? Units must be willing to work together to allow process improvements to be utilized Air Force wide.

3. A Common Language - Defects, opportunities for error, sigma. This is the common language shared by all processes. Using Six Sigma as the basis for all process measures within an organization, leaders and managers can more easily understand process performance without having to interpret numerous types of charts for different processes.

4. Synergism - Reduction of defects is not the only benefit from Six Sigma. It has a synergistic effect in other areas as well (Figure 14). Preventing defects improves the quality of the product. Cycle time is reduced by reducing inspection and rework of defects, and by streamlining the work processes. Those streamlined, defect-free processes produce better results at lower cost. They don't waste resources.

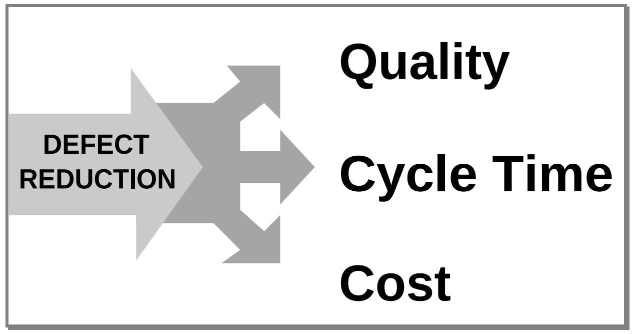

Figure 14 - Synergism of Six Sigma

Cost of defects is very important in a world of dwindling resources and funding. An organization with processes operating at four (4) sigma will, on average, spend as much as 25% of their total budget to correct defects. That's a lot of money to throw down the drain. On the other hand, an organization with processes operating at six (6) sigma will , on average, spend 1% of their budget on rework of defects. That's a tremendous decrease in the cost of doing business. A four sigma organization cannot compete with a six sigma organization. Their lower quality product costs them more money to produce. In today's competitive environment, an organization's survival depends on achieving six sigma.

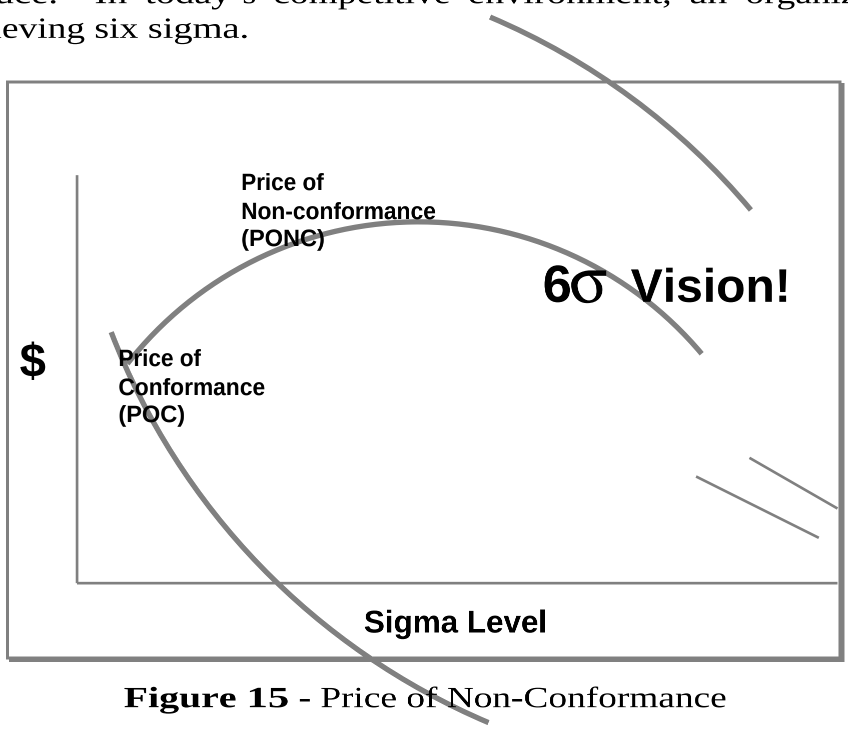

Figure 15 - Price of Non-Conformance

Look at Figure 15. This figure shows a cost comparison of conformance (POC) with non-conformance (PONC) as sigma increases. Conformance identifies a unit of production which had no defects requiring rework. A non-conforming unit of production has defects, requiring additional time and money to repair. As an organization improves its processes, fewer defects occur, driving down the cost of non-conformance. When a defect does occur, the process has improved to the point where less time and money is required to repair the defective item.

