Implementing Performance Trending at Two Department of Energy Sites - 9330

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ABSTRACT

This paper documents implementing performance trending at two U.S. Department of Energy (DOE) sites – Hanford and Savannah River. Using Statistical Process Control (SPC), Fluor has improved the usefulness and application of performance analysis and trending at both sites.

Fluor's 12-year tenure as a primary contractor at Hanford is ending and is just beginning at Savannah River. In August 2008, Savannah River Nuclear Solutions (SRNS), a limited liability company, involving Fluor, assumed responsibility for the management and operations scope at the DOE's Savannah River Site (SRS). The two sites were constructed by DuPont to produce weapons-grade nuclear material for national defense: Hanford, in the 1940s; SRS, in the 1950s.

Fluor's application of SPC at Hanford contributed to significant improvements in safety and quality, higher credibility with the DOE customer, and national recognition by several professional societies. Fluor is applying SPC at SRS based on its experience at Hanford and is expecting the same positive results.

Statistical Process Control, trending, and a systems approach to safety and operational excellence have provided great success at Hanford, and similar success is anticipated at Savannah River. These tools and principles form a connecting thread to provide an integrated approach to the maintenance of, and improvement in, waste-management performance.

INTRODUCTION

Statistical trending of safety, quality, and occurrence data continues to play a key role in improving safety and quality at what has been called the world's largest environmental cleanup project. DOE's Hanford Site played a pivotal role in the nation's defense beginning in the 1940s, when it was created as part of the Manhattan Project. After more than 50 years of producing material for nuclear weapons, Hanford, covering 586 square miles in southeastern Washington state, is now focused on three outcomes:

1. Restoring the Columbia River corridor for multiple uses
2. Transitioning the central plateau to support long-term waste management
3. Putting DOE assets to work for the future.

The current environmental cleanup mission faces challenges of overlapping technical, political, regulatory, environmental, and cultural interests. On October 1, 2008, a contract transition occurred changing the structure and role of Fluor Hanford, Inc. (Fluor Hanford). Currently, Fluor is a subcontractor to the CH2M HILL Plateau Remediation Company (PRC). At the time of this writing, Fluor is maintaining half of its original scope awaiting determination of the contractor for the Mission Support Contract (MSC).

The emphasis has to be on doing work safely, delivering quality work, controlling costs, and meeting deadlines. Statistical support is provided by Fluor to the PRC, the MSC, and a third contractor, Washington Closure Hanford.

This presentation will focus on the key elements of a statistical performance-trending program. It will include the benefits of using SPC as the statistical tool of choice, basic information on constructing a control chart, the process for establishing a baseline, and the method for identifying a trend. Additional topics include Management's use of SPC to detect and act on trends, and differentiate areas that have been stable ~~and~~ **from** those that need improvement. The presentation will demonstrate a performance-improvement model covering the entire life cycle of performance measure development and trending.

Robert W. Campbell Award

In September 2008, Fluor Hanford was awarded the Robert W. Campbell Award. After undergoing a rigorous review and assessment process, Fluor Hanford accepted the Council's international award for business excellence through environmental, health, and safety (EHS) management on Monday, September 22 during the National Safety Council's 96th Annual Congress & Expo in Anaheim, California [1]. Co-sponsored by Exxon Mobil Corporation, the Campbell Award recognizes organizations that demonstrate how integration of environmental, health and safety (EHS) management into business operations is a cornerstone of their corporate success. The review team carefully looks at performance metrics and their use in EHS and in the company's business. The review team was favorably impressed with Fluor Hanford's implementation and use of SPC as part of its performance metric program. This prestigious award provides validation of the worth of SPC in monitoring and managing performance.

STATISTICAL PROCESS CONTROL

Statistical Process Control was developed by Dr. Walter Shewhart [2] in the 1930s. In the past 75 years, several refinements were added, and the use of the desktop computer has made SPC fast, effective, and inexpensive. Dr. W Edwards Deming [3] was a proponent of the use of SPC. Dr. Don Wheeler [4] is a current author of many fine books related to SPC.

A simple SPC chart, or "control chart" is shown in Figure 1. The data are plotted as they occur in each time interval. Each time interval is independent from the others; there is no averaging or running total of the data.

