



STATISTICS

Our Place-Kicker Is Out of Control!

by **Brion Hurley**

After completing my football eligibility at the University of Iowa in 1996 and graduating with a bachelor's degree in statistics, I bounced around between NFL training camps and arena football leagues dur-

In 50 Words Or Less

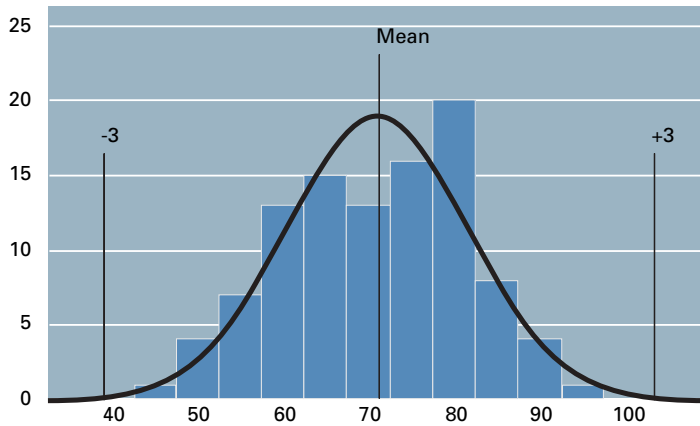
- Some of the best companies are modeled after the likes of legendary coaches John Wooden and Vince Lombardi.
- Most successful sports organizations perform data collection, root cause analysis and statistical process control.
- Learn how to use these tools to rate two place-kickers.

ing the summer months while completing my master's degree in quality management. I was a place-kicker and punter, and there was not a lot of job security in those positions. Instead of applying root cause analysis when a kicker started missing field goals, most teams applied the standard quick fix: "Get rid of the kicker!"

So I decided to get a real job. After spending a few years helping various product improvement teams work through their business problems, I began to see how these same problems existed in my day-to-day life—especially in my kicking and punting, which I had spent nearly 20 years trying to continuously improve.

Being a good quality practitioner, I collected data to better understand where I was and where I needed to be in my place-kicking. It was a perfect example: The goalposts represented engineering limits, and the location of the kicks when they crossed through the uprights represented the process performance. Maybe someday more points will be awarded for being closer to the target, but for now, anything that

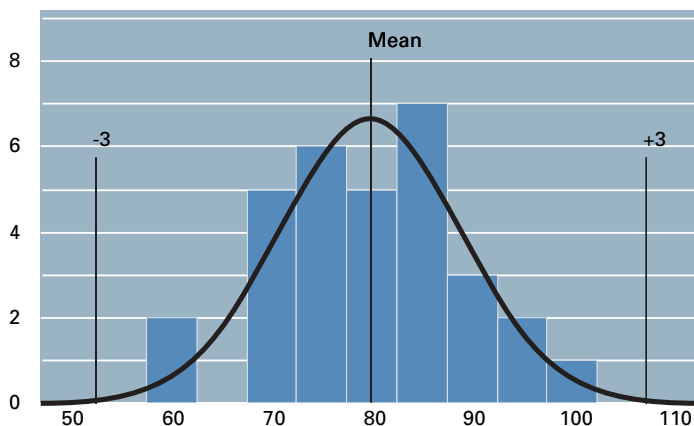
FIGURE 1 2003 NCAA Field Goal Percentages



Samples: 102
Mean: 71.1008
Standard deviation: 10.701
Skew: -0.16448
3 sigma process limits: (38.997, 103.2)

Each sample equates to the field goal percentage of an NCAA Division 1 kicker with at least five field goal attempts.

FIGURE 2 2003 NFL Field Goal Percentages



Samples: 31
Mean: 79.9042
Standard deviation: 9.1563
Skew: -0.0080765
3 sigma process limits: (52.435, 107.37)

passes between the uprights is acceptable and worth three points, and anything outside or under the uprights is unacceptable and considered a defect.

