Savannah River
Nuclear Solutions, LLC
A Fluor Daniel Partnership SM

Using Leading Indicators and Statistical Process Control to Meet Current Challenges

Steve Prevette
Senior Statistician

Savannah River Nuclear Solutions
Fluor Government Group

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Previously . . .

- Presentations at the Spring 2009 CAWG:
  - Dr. Deming's Red Bead Experiment
    - Hands-on demonstration
    - Frustrations with current management practices
    - Intro to Statistical Process Control (SPC)
  - Fluor's Use of Leading Indicators
    - External audit praise
    - Leading indicator theory
    - Examples
    - SPC-based dashboard

This Session

- How to perform SPC
- Choosing indicators (leading and lagging)
- Joint Commission – Sentinel Events
- Ongoing actions at SRNS
- Lessons Learned

Statistical Process Control

A way of:

- presenting data on a chart
- determining if you have a trend
- determining if you are stable
- determining the capability of your process

It is also a way of thinking

http://www.hanford.gov/rl/?page=1148&parent=1144

What is a "Trend"?

- Many procedures and policies call for "trending" to be performed, for "trends" to be identified.
- Webster's Dictionary:
  - to extend in a general direction,
  - a general movement,
  - to veer in a new direction,
  - to show a tendency,
  - to become deflected
- For our purposes: a changing condition

Lessons of the Red Bead Experiment

- In the Red Bead Experiment, we reacted to the random noise from result to result.
- Rewards, punishments, ranking of the workers, feedback to the workers had no effect on the results of the process.
- The process was stable and needed to be changed!

Importance of Trending

- Actions taken to improve a process are different, depending on whether or not the process is “stable”.

- Attempting to explain or correct for individual datum point changes in a stable process will not improve performance. This is a “Type I” error.
  - *You will be making a mountain out of a molehill.*

- Missing initial indication of a change (and missing the opportunity to determine the cause of the change). This is a “Type II” error.
  - *You will allow the molehill to grow into a mountain.*

Management Theory: The Theory of Variation

- **SPECIAL CAUSE VARIATION**

If a statistically significant trend occurs, find the special cause of this trend. Use this information to correct or reinforce these special causes.

- **COMMON CAUSE VARIATION**

If no trends exist, you must look at the long run performance of the process and fundamentally change the process in order to improve the process.

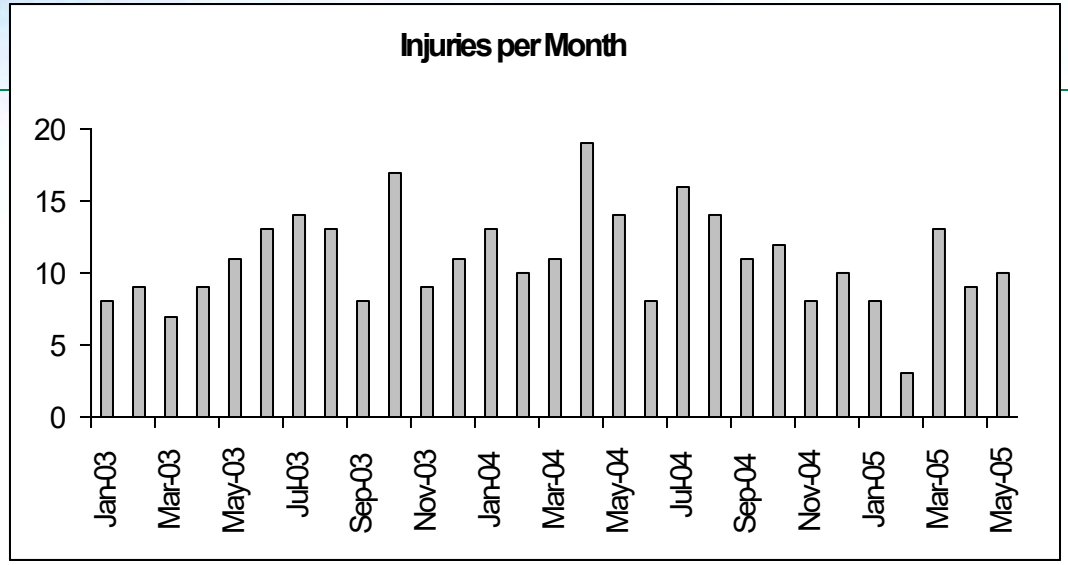
Implications

- **No amount of explanation of, corrective action to, or causal analysis of an event will fix a broken stable process**
  - **What if we did a root cause analysis of why Red Bead #298 fell in hole #19 of the paddle?**
  - **What about "Find it Fix it"?**