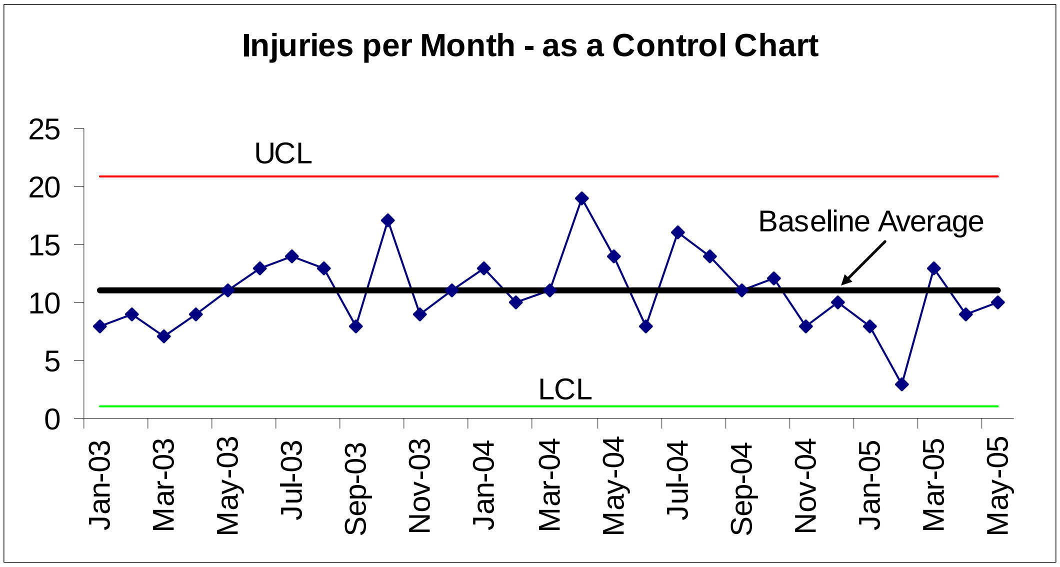

Fig 1. An Example Control Chart

The baseline average is the average (mean) of the data on the chart. It is the "center line" for the chart. The UCL is the Upper Control Limit. It is plotted at the average plus three times the standard deviation of the data. The LCL is the Lower Control Limit. It is plotted at the average minus three times the standard deviation of the data. The average and control limits become the prediction of future performance. As long as nothing changes with the process, then future results will be between the values of the UCL and the LCL, and center about the average. The average and control limits are predictions that are left locked in place until a statistically significant change occurs. Their values are not changed by plotting further data.

Detecting a Change

Specific rules are applied to detect a statistically significant change. Some rules detect a short term, but large deviation change. Other rules detect more subtle changes, but they must be in effect for a longer period of time. Rules vary slightly from author-to-author. Fluor uses the rules in Table I for its control charts [5].

Table I. Rules for Detecting Trends on a Control Chart

One point outside the control limits
Two out of three points two standard deviations above/below average
Four out of five points one standard deviation above/below average
Seven points in a row all above/below average
Ten out of 11 points in a row all above/below average
Seven points in a row all increasing/decreasing.

The trending rules are used as feedback to the workers. A trend in an adverse direction is used as a trigger to investigate and implement corrective action. A trend in the improving direction provides feedback that previous interventions have taken effect. If the trend permanently shifts performance, a new baseline average and new control limits are established. For more detailed information on SPC, trend rules, and control charts, please see the *Hanford Trending Primer* [6]. The Hanford Website also contains training materials helpful toward implementing an SPC-based trending program. These materials are available at http://www.hanford.gov/rl/?page=1156&parent=1144 [7].

Trending

There are many legal and business requirements for trending performance data. More than 80 U.S. Department of Energy requirements documents call for trending of data [8]. The Integrated Safety Management System requirements call for line managers to "watch carefully for adverse trends or indications, and take prompt action to understand adverse trends and anomalies." [9]

The question is, what is a "trend" and how should it be detected? If performance data are plotted from month to month, it is highly unlikely that the number would be the same every month. In fact, most managers would be highly suspicious of a report that stated there were exactly three injuries every month, 24 work packages completed every month, etc. Managers expect that the number will change. Yet, what change in quantity constitutes an indication of an adverse change that requires action? In an SPC-based program, a list such as Table I provides a "black and white" definition of a trend.

SPC Trending Program Overview

The overall view of a SPC trending program cycle is depicted in figure 2 [7].