Not As Accurate As You Might Think

I wanted to know if my kicking process was stable, if I had good capability and what C_p/C_{pk} was acceptable for place-kicking. Here's how C_p and C_{pk} relate to place-kicking:

- The process potential index or C_p measures a process's (kicker's) potential capability, which is defined as the allowable spread (goal post distance) divided by the actual spread (variation in kicks). The allowable spread is the difference between the USL (upper specification limit) and the LSL (lower specification limit). And the actual spread is determined by the process data (kick results) collected in the study and is calculated by multiplying six times the standard deviation, s , of the process (kick results).

$$C_p = \frac{USL - LSL}{6s}$$

- The process capability index or C_{pk} measures a process's (kicker's) ability to create results (kicks) within given specification limits (goal posts). C_{pk} represents the difference between the actual process average and the closest specification limit divided by the standard deviation, s , times three. The higher the C_p or C_{pk} , the better the process for falling within the specification limits.

$$C_{pk} = \text{minimum} \left(\frac{USL - \text{mean}}{3s}, \frac{\text{mean} - LSL}{3s} \right)$$

In most business processes striving for 6σ performance, the minimum goal is a process with less than 63 defects per million opportunities ($C_{pk} = 1.33$, centered,

COLLEGE BALL: The author at the University of Iowa in 1995.

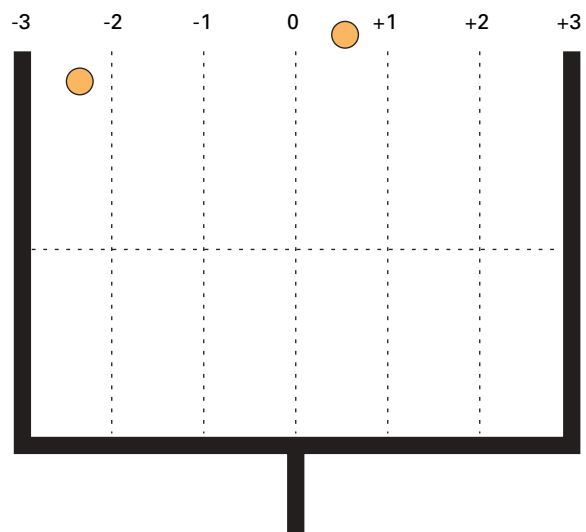


with no shift). In football place-kicking, a missed field goal would be considered a defect. Obviously, 63 misses out of 1 million is a bit unrealistic, as even the best NFL kickers make only about 90% of their kicks.

Based on the typical statistics for a high school or college kicker, 90 to 95% success on field goals in a practice setting is usually pretty good. This is closer to a C_{pk} between 0.5 and 0.7, which is far less than the minimum goal of 1.33. When you factor in the variables that can occur in a game situation, such as weather, snap location, held ball angle, fan noise, nerves, ball variation, ball placement variation, distance and angle from target, a kicker's percentage can drop to between 70 and 80%, which computes to a C_{pk} of about 0.25. This is average for college kickers (see Figure 1). The percentage for NFL kickers, however, is usually between 80 and 90% (see Figure 2) and computes to a C_{pk} between 0.3 and 0.6.

If you are familiar with C_{pk} values, you know these numbers are poor. But they're not as bad as the C_{pk} 's for other sports, such as shooting percentages in basketball, hits per at bat in baseball or, even worse, goals per shots on goal in hockey. Obviously, 6σ is not a reasonable goal for game outputs in most sports, but the concepts used to continuously improve toward that level of performance are the still same.

FIGURE 3 Goal Post Scoring Chart



The values -2.3 and +0.5 are shown on the chart.

My Personal Results

To calculate C_{pk} , I needed to plot the location of my kicks within the uprights as they crossed over the bar. To make it easier, I arbitrarily divided my data sheet into six sections, with three on each side of the target (see Figure 3). My recorded value was



an approximation of the section's distance from the target.

For example, my limits were set at -3 and +3, and the target was set at 0. If my kick crossed at the first section on the right of the target, I recorded +1.0 as my result. If it crossed within the second section on the left of the target, I recorded a -1.5.

Obviously, the results were subjective, and the measurement variation was high, so I personally recorded the location of all my kicks to reduce the impact of these variables (see Figures 4 and 5).