5. Comparison Capability - With the defect-based sigma scale providing variance for process complexity, similar processes can be compared to determine overall performance and improvement opportunities. This comparison identifies those best-in-class and benchmark candidate processes utilizing an objective vs. subjective approach. For example, look at the metric in figure 16.

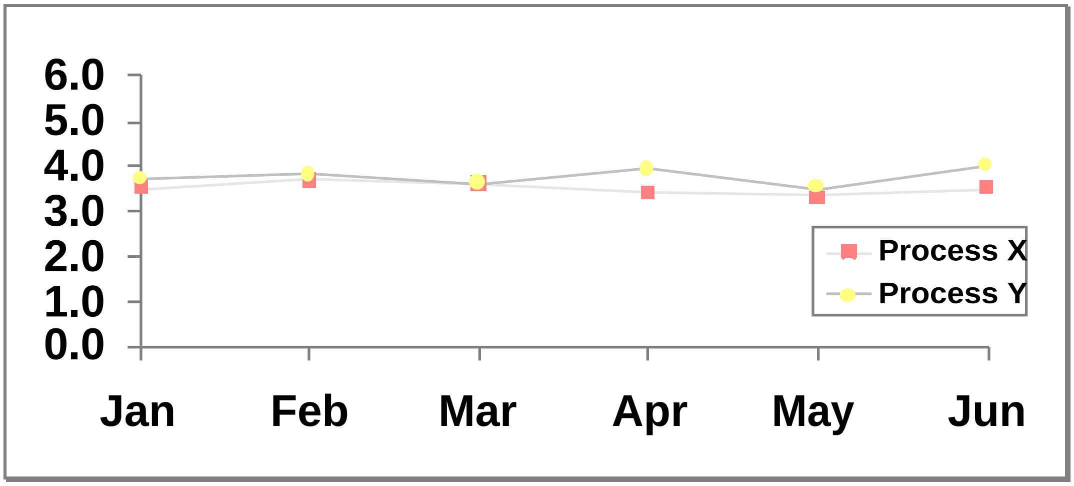

Figure 16 - A Comparison Example

Process X is the same as process Y except that they are performed at different bases. If defects are defined similarly in these processes, then they can be compared. In this case, process owner X should team with process owner Y to find out how process Y is able to consistently perform at a level higher than process X.

6. **Desire for Improvement** - In some organizations, leaders may use measures to try and drive improvement into the process. This approach doesn't work very often, and when it does, the improvement doesn't last very long (Figure 17).
7.

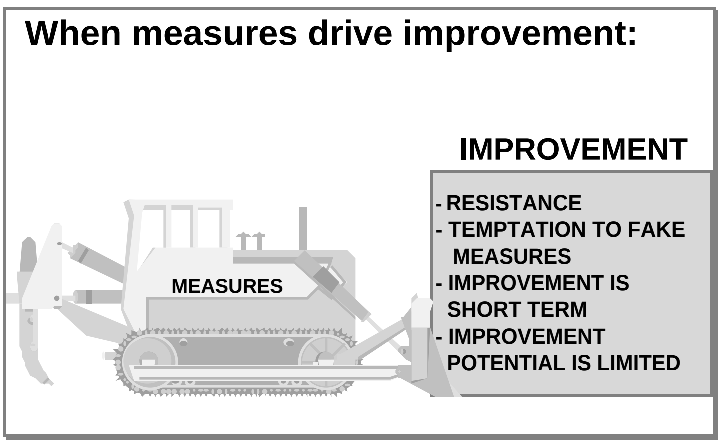

Figure 17 - Measures Drive Improvement

- People may try and manipulate the measure. If a negative direction in the metric caused undue attention, then a positive turn in the metric - with or without actual process improvement, will result in reduced pressure from leadership. This manipulation results in lost confidence in the metric to provide adequate information of the process performance.
- We also see resistance, or an unwillingness to provide accurate information. Workers may be afraid to tell the truth because it will make them look bad or give a bad impression of the organization.

- The potential for improvement is limited with this approach. Many metrics have a standard that acts as a “don’t rock the boat” point. As long as performance is at an acceptable level of defects, no one needs to try and improve. If the performance drops below the standard, you need only to increase performance to the standard where you can stop.