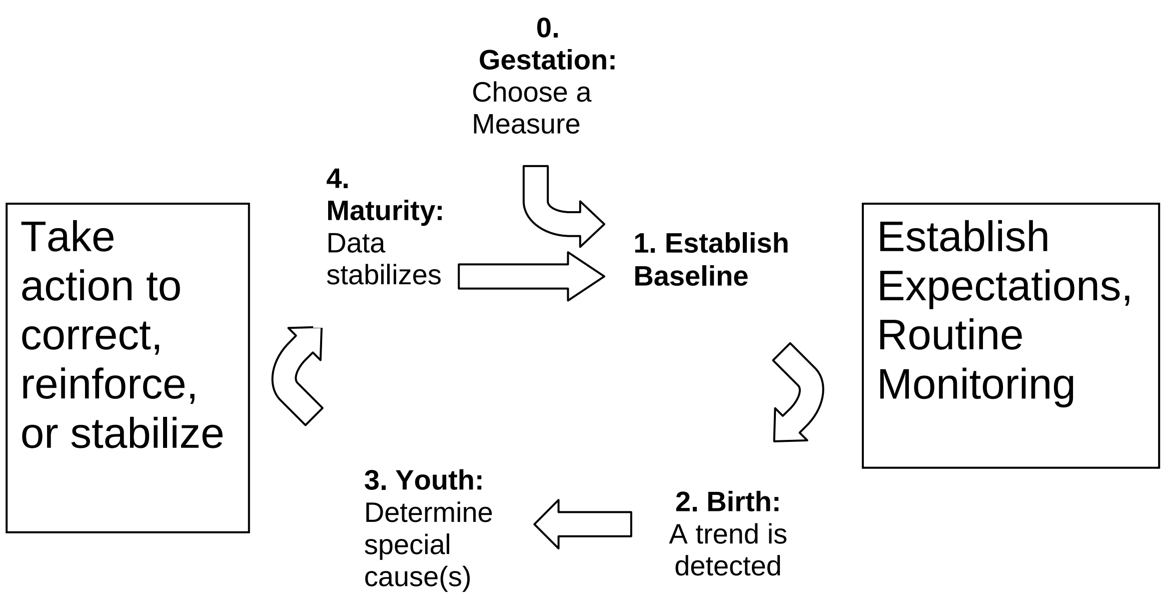

Fig 2. Trending Program Overview

The first activity is to choose what to measure (step 0 in Figure 2). Many organizations struggle with this, and never actually start measuring anything. Table II below provides a means for getting started with measurement activities.

Table II. Questions to Help Determine What to Measure

What is the organization's mission and vision? What are desired outcomes? How can these be measured?
Who are the organization's customers? What is important to them? Can it be measured?

How is the organization conducting business? What processes are used?
For each process, consider inputs, budget, outputs, schedule, cycle time, compliance, scrap and rework.
What data are the organization already collecting? Can it be put to use to support an item above in this table?

Once some measures are chosen (and these may be refined with time, one does not need to be perfect the first time), data sources need to be defined and the data collected. In many cases, the data may already be readily available. In other cases, new systems for collecting data may need to be established.

When the data are collected, an SPC control chart is established (step 1 in Figure 2). The baseline average and control limits are calculated and set in place. There are then several questions to answer. First, is the performance stable? If not, action may be needed to stabilize the process, or continue any improving trends. If the performance is stable, is it stable where management desires it to be. If improvement is needed, this goal should recorded, announced, and actions to change the underlying process are made. Long-term results from the process should be reviewed and analyzed. Pareto charts such as Figure 3 below help determine what needs improvement. Dr. Deming referred to problems related to stable processes as “Common Causes”.

