

## **Choosing Leading Indicators and Learning from the Results - 11431**

Steven S. Prevette, Anthony M. Umek  
Savannah River Nuclear Solutions, Aiken, SC 29803

### **ABSTRACT**

This paper documents the implementation of leading indicators for Environment, Health, and Safety, as well as Operations at Savannah River Nuclear Solutions (SRNS) in Aiken, South Carolina. This process includes the use of Statistical Process Control (SPC), which is a critical component of a leading indicator system. Three potential sources of Leading Indicator information are discussed: **severity pyramids** (work on the base of the pyramid – behaviors, close calls, corrective action deficiencies), **means to achieve a better future** (Behavior Based Safety data, Human Performance flawed defenses and error precursors), and **measures of culture** (employee surveys, opinions, suggestions, and interviews)

If one makes good use of their data, and understands systems and workers, they are more likely to achieve continual improvement and performance success. Leading indicators are intended to provide management precursor information to preclude serious events. Trending and leading indicators are current topics in the U.S. Department of Energy (DOE) complex. Past attempts at monitoring the level of leading indicators through moving averages and targets have resulted in frustration and misdirected efforts. Experience by the authors in SPC and leading indicators show how the combination of these two techniques may be used to monitor for changes in a site's safety culture. These methods allow for the timely and accurate detection of changes in culture and performance. Fluor Hanford received national recognition at past DOE conferences, and recognition by the National Safety Council's Robert W Campbell Award in part due to these methods. These techniques continue in use at Savannah River Nuclear Solutions and led to significant improvement in safety performance in operations.

### **INTRODUCTION**

In August 2008, SRNS, a limited liability company, of Fluor, Northrop Grumman and Honeywell, assumed the management and operating contract of the DOE Savannah River Site (SRS). The site was constructed by DuPont to produce weapons-grade nuclear material for national defense in the 1950s.

Fluor's past application of leading indicators and SPC at the DOE Hanford site (located near Richland, Washington) contributed to significant improvements in safety and quality, higher credibility with the DOE customer, and national recognition. Fluor, through SRNS, is applying leading indicators and SPC at SRS based on its experience at Hanford and is achieving the same positive results.

Experience at SRNS and Fluor Hanford demonstrated that the critical issue with leading indicators (and all performance data for that matter) is "how" the data are used, not necessarily "what" the data are. In both DOE and in commercial industry, performance indicators are used

as tools to assist in managing complex systems. In general in DOE there is wide use of “lagging indicators”, reflecting historical performance in DOE supplied reporting systems. As these data are event driven, this can lead to “reactive” vs. “proactive” management decision making. When properly selected and analyzed, leading indicators can support proactive management of complex systems. There exist positive experiences from the application of leading indicators by Fluor at both the Hanford Site and the Savannah River Site. Leading indicators, when effectively correlated to Lagging Indicators, can relate directly to the cross cutting issues of safety conscious work environment and problem identification and resolution and the general principles of *Conduct of Operations*. In turn these can be used to implement continual improvement in the overall work place within the DOE’s Integrated Safety Management System (ISMS).

## MANAGEMENT AND METRICS

Dr. Russell Ackoff, a management systems author, identified three functions of management related to performance improvement: identification of actual and potential problems, decision making - deciding what to do and doing it or having it done, and maintenance and improvement of performance under changing and unchanging conditions. [1]

Leading indicators provide information which assist in all three functions. Leading indicators and good analysis of leading indicators help identify emerging problems, assist in choosing a good and timely decision, and can provide evidence if maintenance and improvement of performance are being accomplished.

## IMPORTANCE OF TRENDS

An important issue with the use of leading indicators is the ability to detect trends and changing conditions. Dr. Peter Winokur of the DNFSB has noted that “trends over time are more important than absolute values”. [2] This implies that one needs the ability to detect trends in the data, and not be distracted by random results which do not indicate a trend or change in performance. SRNS combines the use of leading indicators with the use of SPC in order to reliably detect changes in data, detect those changes early, and take corrective actions prior to an adverse effect. Numerical targets have not been shown to be effective in detecting such subtle signals and changes in the data.