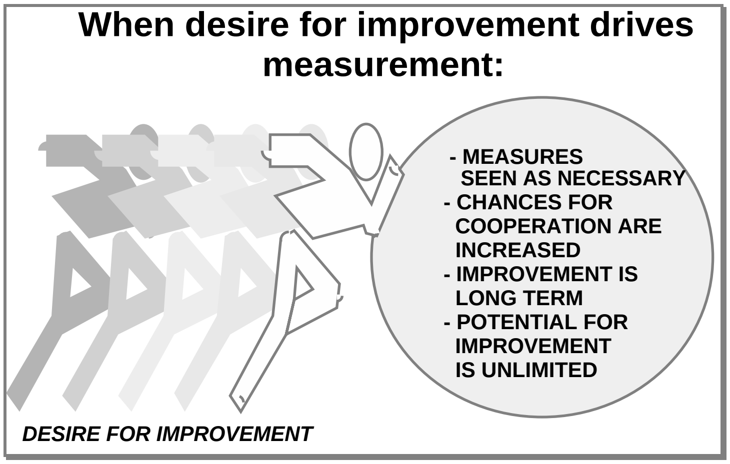

Figure 18 - Desire for Improvement

On the other hand, when you create a desire for improvement, people see the metric as an essential tool to see how the process is performing (Figure 18). They are much more willing to cooperate with other process workers and leadership to try and improve the process which leads to higher process performance. In this type of situation the potential for improvement is unlimited.

Road To Utilization

When utilizing Six Sigma in an organization, there are two roads the leader can take depending on their philosophy towards the concept. The first road is the road to failure. Several actions guide leaders toward **the road to failure**:

1. Setting unrealistic goals. Setting high goals for process performance without understanding resource availability and capability will doom efforts from the beginning. Measures must be taken to determine the current operating level of the process. Then, realistic goals can be set utilizing the existing resources on hand.

2. Expecting immediate results. Expecting processes to perform to a certain sigma level in short order only demoralizes individuals when the goal is not met. It takes time to adequately understand a process and set a course for improvement. Don’t ask more of the process than is immediately possible.

3. Beating people up. This system is not meant as a system to measure individual performance. It measures process performance. Processes are responsible for 85% of the problems in products today. People only 15%. Aim improvement efforts at the 85%.

4. Pitting one organization against another. By comparing metrics, it is not meant for commanders to pit one organization against another. Everyone is working on the same team…the national defense team. When leaders find an organization leading the way in process improvement, they should team them with other organizations so everyone can benefit from the improvement.

These four will lead to failure in an effort to improve process performance. On the other hand, there are actions which will help lead to success. The **road to success includes using Six Sigma**:

1. As a common / collaborative approach to process improvement. By working with other people throughout the organization, the customer, and the supplier, everyone together can produce a substantially better product to the customer.

2. To motivate people. By showing individuals how the process is performing and how their efforts have improved the product, you can motivate them to even higher levels of performance.

3. To improve products and services. Again, by focusing on defects and ways to eliminate them, Six Sigma reduces waste, cycle time, and cost, ultimately improving the products and services generated for the customer.

4. As a customer / user focused strategy. By talking to the customer, finding out their requirements, and building a strategy for improving the process to meet those requirements, organizations reach the level of world-class.

5. To strive for "Excellence in All We Do". No one wants to have their name put on a mediocre product. Sometimes people feel overwhelmed by the process, unable to act as an element for change and improvement. They resign themselves to the feeling that they cannot do better than average. Using Six Sigma to get people actively involved in process improvement makes them feel as if they can make a difference for the better. And they can! All they need is the chance.

Adaptation Of Six Sigma To Air Combat Command

The Six Sigma concept is new to the military. The tools and techniques it utilizes are not. The key to a smooth transition to the Six Sigma concept is found in integrating this new concept into those already existing tools and techniques. This approach minimizes any negative impact on operations tempo and training while still providing an effective process improvement system.

As has been said before, Six Sigma aligns conveniently with the Air Force core value of "Excellence in All We Do." Additionally, this concept helps achieve several elements of the desired "End State" for the Air Force culture as outlined by the Chief of Staff of the Air Force. Those elements include the following:

1. Link mission accomplishment to strategic planning. Unfortunately, in most cases, strategic planning is a square-filling activity which is accomplished once a year before shelving it and returning to do the mission. The two are not linked together, though the strategic plan should be main organizational document showing current capabilities and projected future growth and improvement to be used as a blueprint.