As you can see, my kicking process is stable (see Figure 4), but I don't have a perfectly normal distribution (see Figure 5). I need to take a closer

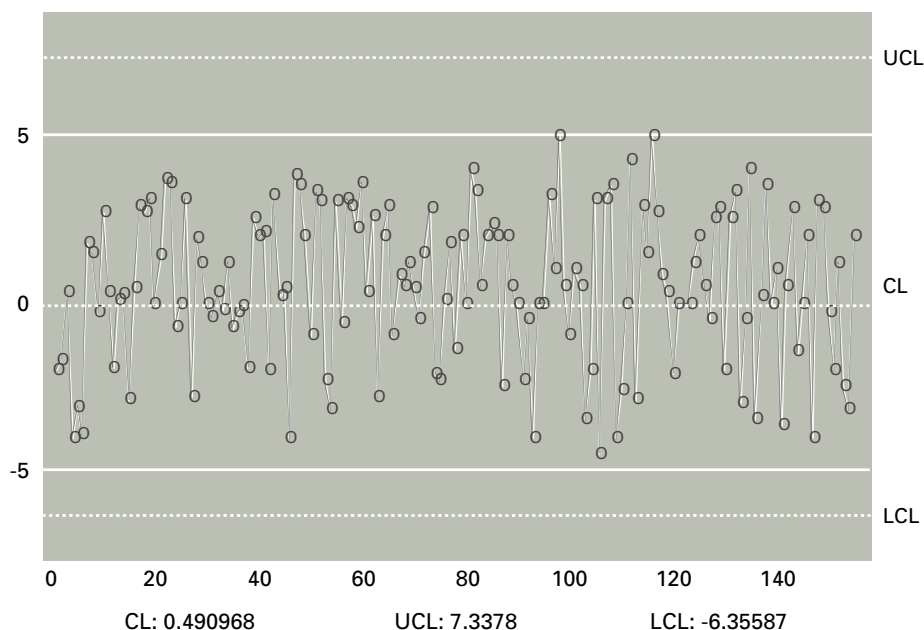
look at some outliers and consider the fact my average kick location is off target. I need to make a process change to align my kicks closer to target, and I definitely need to further investigate the high peak near the right upright. Clearly, this information could be very valuable to a kicker and his coach.

How To Compare Kickers

My next question was, "How do I compare to other kickers on my team?" This is a question every coach must deal with when more than one kicker is competing for the job.

In the past, the only way to compare kickers was to look at their percentage of success (yield). If they had the same opportunities for

FIGURE 4 Individuals Control Chart Showing Deviation From Target



UCL: upper control limit.
LCL: lower control limit.
CL: control limit.

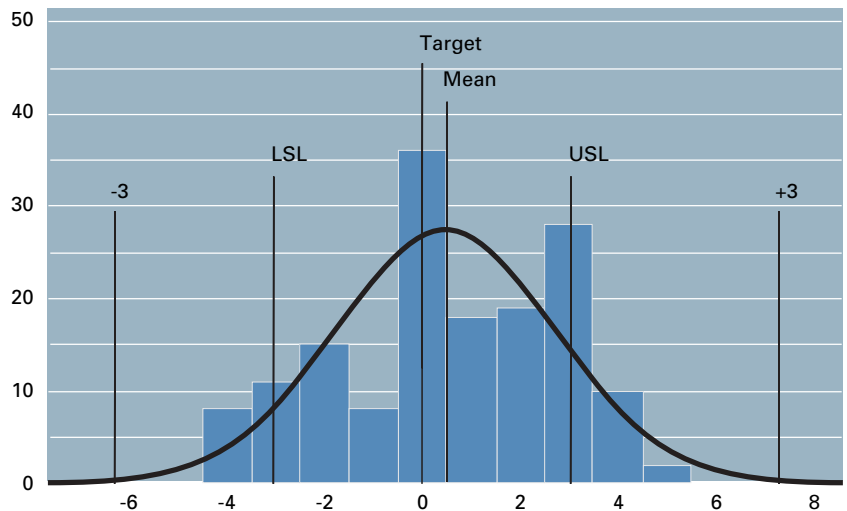
success at similar distances, angles and situations, then that's the percentage that was used to make a decision. Unfortunately, too much information is lost when attribute (pass/fail) data are used instead of variable or measurement data.

By collecting detailed information about each kick, I will show how coaches can make better personnel decisions (who should be the starter) and get a clearer understanding of the changes needed to improve an individual's performance.

I decided to use a couple of local high school kickers, John and Tom, to perform my simple comparison test. I originally planned to have them both kick the same kicks on the same field on the same day. Unfortunately, I was forced to record their results on separate days, but I did keep the distance and angles of the kicks relatively the same.