Experience at SRNS and Fluor Hanford has demonstrated that the critical issue with leading indicators (and all performance data for that matter) is **how the data are used**, not necessarily **what the data are**. Good use and analysis of data will show which data have inherent value and which have low value. Good use of data will also minimize the tendency to tamper with and “game” the source data. Good analysis will detect artificial manipulation, or even falsification of performance data.<sup>1</sup> Most efforts on developing a leading indicator system have focused most of their effort on choice of metrics, rather than what to do with the metrics. Collection of leading

---

<sup>1</sup> Dr. Deming related the story of a quality inspector who artificially kept the reported defect rate low (in a perceived need to save fellow employees’ jobs), and this manipulation was detected through the data having too small of a spread on a p-chart control chart (W Edwards Deming, *Out of the Crisis*). There are also statistical techniques to check for randomness the first or last digit entered data. One example is Benford’s Law ([http://en.wikipedia.org/wiki/Benford's\\_law](http://en.wikipedia.org/wiki/Benford's_law)).

indicator information is seen by many as highly complex, resource intensive and expensive, while a slight shift of focus to using data already collected, but shifting the focus to analyzing available data smarter will save considerable expense. Most organizations are awash in data, and many of these data sources would make acceptable leading indicator information. After experience is gained with readily available data, additional leading indicators may be developed as information gaps are revealed. In a short time, a robust leading indicator system will be established.

## SEVERITY PYRAMID

The traditional concept of the severity pyramid or severity triangle can provide a ready source of leading indicator data. It has long been proposed that if the base of the pyramid is understood, controlled, and improved, one will have less of the more severe events at the top of the pyramid. Figure 1 shows a typical severity pyramid for injuries (left) and for operational events (right).

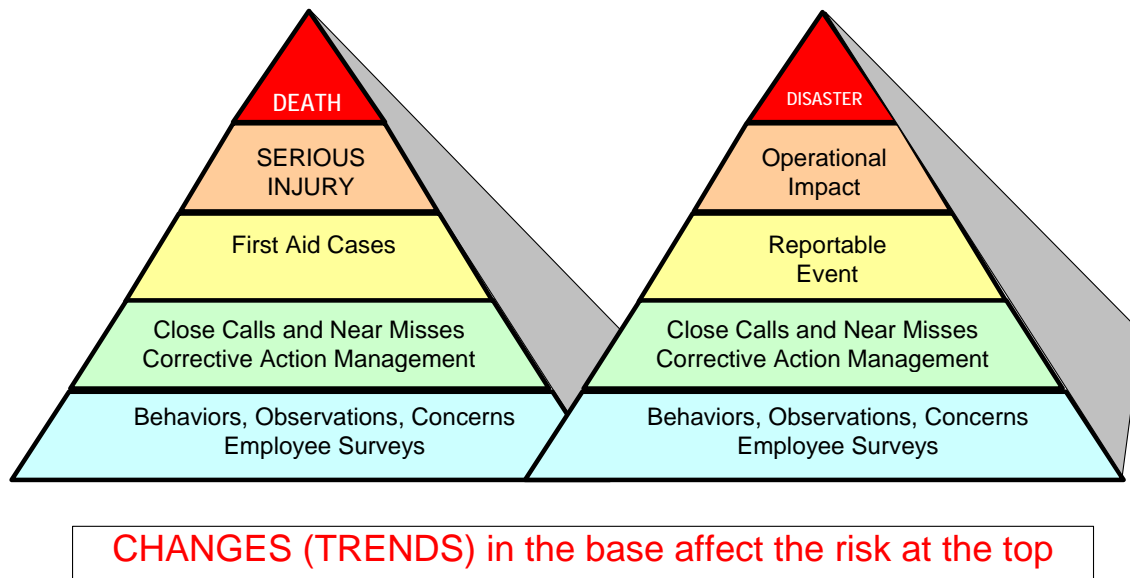


Fig. 1. Severity pyramids for injuries and operational events are one source for leading indicators.

If an organization looks to the base of its severity pyramid, many leading indicators may come to mind. At the base of the pyramid, the willingness to self identify issues (while they are still molehills) will lead to the ability to prevent the molehills from growing into mountains.