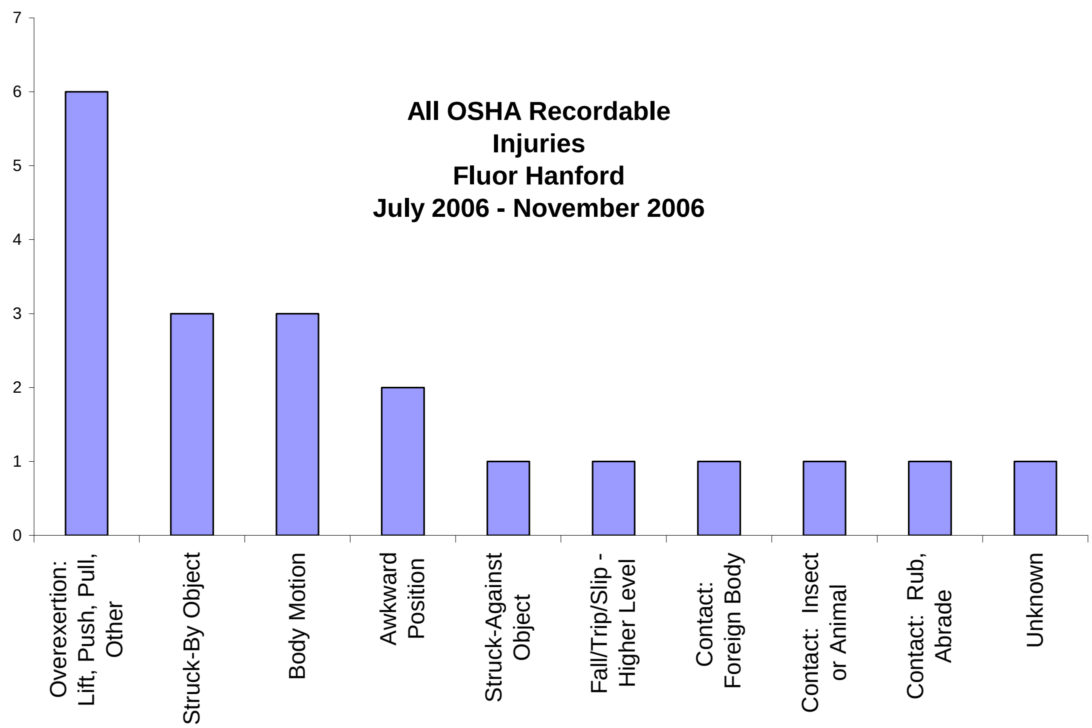

Fig 3. An Example Pareto Chart

One may need to consider benchmarks of others, customer desires, and risk management in order to determine if improvement is needed. Both the baseline average and control limits should be considered. Note that the control limits represent “worst case” results, and can be used as part of risk planning and evaluation.

Either due to actions taken as part of process improvement, or due to external influences, a trend may arise (step 2 in Figure 2). A trend is defined as a pattern of data matching one or more requirements in Table I. When a trend is discovered, the organization should determine what is the impact of the trend (adverse, improving, or no effect). Many times a trend in an adverse direction represents increased risk, and the SPC-based trend program can reinforce the organization's risk management program.

If the trend needs action, causes of issues during the time interval of the trend should be analyzed (step 3 in Figure 2). Short-term Pareto charts (matching the time interval covered by the trend) may be of assistance in isolating the causes of the trend. Dr. Deming referred to such causes as "Special Causes."

Once the trend ends (either on its own, or due to actions taken) a new baseline average and control limits may need to be calculated (step 4 in Figure 2). On some occasions, performance may return to the previous baseline, and the previous baseline average and control limits may be brought forward. Otherwise, a new average and standard deviation should be calculated and plotted.

The new baseline average and control limits should then be reviewed to determine if the stable performance is sufficient, or if improvement is needed (back to step 1 in Figure 2). Thus, a cycle of continual improvement is established.

Technical Advantages of SPC

Statistical Process Control is one of the easiest statistical tools for identifying trends, and is displayed in a graphical method. There are other statistical tools such as tests of hypothesis and Analysis of Variance (ANOVA) that provide a "level of significance" as to whether data patterns are significantly different or not. However, their results are difficult to interpret by a non-statistician, and are a set of tabulated numbers. Regression analysis (commonly known as "least square fit") can supply a statistical evaluation IF confidence and predication intervals are calculated for the fitted curve. However, these calculations are difficult, and most software (including Excel) only provides the fitted line or curve, and not the prediction intervals. Moving averages (as discussed later) do not offer any statistical criteria separating trends out from random noise. "CUSUM" control charting can be mathematically superior to SPC [10], but the technique is quite complex, and requires a trained statistician.

SPC GENERATES SUCCESS

Fluor successfully implemented SPC at Hanford from 1996 to 2008. This approach provided the foundation for success in the DOE Voluntary Protection Program and the DOE Integrated Safety Management System. SPC also improved Hanford management's ability to detect and address emerging issues and constantly improve existing performance. Presentations and articles on the 12-year effort by Fluor Hanford to reduce its OSHA occupational injury rate to less than one case per 200,000 hours have been published in the proceedings of previous Waste Management conferences, the American Society for Quality, and the American Society of Safety Engineers. Training on the methods used by Fluor Hanford has been provided to Bechtel, AREVA, Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, and the University of Washington. In December 2007, the Institute of Nuclear Power Operations reprinted Fluor's "Hanford Trending Primer" [6] as part of a "Best Practice" [11] for performance analysis to its members.