The Losses

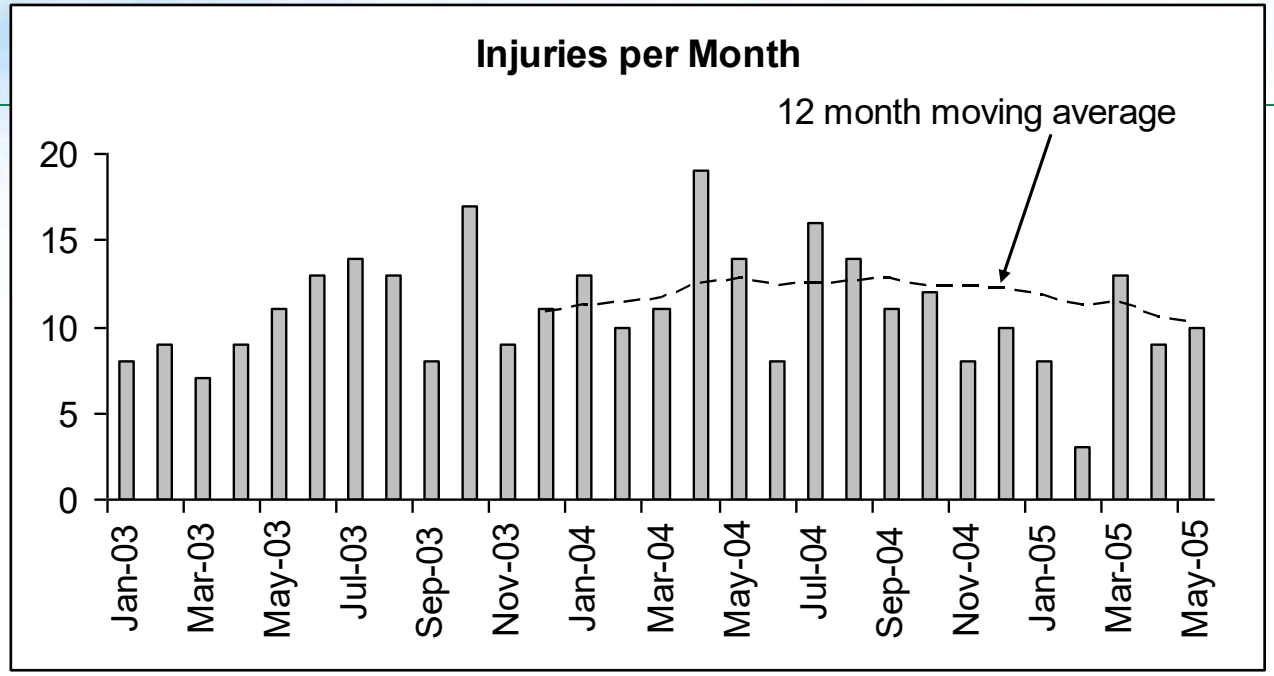
- **Misinterpretation of Performance Results can lead to:**
  - **Missed Opportunities**
  - **Incorrect Actions**
  - **Frustration and Bewilderment**

Let's take an example:



Great improvement from July 2004 – February 2005 !!!

Alas, something obviously has gone wrong in March. We jumped from 3 injuries to 13. The injury rate increased more than 400%! April and May have recovered somewhat, but not by much.