## SAFETY CULTURE METRICS

There may be certain readily available and inexpensive metrics such as overtime rates or sick days which give an indirect measure of safety culture problems. Employee surveys and structured interviews may provide indication of employees' emotions. No cost survey software,

such as SurveyMonkey™ allow a person knowledgeable of survey construction and theory to gather data inexpensively.

Dr. Winokur has also pointed out that under certain circumstances a lagging indicator may be a leading indicator for another system. For example, overtime hours may be a lagging performance metric for financial performance. However, significant increases in overtime may indicate threats to accomplishment of the mission (due to lack of personnel) or may be an advance warning of increased worker stress due to lack of free time, causing degradation of the safety culture.

Observed behaviors are readily related to safety culture. For those organizations using Behavior Based Safety (BBS) techniques, observation rates and percent of safe behaviors observed provide excellent leading indicator data. Conversely, if a site has chosen not to use BBS, a directive from senior management or oversight personnel to use BBS as a leading indicator would be viewed as expensive, arbitrary, and inappropriate. This demonstrates a principle that will be expanded upon in this document – leading indicators are best when chosen locally, based upon the management principles of the business unit.

Finally, the perceptions of managers and their involvement with workers may directly observe the safety culture, and there are data tools that can assist in measuring those perceptions.

## **BUILDING A BETTER FUTURE**

A significant source of confusion about leading indicators has arisen from the assumption that somehow the leading indicator needs to “predict” coming injuries and events. Rarely is this achieved, as any prediction that a significant event is about to happen would be acted upon, preventing the significant event.

Dr. Ackoff’s view towards planning and predictions is that living within the future spelled out in plans and predictions is one thing. The concept of “building a better future” is far superior. Thus, it is proposed for leading indicators that one ask not whether the leading indicator predicts the future, but if it enables the organization to build a better future.

Initiatives such as Human Performance, BBS, and High Reliability Organizations fall into this category, as well as simpler items such as safety meeting attendance. Whatever the organization is doing that they believe will build a better future should be measured and trended. There should also be an eventual analysis to see if these efforts are having any impact on the lagging indicators.

## **LOCAL CUSTOMIZATION**

If one acknowledges the above three sources for leading indicator information, it becomes apparent that a leading indicator for one organization’s culture and means to build a better future will not necessarily be good for a sister organization that may have a different culture and programs. Commonality of lagging indicators, such as Occurrence Reporting events and injury

cases per 200,000 hours may exist, however, leading indicators need to be customized to the local organization.

Dr. Deming stated that not everything is measurable (such as love, devotion, morale). Experience has shown, however, that useful indirect measures may be developed. One book with the enticing title of “How to Measure Anything” [3] provides some useful methods and ideas for indicator generation. The critical point is the ability to find changing conditions (trends) using SPC in conjunction with such measures.

## **THE SYSTEM OF PROFOUND KNOWLEDGE**

Control charts and understanding the variation in your indicators (both leading and lagging) were a significant component of Dr. W Edwards Deming’s teachings. The DOE PANTEX site (located near Amarillo TX) has adopted Dr. Deming’s overall philosophy of “Profound Knowledge” as the basis for their Human Performance and High Reliability Organization efforts. [4]

The System of Profound Knowledge includes not only understanding variation, but also understanding systems, theory of knowledge (how do we “know” what we know) and psychology. All four components, applied in conjunction with good use of leading indicators are capable of transforming a safety culture to support reliable operations.

There is a caution that needs to be kept in mind. If employees perceive the leading indicators will be used as a “punitive” measure; their use will sub-optimize. Also, goals and targets applied to leading indicators may cause unintended consequences. Rewards for no first aid cases or near misses may result in lowered reporting and hiding of events and injuries. Rewards for reporting of first aid cases or near misses may lead to superfluous reporting of issues of no value. Worse, goals and targets may cause employees to artificially manipulate and/or destroy the very systems needed for improvement. Application of the System of Profound Knowledge will mitigate the issues.

## **PERSONNEL SURVEYS**

Use of a personnel survey to help identify trends in safety culture was documented by the author in an article with the American Society for Quality (“Waste Management” May 2010 Quality Progress). This survey had been run for twelve years at the Hanford Site and the 17 individual questions were analyzed for trends using SPC. General times of worker stress could be identified, such as changes in Chief Executive Officers, and layoffs. The survey was reviewed as part of Fluor Hanford’s application for the Robert W Campbell Award, and was judged to be a best practice. An example chart is shown below in figure 2.