Did that introduce some additional variables into the experiment? Sure, but due to the nature of the position, it was important to include the location and distance variables to give a pure picture of the kickers' abilities and best represent the range of abilities needed in a

FIGURE 5 Histogram of the Deviation From Target For Field Goal Attempts



Samples: 551
Mean: 0.490968
Standard deviation: 2.266
Skew: 0.2962
C_{pk}: 0.3691
C_p: 0.4413
C_{pm}: 0.4312
USL: upper specification limit.
LSL: lower specification limit.

3 sigma process limits: (-6.3069, 7.2888)
Target: 0
Specification limits: (-3, 3)
Estimated percentage outside of specifications: (6.1705, 13.409)

Each sample equates one kick attempt.

real game. The target location on any kick attempt was the same—centered between the uprights—so I don't believe the variables were a major concern. If I held everything constant, I might have established an unrealistic prediction of their abilities in a game situation.

Who's the Better Kicker?

I decided to have John and Tom attempt 30 kicks each to give me enough data for a good comparison test, and I used the previous scoring system to record the results (see Table 1).

Based on a visual comparison of the two, it was difficult to tell who performed better

TABLE 1 Summary of Deviation From Target Results

	John	Tom
Mean	0.71	-0.2
Standard deviation	1.36971	2.35726
Variance	1.8761	5.55666

TABLE 2 Comparison of Variances (F-Test Ratio)

	John	Tom
Standard deviation	1.36971	2.35726
Variance	1.8761	5.55666

Ratio of variances = 0.337632

95% confidence intervals

Standard deviation of John: [1.09085, 1.84132].

Standard deviation of Tom: [1.87733, 3.16889].

Ratio of variances: [0.160701, 0.709363].

F-test to compare standard deviations

Null hypothesis: $\sigma_1 = \sigma_2$.

Alternate hypothesis: $\sigma_1 \neq \sigma_2$.

F = 0.337632; p-value = 0.00462187.

(see Figures 6 and 7). Tom was closer to target (mean = -0.2, where 0.0 is ideal), but had more variability ($s = 2.36$). John had a larger deviation from target (mean = 0.71), but less variation ($s = 1.37$). I also looked at the C_p and C_{pk} values to determine who was better. Tom had a C_p of 0.424 and a C_{pk} of 0.396, while John had a C_p of 0.730 and a C_{pk} of 0.557. Based on the standard deviation and C_p/C_{pk} calculations, I determined John was the better kicker.

As with most business processes, reducing variation is key. The same is true for place-kicking. The less variation, the more consistent the place-kicker. It is much easier to realign a place-kicker to a new target line than it is to reduce variability in his steps, approach speed, approach angle, foot placement and leg swing.

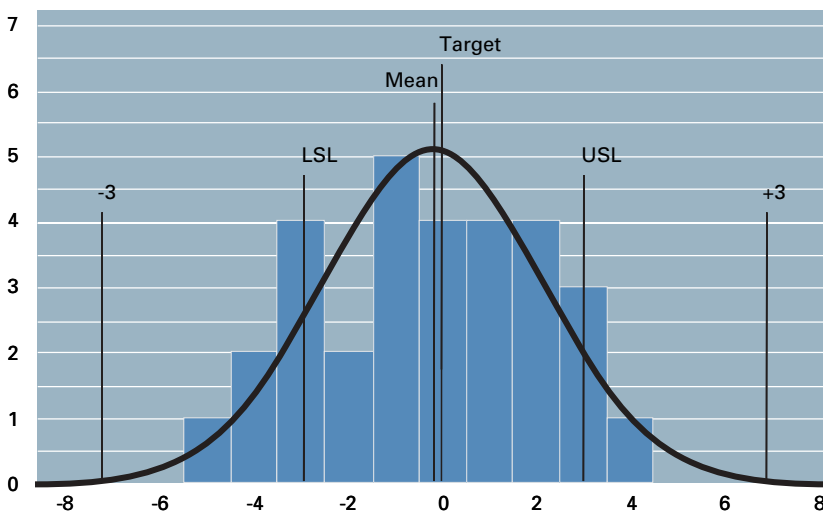
I then performed an f-test against John and Tom's variances to see if that difference was significant (see Table 2). An f-test compares the variances (squared standard deviations) of each kicker to see if the ratio (John's variance/Tom's variance) is significantly different from 1.0 (the ratio if both variances are equal).

The results showed a significant difference between the variances of the two kickers (a p-value of 0.0046 is less than 0.05). I would recommend their coach choose John as the kicker because his variation was smaller, but John should work to realign his kicks more to the left, which would bring them much closer to target. Tom should keep the same alignment to his target, but he should work on reducing special causes in his kicking process through practice and concentration.