2. Team-based approach. "Functional and cross-functional teams are the way we work." Stovepiping needs to be eliminated to allow the Air Force to reach the synergistic capability of the team-based approach. Remember, "Two heads are better than one."

3. Encourage innovation and achieve breakthrough performance and import, implement and export "Best Practices." The Air Force cannot afford to re-invent the wheel in every squadron. When innovative, breakthrough performance is achieved in one organization, it must be exported to others to take advantage of the improvement while minimizing numerous similar, costly, individual efforts.

4. Metrics that strike a balance between process measurement and performance results. Most metrics in existence in the Air Force only measure process results without providing an adequate scope of the process. Personnel must have metrics which allow a wide perspective of the entire process from the supplier through the process to the customer.

5. Actively use the tools of the quality culture. The tools which have been introduced in the military during the last five years are effective tools which need to be utilized to bring about the continuous improvement required in today's competitive environment.

When adapting Six Sigma to Air Combat Command, an objective must be developed which links the Six Sigma concept with these desired end states.

The objective of Six Sigma in Air Combat Command is to provide wing leadership a common key process measurement system which drives objectively focused improvement efforts.

This system must be able to allow wing leaders to objectively review process performance, then determine where to apply their limited resources towards more effective mission accomplishment. The objective is not to make a process "*six sigma*", not to take this individual process and make it better than anything else. The objective is to provide a common measurement system which drives objective data-driven decisions.

The vision of the Six Sigma concept in ACC aligns well with the objective.

The vision of Six Sigma in Air Combat Command is to:

- ***Provide a common measurement system for continuous improvement utilizing data-driven decisions.***
- ***Increase the quality of products and services by reducing defects, variation and cycle time.***
- ***Identify savings in dollars and man-hours***
- ***Free up resources for increased combat capability***

DO OUR JOBS FASTER, CHEAPER, SMARTER, AND BETTER

Without data, leaders are forced to make decisions based on gut feeling or intuition, which may or may not be accurate. Data helps to positively identify improvement opportunities, leaving less doubt as to correct courses of action.

By focusing on defect reduction, product and service quality are increased. Variation in product quality is minimized, increasing predictability of process outcome and customer confidence. In addition, defect reduction decreases cycle time required for rework, saving the added cost and man-hours involved. Resources which spend less time in the process, spend more time available for utilization, increasing combat capability. An aircraft which spends less time in maintenance, spends more time on the flightline ready to fly the mission.

In short, the vision of Six Sigma is to allow Air Force personnel to do their jobs faster, cheaper, smarter, and better.

What Needs to be Adapted?

Most of the current measurements in use will have to be re-evaluated and changed to a process-centered measurement approach using the sigma format. Why do these measures need to be changed? Look at figure 19 on the next page.

There are numerous measures in use today which do not measure performance or output of the process. In addition, there are very few metrics developed which focus on customer satisfaction. As a matter of fact, there are some metrics which are developed by suppliers which dictate that satisfaction level to the customer. "You will be satisfied if I attain this level! And that's an order!" Metrics must be developed with a focus on the supplier, process, and customer in order to provide an overall picture of the entire operation. The customer actually defines defects and requirements in the product and identifies satisfaction levels. The process personnel develop metrics to measure process performance. In addition, the process personnel develop metrics to measure defects and requirements in the products they receive from suppliers so there is a thorough understanding of the entire process from receipt of supplies to feedback from customers.

CURRENT MEASUREMENTS	PROCESS CENTERED MEASUREMENTS
- Numerous measures unrelated to process focus **- Customer metrics not developed**	**- Metrics developed form supplier, process and customer data to provide overall process focus**
- Non-standard format	**- All metrics in standard sigma measure format**
- Non-comparable metrics	**- Defect levels can be compared in similar processes**
- Data analysis difficult or non-existent	**- Data analysis from macro to sub-system level**

Figure 19 - Measurement Comparisons

There is currently no standard format for metrics. In meetings where metrics are reviewed, metric format changes from slide to slide, requiring the reader to re-orient and individually interpret each slide. “Up” may be good on one slide while “Down” is good on the next one. With process-centered measurements, each chart is formatted in one of two ways with “Up” meaning good in both cases. The metrics are easier to read and the reader doesn’t need a degree in statistics to understand and interpret them.