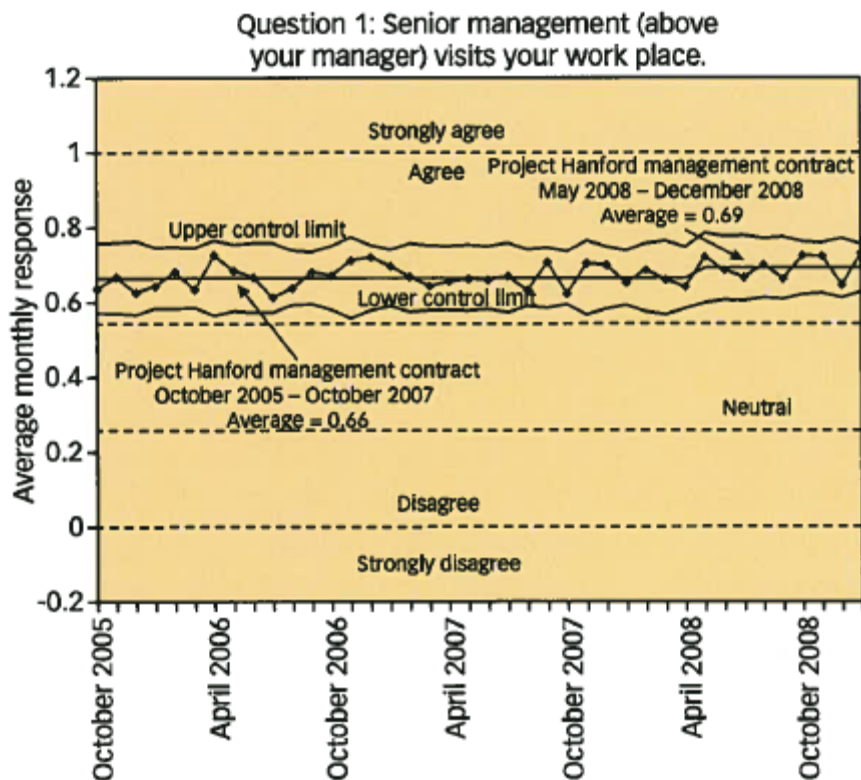


Fig 2. Question 1 from the Hanford Survey, analyzed using SPC

## SRNS ACTIONS

In 2009 SRNS implemented a new trending program for Occupational Safety and Health information. The SPC methodology was imported from prior experience by the authors at the DOE Hanford site. This methodology is based upon Dr. Shewhart's original development of Control Charts in 1930, and upon Dr. Deming's management methods. The methodology is documented in American Society for Quality and American Society of Safety Engineers articles, and on the internet at the Hanford Trending Primer<sup>2</sup>. The Institute of Nuclear Power Operations (INPO) reprinted these materials in "Performance Assessment and Trending." [5] The acceptance of the methodology by INPO and its promulgation in its publications lends considerable credibility to this approach. Fluor Hanford's experience with SPC and leading indicators has been well documented in previous Waste Management conferences. [6], [7]

SPC trending was implemented on the existing lagging indicators early in 2009. These indicators included OSHA Recordable, Restricted and Days Away From Work injury rates. Data from the DOE Occurrence Reporting and Processing System (ORPS) event reports were also analyzed. Packages of these charts were provided to project vice presidents for their respective organizations. The SPC trending has helped to identify trends in the data, leading to early confirmation of problems in August/September 2009. See Figure 3 for a SPC chart of the SRNS

<sup>2</sup> At the time of writing, the Hanford Trending Primer had been removed from the DOE Hanford internet site, and is being transferred to the Energy Facility Contractors Group (EFCOG) internet site.

Total Recordable Case (TRC) Rate from the start of the SRNS contract through October 2010. The initial baseline average and control limits were from the performance of similar scope of work by the previous contractor. The timely identification of the July – August 2009 spike allowed SRNS management to make quick reactions to the trend and contain the problem. Actions taken in the compensatory initiative were designed following analysis of the fact findings and the trending of the events.