Other Uses

I made my recommendation after looking at the results after one day, but what if Tom was more consis-

FIGURE 6 Histogram of Tom's Deviation From Target



Samples: 30

Mean: -0.2

Standard deviation: 2.3573

Skew: -0.085562

C_{pk} : 0.3959

C_p : 0.4242

C_{pm} : 0.4227

USL: upper specification limit.

LSL: lower specification limit.

3 sigma process limits: (-7.2718, 6.8718)

Target: 0

Specification limits: (-3, 3)

Estimated percentage outside of specifications: (11.745, 8.7309)

tent day-to-day, or John had a great performance the day of the competition, but his performance was erratic after that?

I might have ended up making a decision that would not be ideal in the long run. To prevent this problem and monitor the kickers' performance over time, I could input the data on a control chart. In this case, John's control chart would show a trend or shift in his performance, and Tom's would show stable results over time.

But what if John was made starting kicker at the beginning of the season, and midway through he started to pick up bad habits, forcing kicking out of control? A control chart would likely see the trend, and the coach could make a position change before John missed a kick in a game. The coach would be able to use data instead of instinct and gut feelings to support a position change and prevent a poor performance from happening in a game.

Similar analysis can be performed on a punter's hang time (time between when the ball leaves the foot and when it hits the ground or is caught) and punt distance (yards landed from the line of scrimmage). When a control chart for hang time in seconds goes out of control on the high side, the coaching staff can state a significant improvement (see Figure 8, p. 66). Coaches can also create Pareto charts for defect types, such as mishandled snap, poor snap, inside drop or outside drop. The possibilities for using statistical process control and basic quality improvement tools in these applications are endless.

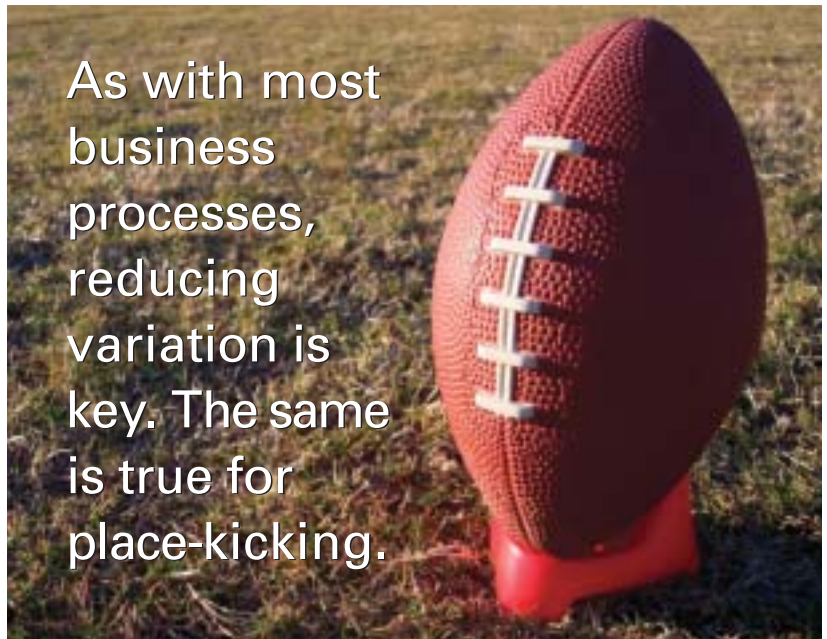
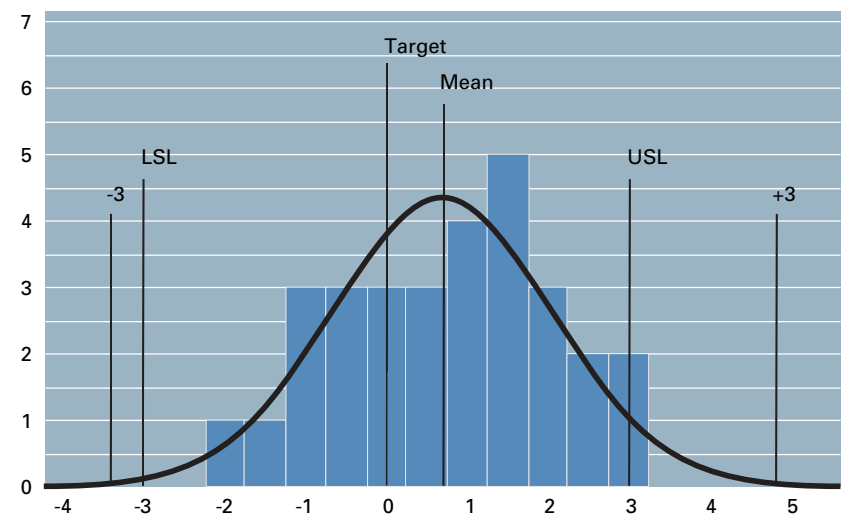