Since there is no standard format for metrics, it is difficult to impossible to compare one process to another. Using sigma as the standard metric format, similar processes can be compared to one another since they are normalized to account for their varying complexity.

Finally, in many cases, data analysis is difficult to non-existent. Metrics do not logically identify improvement opportunities. Sigma takes a logical, progressive approach towards data analysis from the macro level of performance down to sub-system level.

The Methodology For Adaptation

There are four steps to take towards adapting the Six Sigma concept to ACC processes.

4 STEPS TO SIX SIGMA

1. **DEFINE THE PROCESS.**
2. **MEASURE AND ANALYZE THE PROCESS.**
3. **IMPROVE THE PROCESS.**
4. **STANDARDIZE THE IMPROVEMENT.**

Figure 20 - The Four Steps to Six Sigma

1. DEFINE THE PROCESS. Before measurements and improvements can be made to a process, people must first understand the process; defining its beginning and ending points, the main steps, the unit, the customers, the suppliers, defects, and opportunities for error. A COPIS provides a good start to accomplishing this task. A COPIS is an existing tool which identifies the main elements of a process, starting with the customer and working through the process all the way back to the supplier for the specified process.

Building A COPIS

There are ten main elements which comprise a COPIS. They are:

1. **Key Outputs** - Those products and services which are delivered to the customer. A key output is the same as a unit used to compute DPU, dpmo, and sigma level.
2. **Key Customers** - The person(s) or organization(s) to whom you provide products and services. These are the individuals who will determine your customer satisfaction metrics.

3. **Key Customer Quality Indicators** - An internal measure which predicts the ultimate customer satisfaction. Though this measure can be used in the sigma format, it is not included in the demonstration plan.
4. **Key Customer Satisfaction Indicators** - Criteria you must meet to gain customer satisfaction. These are the metrics which are defined by the customer and are used to determine product quality. Specific metric development is discussed under "**Measure and Analyze the Process**" following this section.
5. **Key Processes** - Organizational process(es) used to produce / deliver key outputs. At the macro level, there may be several processes which are involved in providing a product or service to a customer. If the COPIS is built around just one process, include the macro steps of the process in this section.
6. **Key Process Performance Indicators** - Measures that track process quality and performance. These metrics are defined and developed by process personnel. Specific metric development is discussed under "**Measure and Analyze the Process**" following this section.
7. **Key Data Systems** - Methods to collect, analyze and use organizational data. These systems can be as sophisticated as an integrated statistical simulation model or as simple as a check sheet. It is simply the tools you use to gather, store, review, and utilize data.
8. **Key Inputs** - Resources provided to the organization from suppliers. It includes those key resources required from suppliers to perform a service or produce a product for the customer.
9. **Key Suppliers** - Person(s) or organization(s) which supply the material and resources to the process.
10. **Key Indicators of Supplier Quality** - The criteria you expect suppliers to meet in order to provide an available and reliable product to your process. Specific metric development is discussed under "**Measure and Analyze the Process**" following this section.

Your COPIS can be structured and display in any form you choose, as long as it is useful and easy to understand. The COPIS provides a systems approach to the process (Figure 21), identifying the interrelated elements which take an input, process it, and provide a product to the customer. For more information on building an effective COPIS, refer to the COPIS User's Guide available from ACC QMIS/XPIE (DSN 574-4010).