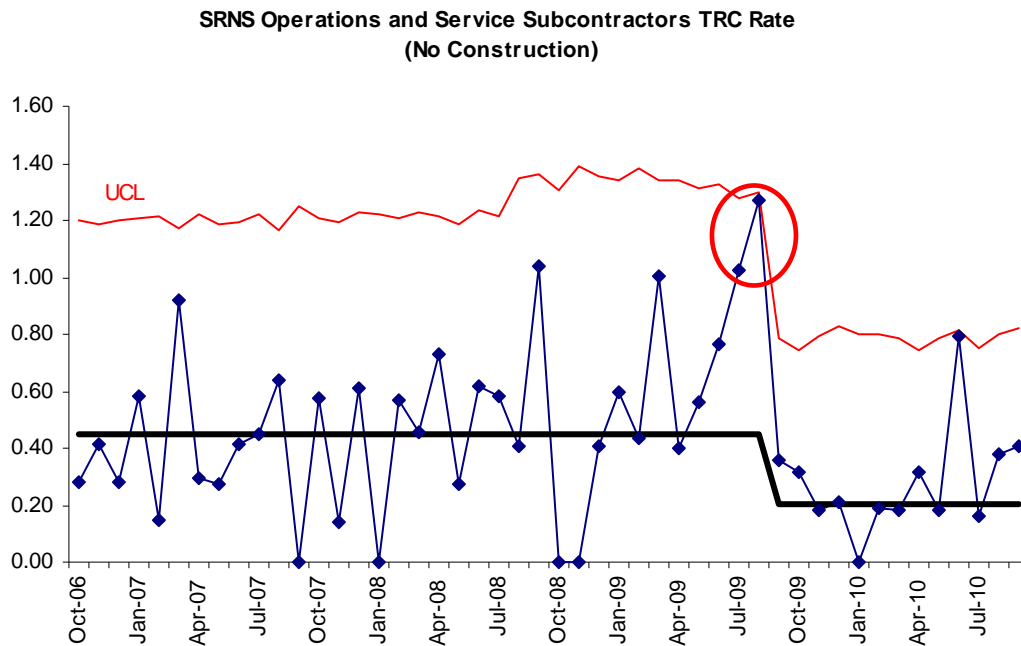


Fig. 3. TRC Rate chart for SRNS Operations and Service Subcontractors, showing the July/August 2009 spike, and improved baseline following the 2009 spike

Leading indicators developed in support of an ISMS Phase II Corrective Action Plan. These indicators were developed from a variety of sources, including Employee Concerns, the Individuals Developing Effective Alternative Solutions (IDEAS) employee suggestion program, first aid injury data, corrective action and observation data, and BBS data. Review of the indicators show that many are well-correlated with the lagging indicator data, and could have provided even earlier detection of the August/September 2009 problems.

One example Leading Indicator was found in the company corrective action management system. Corrective actions are coded by functional area, and functional area 20 is Occupational Safety and Health (OS&H). A good correlation was found between error reports and fact findings as compared to the TRC Rate, as shown in Figure 4.