FIGURE 7 Histogram of John's Deviation From Target



Samples: 30
Mean: 0.71
Standard deviation: 1.3697
Skew: -0.20493

C_{pk} : 0.5573
 C_p : 0.7301
 C_{pm} : 0.6458

USL: upper specification limit.
LSL: lower specification limit.

3 sigma process limits: (-3.3991, 4.8191)
Target: 0
Specification limits: (-3, 3)
Estimated percentage outside of specifications: (0.33784, 4.7273)



TABLE 3 Application to Other Sports

Sport	Measurement	Limits	Application	Usefulness
Volleyball and tennis	Distance above the net per serve.	Top of net (one sided).	Mark balls with chalk, and serve against wall with net line identified.	Predict percentage of serve errors that hit the net.
Baseball	Distance from middle of strike zone.	Strike zone (width of home plate).	Record location of pitch within strike zone limits, always aiming for center target.	Predict accuracy of being able to hit a target location.
Basketball and football	Distance from middle of teammate's chest when passing the ball.	Average player's chest width.	Mark balls with chalk, pass ball against wall with target identified.	Predict which players are best at passing the ball.
Hockey and soccer	Distance from middle of goal.	Goal net posts.	Mark puck with chalk, shoot against target location.	Predict those with best shooting accuracy.

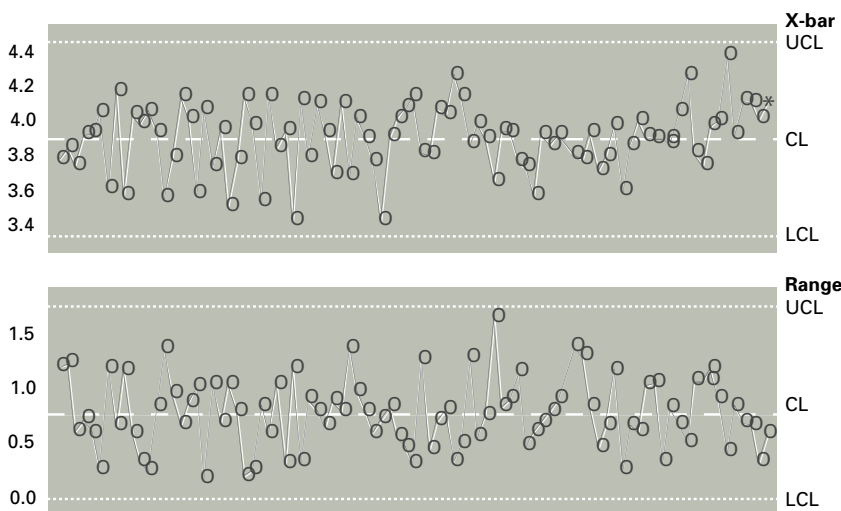
As future athletes become bigger, faster and stronger, a greater emphasis will be placed on using statistical techniques to better understand how sports athletes perform and provide teams

with the extra edge they are always looking for. Table 3 shows how other sports could easily apply these types of analyses, even at the youth level.

NOTE

All histograms and control charts were generated with Northwest Analytical Quality Analyst 5.2, www.nwasoft.com.

FIGURE 8 X-bar and R Chart of Punting Hang Times by Date and Direction Grouping



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Please comment

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Date: 06/05/03 06/05/03 06/12/03 07/03/03 08/07/03 07/10/03 08/14/03 08/14/03
X-bar: CL: 3.89702 UCL: 4.45847 LCL: 3.33557 **UCL:** upper control limit.
Range: CL: 0.770682 UCL: 1.75861 LCL: 0 **CL:** control limit.
LCL: lower control limit.

The X-bar chart shows an out of control condition, which means a positive improvement in hang time has occurred. This improvement was the result of private instruction provided to John once a week over the summer.