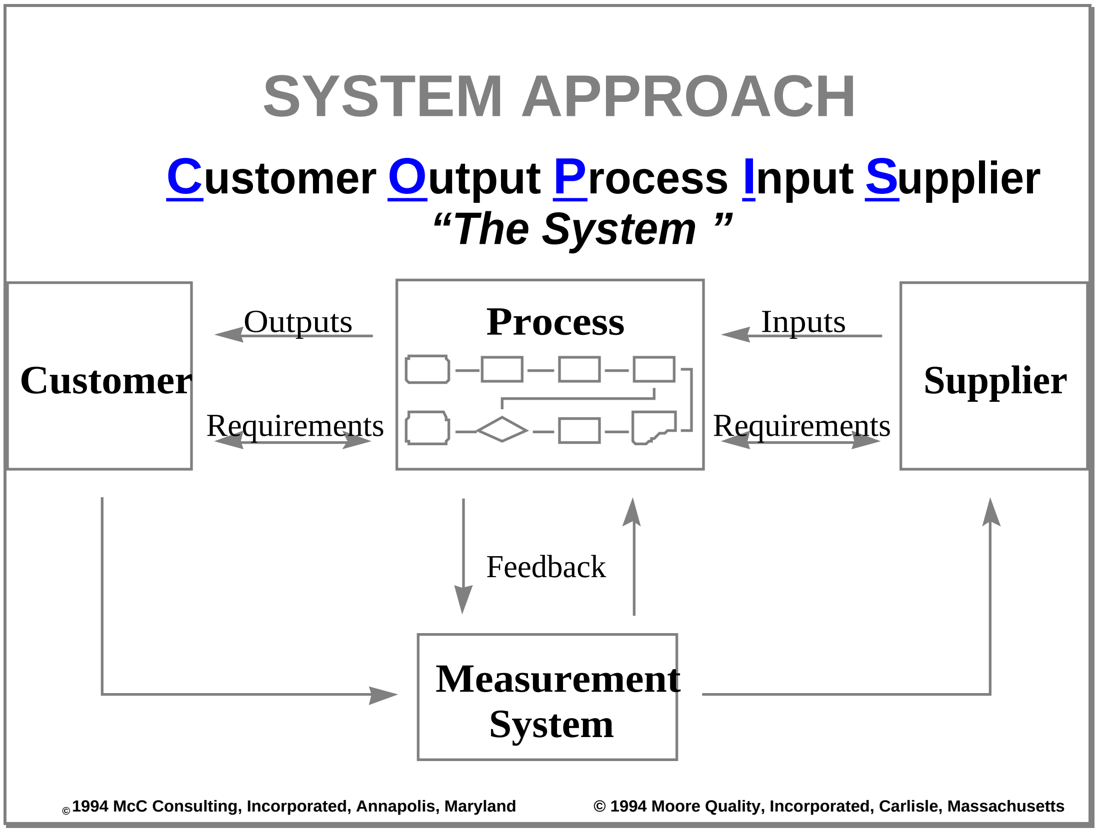

Figure 21 - COPIS, A System Approach

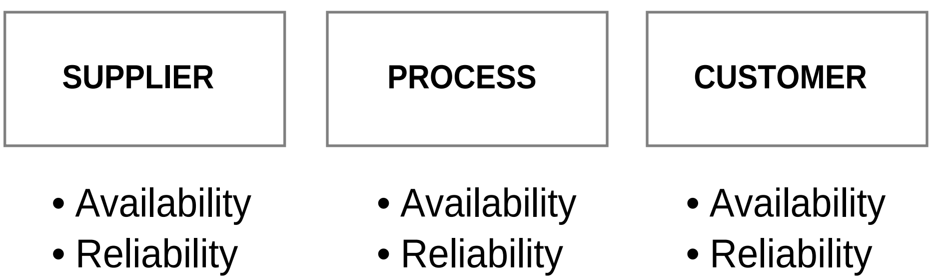

Figure 22 - The Six Basic Metrics

2. MEASURE AND ANALYZE THE PROCESS. The process COPIS identifies three different types of metrics used in performance measurement: Supplier Metrics, Process Metrics, and Customer Metrics. There are two metrics which can be developed for each type which are vital to knowing the overall health of a process. In customer satisfaction, the area of availability (Do I get it when I need it?) and reliability (Does it work as intended when I get it?) reflect the key customer requirements. Within the process, these same areas determine how well a process is working. Process measures focus on the availability (How much can I produce for the customer?) and reliability (How much confidence do I have in the process?). Supplier availability focuses on the availability of the supplier to meet my needs as far as delivery (Do I get it when I need it?) and reliability (Does it work as intended once I get it?). So, there are six metrics which should help us to understand process performance from start to finish, as shown in Figure 23.