IMPLEMENTATION OF SPC

Statistical Process Control implementation is not difficult, but can be challenging. In 12 years [12] Fluor Hanford went from the statement "We don't know why Westinghouse [predecessor to Fluor at Hanford] employed a statistician, Fluor doesn't do statistics" to the robust, award-winning performance metrics program in place today.

Lessons Learned from Fluor Hanford

The use of SPC in managing the Hanford Site led to many successes for Fluor Hanford. Last year's WM 2008 presentation [13] documented positive comments by the US Department of Energy Headquarters, and by a DuPont safety review team. More than a dozen presentations were made in 2008 to a variety of DOE and professional groups on Fluor's use of SPC, often with standing-room only audiences.

The initial implementation of SPC at Fluor Hanford presented challenges. Much of the story was told in Reference 12. Six years were required to reach a level of acceptance for control charts in Occupational Safety and in Quality. During the implementation, there were several cases of taking a few steps backwards in order to take many steps forward. A "management assessment" concluded that SPC was not appropriate in "all cases." This led to a temporary use of dashboard charts plotting the recent month's result against numerical targets. This methodology was used within the DOE complex [14]. After one year, the dashboard charts were returned to the control chart format. The failure of the alternative methodology actually strengthened the final case for SPC.

Similarly, a new Vice President called for moving averages for project safety rates. The existing SPC charts were discarded, replaced with 12-month moving averages. Again, within a year frustration grew with the moving averages. The incoming Vice President could not explain to senior management why the moving averages moved the way they did. Some of the frustration was in the natural random noise of the safety data. Another source of frustration was the failure to realize that the current moving average moves upwards if the new month's datum is higher than the month 13 months ago (which falls off the moving average). Similarly, if the new month is lower than the one 13 months ago, the moving average moves downward. Many times, the previous month was higher than the current month, but the moving average moved upwards as the datum from 13 months ago was lower than the current month.

The use of moving averages is very common in the DOE complex and in business. Yet, moving averages perform very poorly against SPC in two regards:

1. The moving average does not have distinct criteria for flagging a trend. The moving average is always "moving" − what signifies a movement needing action and what is just a "normal" movement.

2. A 12 month moving average simply compares the result from 13 months ago to the current result.

Rigor - Positive and Negative Effects

Fluor Hanford's client, the U.S. Department of Energy, has been impressed with the rigor of the trending analysis products they receive (Reference 13 SP-44 comments). Paradoxically, the perceived level of rigor has on occasion been used as a negative issue towards SPC. One comment received over time was that SPC was too difficult, and only a very small number of people in the country can perform SPC. The response is that any college degree in statistics, industrial engineering, or operations research will include courses in Statistical Process Control. Dr. Deming said [3] that statistical talent is rare, but it is not unobtainable. In the summer of 2007, the Fluor Hanford statistician was assigned a summer intern who had completed his freshman year in Mathematics. Within a few weeks, the intern was performing SPC, and through the summer did half of the statistician's work. With the proper training and oversight by a qualified statistician, most of the SPC production can be accomplished by non-statisticians.

Another potential false impression of the rigor of SPC is cost. Fluor Hanford has found that implementing SPC usually reduces costs, as the chart format and construction becomes standardized. If the data in question are already being collected and entered into a computer database, the additional cost of construction of an SPC chart is minimal − less than 30 seconds per chart update.

Questions from attendees at other presentations of the Fluor trending system have shown some level of the attendee being overwhelmed with the apparent rigor and complexity of the complete system Fluor has evolved over 12 years. These observers need to understand they are observing the final product that was created in phases over the course of the 12 years. Many observers are already collecting data in databases, but not putting it to use in trending and management decision-making. Such observers could learn from the Fluor lessons stated here, and implement an efficient and effective SPC based trending system within a short period.

CULTURE CHANGE

Implementing SPC, and the thinking that accompanies it, is a culture change. To some managers, it represents a loss of control. Many mangers are comfortable providing explanations of the previous month's results, yet the control chart may point out that each month's result is stable, and the differences being explained are simply random noise. Replacing the narrative reports with SPC may represent a perceived loss of control by the affected managers accustomed to explaining the most recent results, thereby demonstrating their knowledge of the results.

Monthly reports with control charts move away from explaining the most recent results to determining if the data are stable or if there is a trend. If there is a trend, what actions are being taken because of the trend? If the data are stable, does the process need to be improved? If the process needs to be improved, what is being done to improve the process?