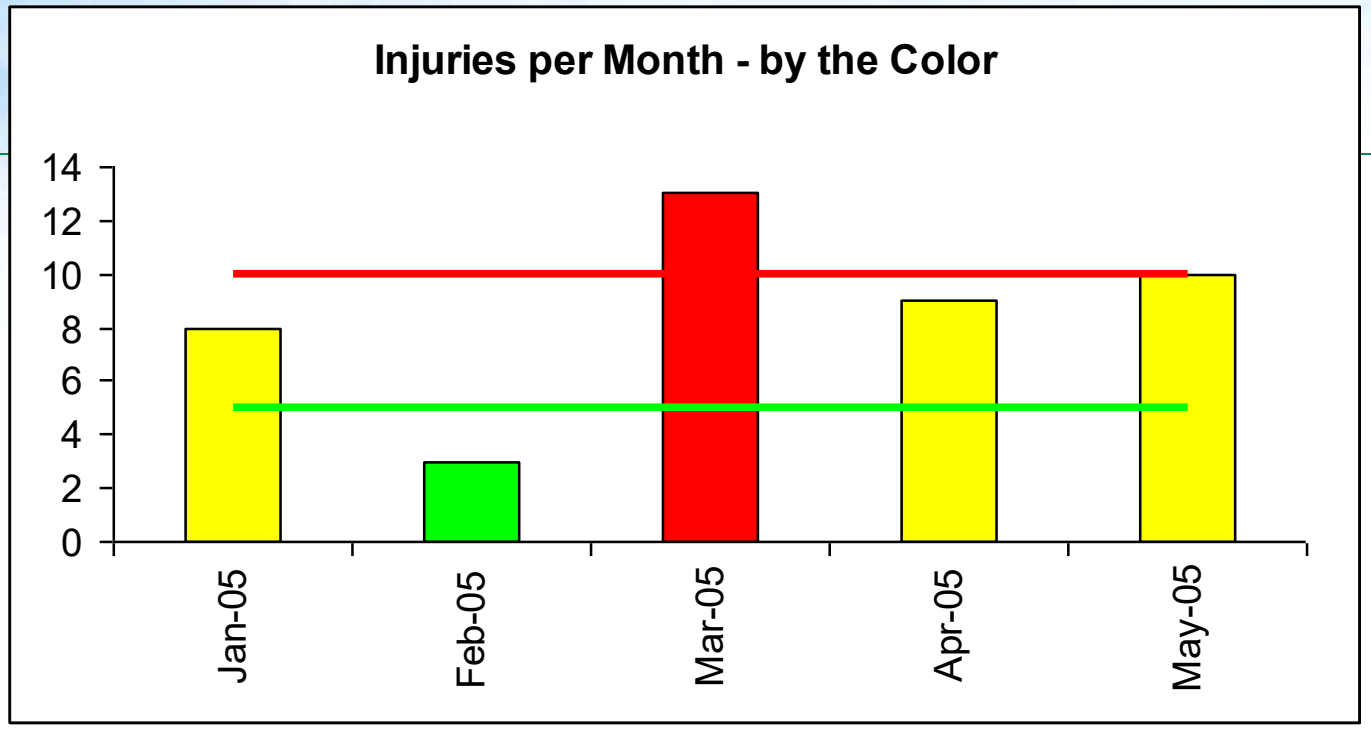


Addition of a 12 month moving average shows us we are actually improving!

Or are we?

The Hazards of Moving Averages

- A moving average simply compares the new datum point to the oldest. If the new point is higher, the moving average moves up; if lower, the moving average moves down.
- There is no criteria for when to declare a trend, when to sound the alarm