Are all six of these metrics sigma measurements? No. Only four of them are sigma measures. Remember the previous discussion on perspective. Your customers can't calculate a sigma level on customer metrics because they don't know the complexity of your process. Now, you know the complexity of your process, so you can apply that complexity to the customer metrics to calculate sigma. But, can you do the same with your supplier? No, because you don't know the complexity of your supplier's process. All you can give your supplier is DPU, then they will have to apply complexity to determine sigma level. That is, if they have sigma metrics. To recap; **Customer and process metrics can be measured in sigma while supplier metrics are measured in DPU (Figure 23)**.

Supplier	**Process**	**Customer**
Availability **Reliability** **(DPU)**	**Availability** **Reliability** **(σ)**	**Availability** **Reliability** **(σ)**

Figure 23 - Metric Measures

Just remember, sigma is useful in comparing similar processes of varying complexity. If you are not comparing / benchmarking with other processes, DPU is the measurement to use since DPU is the best measure of process performance.

Once metrics are established, measurements should be taken over time to assess process performance. Once you have enough data to determine process control, analyze it to determine process performance and capability. (If you are unsure of how to determine process control, refer to Air Force Handbook 90-502 "The Quality Approach", pp 107 - 122.) Establish current process performance level by analyzing all six process metrics for correlation and inter-relation. There are some questions you should ask at this point:

- What is the optimum operating sigma level of this process?
- Is this process operating at this optimum sigma level given the resources and manpower dedicated to it?
- Where are the opportunities for improvement in this process which will provide the best increases in efficiency and effectiveness?
- If there is a deficiency in the process, where is the root cause?
- Can deficiencies be corrected with existing resources in the process?
- Do the resources exist to increase the efficiency and effectiveness of the process to higher levels?
- Do I want / need to dedicate more resources to this process to improve it? If so, are those resources available? How do I obtain them?
- Is there a better area to invest improvement resources and manpower?

You should compare the different metrics of a process to identify the true operating nature of that process. Sigma measures should allow you to identify deficiencies in your process and trace them back to the root cause. Once you have identified the root cause of the deficiency, you're ready to move on to step 3, improving the process.

3. IMPROVE THE PROCESS. Once you've decided to improve a process, you must determine the best way to go about it. This is where the tools you have at hand come to good use. Select the best type of team to use for process improvement. Should it be a Process Action Team (PAT), a Natural Working Group (NWG), a Tiger Team, or maybe an Action Work Out? The choice is yours. Refer to Air Force Handbook 90-502 "The Quality Approach", for discussion on the best teams to use.

Once a team is formed, they should use process improvement tools available at their disposal to attack the process problems. The Wing Manpower and Quality office should be able to provide assistance on available tools, such as the 7-step Continuous Improvement Process (CIP) and analysis tools like histograms, cause-and-effect charts, flow charts, and pareto charts. These tools will help teams focus on reducing waste, cycle time, variation and defects.

4. STANDARDIZE THE IMPROVEMENT. Once improvements have been made to the process, ensure that regression doesn't take place by standardizing the new process. Develop continuity books on the new process. Train personnel on the new procedures. Make visual cues wherever possible to help in understanding the new way of doing business. Without standardizing the new process, regression will occur, resulting in higher defects and less efficient operations.

Identify, on the sigma metrics, where changes to the process were made. As time goes by and additional measurements are made, you will be able to identify improvements which were a result of your efforts. Do not start metrics over when a change is made. You are looking for improvement over time. When the process is established at its new operating level, you can again analyze for improvement, striving towards "Excellence in all we do."

Conclusion

Remember, Six Sigma is a system to be used in analyzing your processes, identifying defects, applying existing tools to reduce defects, then standardize the new process to prevent regression. Implemented properly, Six Sigma can help your organization cope and adjust with the fluid nature of today's military environment.

If you have any questions concerning this guide, its contents, or recommendations for improvement, please contact the ACC Quality and Management Innovation Squadron, ACC QMIS/XPIE at DSN 574-2050. Major Eric "Dome" Brenkert or Chief Master Sergeant Ed "The Man" Miller will be glad to assist you in your strive towards "Excellence in all you do."