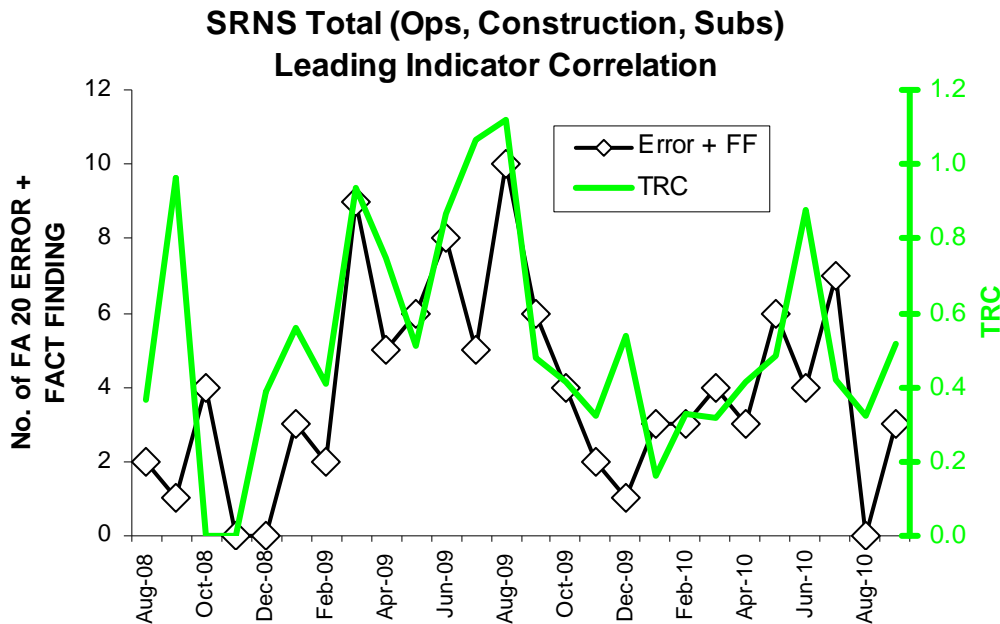


Fig. 4. TRC Rate for SRNS versus the Functional Area 20 (Occupational Safety and Health) corrective action data for Errors and Fact Findings

The OS&H Leading indicators have been institutionalized in a series of monthly reports. These reports have been provided to SRNS management and DOE management, and have been instrumental in understanding ISMS performance, and achieving improvements in performance.

## RESULTS

The actions taken as a result of the corrective and compensatory actions have resulted in a lower OSHA recordable case rate than was in effect prior to the summer of 2009. The additional training and employee involvement have led to improvements in safety conditions on the site.

The DOE customer has been involved with the use of the new trending methodology. Joint meetings led to adoption of SPC trending as a basis for the Fiscal Year 2010 Performance Objectives, Measures, and Commitments. SRNS used existing measures, but rather than specifying numerical thresholds, pledged to “maintain or improve” performance as defined by SPC trend rules. Three of the seven metrics showed significant improving trends during the year, and the improvement was sustained through the end of the year. Two metrics developed adverse trends during the year, but the deviations were quickly detected and corrected, returning performance to the previous stable values.

## CONCLUSION

The use of SPC and leading indicators, if used effectively, helps to improve understanding of safety culture. Understanding the safety culture, tied with appropriate management and employee actions combined with ISMS do lead to improved safety performance at DOE. The



critical issue for effective use of leading indicators is appropriate statistical analysis, tied with management understanding of Dr. Deming's System of Profound Knowledge.

## REFERENCES

1. R. L. ACKOFF, "Ackoff's Best His Classic Writings on Management", John Wiley and Sons, New York (1999).
2. P. S. WINOKUR, "Chemical Safety Leadership and Leading Indicators", EFCOG's Eleventh Annual Joint Chemical Workshop, [http://www.dnfsb.gov/pub\\_docs/testimonies/all/sp\\_20090310.pdf](http://www.dnfsb.gov/pub_docs/testimonies/all/sp_20090310.pdf) (2009).
3. D.W. HUBBARD, "How to Measure Anything Finding the Value of Intangibles in Business", John Wiley and Sons, New York (2007).
4. R. S. HARTLEY, "Introduction to Pantex High Reliability Operations a Practical Approach to Avoid the System Accident" [http://www.efcog.org/wg/ca/events/fall08mtg/presentations/Intro\\_to\\_BW\\_Pantex\\_HRO\\_Program\\_10-08\\_b.pdf](http://www.efcog.org/wg/ca/events/fall08mtg/presentations/Intro_to_BW_Pantex_HRO_Program_10-08_b.pdf) (2008).
5. INSTITUTE OF NUCLEAR POWER OPERATIONS, "Performance Assessment and Trending", INPO 07-007 (2007).
6. H. E. BILSON, S. S. PREVETTE, "Integrating Safety and Lessons-Learned Data with Human Performance for Successful Management and Oversight", WM 2008 Conference, Phoenix AZ, <http://www.wmsym.org/archives/2008/pdfs/8053.pdf> (2008).
7. S. S. PREVETTE, W. H. PREVITY, "Implementing Performance Trending at Two Department of Energy Sites", WM 2009 Conference, Phoenix, AZ, <http://www.wmsym.org/archives/2009/pdfs/9330.pdf> (2009).