The Red Bead Experiment

One tool that proved to be of great benefit to implementing SPC at Fluor was Dr. Deming's Red Bead Experiment [15]. The Red Bead Experiment is a hands-on exercise that physically demonstrates the advantages of using SPC for data analysis, among many other leadership lessons.

The "Experiment" uses six volunteers from the audience to act as "willing workers". Each willing worker is tasked to make white beads from an incoming bead supply. They dip a paddle with 50 depressions in it in order to collect 50 beads. Unfortunately, there are defective red beads in the incoming bead supply. The willing workers are told to avoid the red beads and make only white beads. As the experiment proceeds, workers are provided a target (make three or less red beads), a "worker of the day" is identified (best person at making white beads), a worker is put on probation (worst person at making white beads). Later, results from worker to worker and day to day are compared. After a few "days" of production, the workers are provided a performance appraisal and ranked from best to worst. Finally, all of the below average workers are fired, and production continues with the best workers.

Although many of the actions taken during the Experiment are typical management techniques, no action taken changed the mix of red beads in the incoming bead supply. There always will be a "best worker" and a "worst worker," but the cause behind that difference is simply random noise, or "common cause variation" as Dr. Deming put it.

The initial rollout of Red Bead Experiments happened at three workshops held for Hanford workers and managers as part of Integrated Safety Management System (ISMS) implementation at Hanford in 2000. One of the sessions was videotaped and made available in the Hanford library, and the tape has generated a moderate amount of sales to personnel outside of Hanford.

The connection to humor and emotions with the Red Bead Experiment helped to overcome the fear and anxiety of the technical issues behind SPC. Without the series of Experiments in 2000, Fluor Hanford would still be debating the technical merits and demerits of implementing SPC.

PATH FORWARD AT SAVANNAH RIVER

SRNS is in the initial stages of implementing SPC at Savannah River. Key existing performance metrics have been identified for the potential shift to SPC. Currently, Savannah River uses 12-month moving averages and year-to-date values to track most Site-level metrics. Additionally, most existing performance analysis tends to focus solely on lagging indicators. There is currently a great deal of interest in the DOE for the use of leading indicators, so the techniques of References 5 and 16 will be utilized to also implement SPC for leading indicators. The Fluor Government Group statistician (an author on this paper) has supported the implementation of SPC at SRNS. An incumbent statistician, a certified Six Sigma Black Belt, is leading the effort to accomplish implementation for SRNS.

To date, several control charts have been made of Savannah River data. These include event from the Occurrence Reporting and Processing System (ORPS) and injuries and illnesses from the Computerized Accident and Injury Reporting System (CAIRS). SPC charts have also been developed for site vehicle accidents, security infractions and the maintenance program.
Once the key existing metrics are shifted, then the worth of the metrics will be evaluated, and an individual determination made as to whether or not to keep producing it.

The next step will be collecting the important leading and lagging indicators into an SPC based dashboard [5] [16]. Table III provides an overview of the color coding scheme for the SPC based dashboard.

Table III. Control-Chart-Based Dashboard Rules

Control Chart Result	Decision	Color	Leadership Action Needed
Stable (common cause variation)	Level is superior	GREEN	Stay the course
	Level is acceptable	WHITE	May continue at this level, or decide to improve
	Level is not acceptable	YELLOW	Improve the system
Trend (special cause variation)	Trend is in adverse direction	RED	Correct for the problem
	One point away from an adverse trend	YELLOW	Warning that next result may be red
	Trend is in improving direction	GREEN	Keep the trend going
	One point away from an improving trend	WHITE (if chart would have otherwise been red or yellow)	Preliminary feedback that a improvement may be developing

CONCLUSION

Fluor Hanford has seen several benefits from implementing Statistical Process Control as its primary trending tool. Fewer resources have been spent in the act of conducting the analyses, and fewer resources have been spent chasing random changes in performance. Statistical Process Control has allowed the identification of adverse trends in a timely manner, and the identification of stable processes in need of improvement. In addition to the direct results in performance improvement, relations with the U.S. Department of Energy client improved. As the client saw that Fluor Hanford was taking a rigorous look and rigorous actions on its own performance, the client was able to trust reports from Fluor Hanford, and to lessen its need to provide specific directions to Fluor Hanford.

Statistical Process Control at Fluor Hanford has also been viewed favorably by professional organizations and peers, up to and including the National Safety Council and the Robert W. Campbell Award. This recognition has furthered Fluor's competitiveness in future bids for government and non-government contracts. SRNS intends to replicate the Fluor Hanford successes at Savannah River.

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