EXERCISE 1 - ANSWERS

Process	Defect	# Defects	Unit	# Units	Opportunities for Error
Preflight Inspection	Worn/Defective Part Missed on Inspection	26	Each Inspection	46	67 Steps per Inspection
Injection	Incorrect Amount Incorrect Drug	2	Each Inspection	1050	2
Vehicle Checkout	Low Tire Pressure	3	Each Checkout	35	4 Tires

Process	DPU	dpmo	Sigma
Preflight Inspection	26 / 46 = .5652	(.5652 x 1,000,000) / 67 = 8436	3.88
Injection	2 / 1050 = .0019	(.0019 x 1,000,000) / 2 = 950	4.61
Vehicle Checkout	3 / 35 = .085	(.085 x 1,000,000) / 4 = 21,250	3.53

dpmo to Sigma Level Conversion Chart

Sigma Level - Hundredths

σ	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1.5	500000	496011	492022	488034	484047	480061	476078	472097	468119	464144
1.6	460172	456205	452242	448283	444330	440382	436441	432505	428576	424655
1.7	420740	416834	412936	409046	405165	401294	397432	393580	389739	385908
1.8	382089	378280	374484	370700	366928	363169	359424	355691	351973	348268
1.9	344578	340903	337243	333598	329969	326355	322758	319177	315614	312067
2.0	308538	305026	301532	298056	294599	291160	287740	284339	280957	277595
2.1	274253	270931	267629	264347	261086	257846	254627	251429	248252	245097
2.2	241964	238852	235762	232695	229650	226627	223627	220650	217695	214764
2.3	211855	208970	206108	203269	200454	197663	194895	192150	189430	186733
2.4	184060	181411	178786	176186	173609	171056	168528	166023	163543	161087
2.5	158655	156248	153864	151505	149170	146859	144572	142310	140071	137857
2.6	135666	133500	131357	129238	127143	125072	123024	121000	119000	117023
2.7	115070	113139	111232	109349	107488	105650	103835	102042	100273	98525
2.8	96800	95098	93418	91759	90123	88508	86915	85343	83793	82264
2.9	80757	79270	77804	76359	74934	73529	72145	70781	69437	68112
3.0	66807	65522	64255	63008	61780	60571	59380	58208	57053	55917
3.1	54799	53699	52616	51551	50503	49471	48457	47460	46479	45514
3.2	44565	43633	42716	41815	40930	40059	39204	38364	37538	36727
3.3	35930	35148	34380	33625	32884	32157	31443	30742	30054	29379
3.4	28717	28067	27429	26803	26190	25588	24998	24419	23852	23295
3.5	22750	22216	21692	21178	20675	20182	19699	19226	18763	18309
3.6	17864	17429	17003	16586	16177	15778	15386	15003	14629	14262
3.7	13903	13553	13209	12874	12545	12224	11911	11604	11304	11011
3.8	10724	10444	10170	9903	9642	9387	9137	8894	8656	8424
3.9	8198	7976	7760	7549	7344	7143	6947	6756	6569	6387
4.0	6210	6037	5868	5703	5543	5386	5234	5085	4940	4799
4.1	4661	4527	4396	4269	4145	4025	3907	3793	3681	3573
4.2	3467	3364	3264	3167	3072	2980	2890	2803	2718	2635
4.3	2555	2477	2401	2327	2256	2186	2118	2052	1988	1926
4.4	1866	1807	1750	1695	1641	1589	1538	1489	1441	1395
4.5	1350	1306	1264	1223	1183	1144	1107	1070	1035	1001
4.6	968	935	904	874	845	816	789	762	736	711
4.7	687	664	641	619	598	577	557	538	519	501
4.8	483	466	450	434	419	404	390	376	362	349
4.9	337	325	313	302	291	280	270	260	251	242
5.0	233	224	216	208	200	193	185	178	172	165
5.1	159	153	147	142	136	131	126	121	117	112
5.2	108	104	100	96	92	88	85	82	78	75
5.3	72	69	67	64	62	59	57	54	52	50
5.4	48	46	44	42	41	39	37	36	34	33
5.5	32	30	29	28	27	26	25	24	23	22
5.6	21	20	19	18	17	17	16	15.3	14.7	14.0
5.7	13.4	12.9	12.3	11.7	11.3	10.8	10.3	9.9	9.4	9.0
5.8	8.6	8.5	7.9	7.5	7.2	6.9	6.6	6.3	6.0	5.7
5.9	5.4	5.2	5.0	4.8	4.6	4.4	4.2	4.0	3.8	3.6
6.0	3.4	3.3	3.1	3.0	2.9	2.7	2.6	2.5	2.4	2.3

Note: Values in this table account for a +/- 1.5 sigma