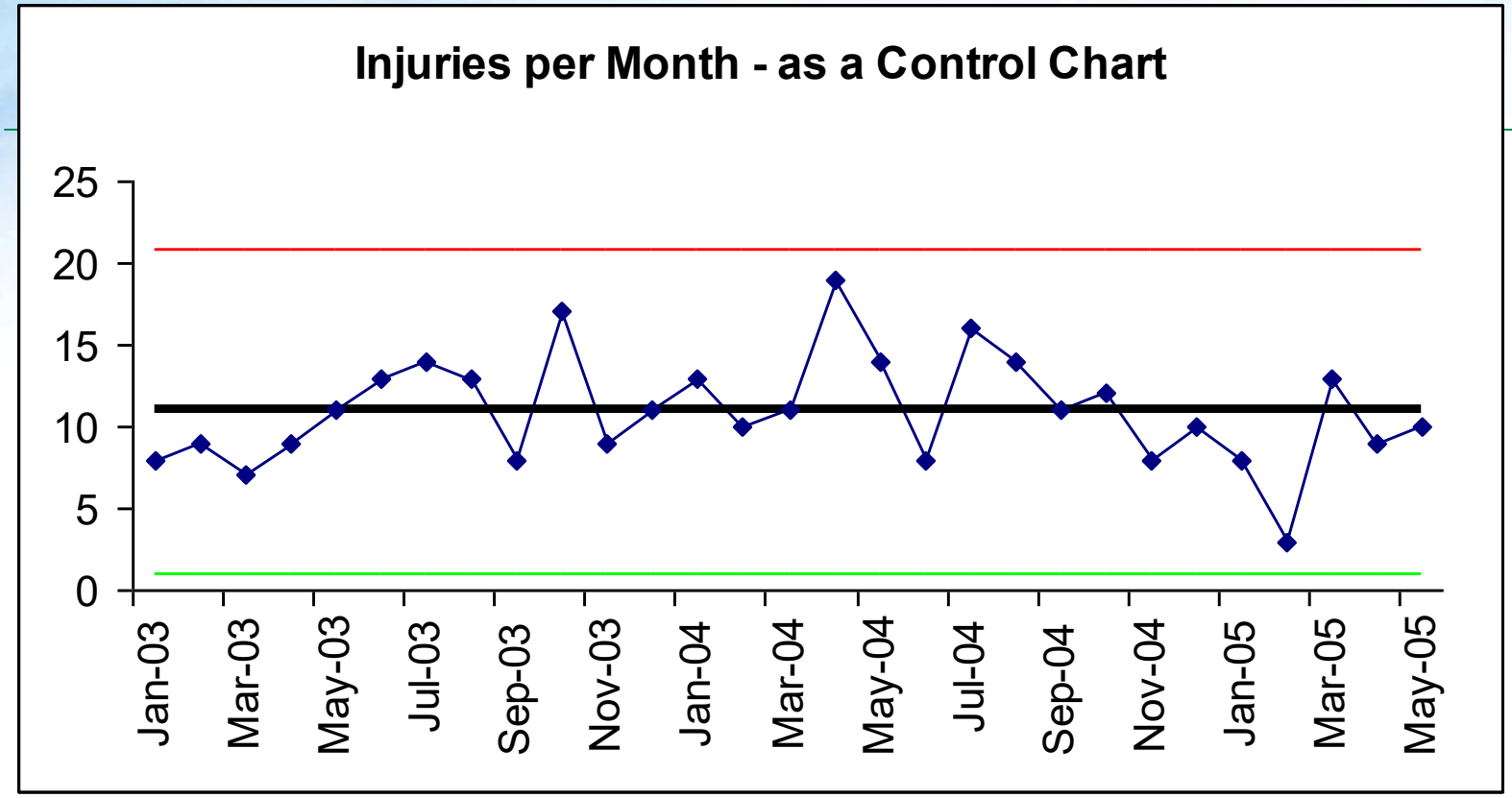


Adding color and cutting back to the current year certainly eliminates confusion . . .

Oh, really?

The Hazards of Rainbow Charts

- The traditional color coded charts against numerical targets add to the reaction to random noise
- Although we now have an alarm threshold, there is a high rate of false alarms against arbitrary thresholds



The control chart allows us to see that this is a stable, but random process

Yes, Really – it was random numbers

Construction of the Control Chart

- Plot the actual data by month (or whatever time interval you are using)
- Plot at least 25 points (when available)
- Calculate a baseline average rate
- Add 3 standard deviation control limits
- Incorporate a set of trend rules
- Adjust the baseline only when there is a significant trend

Why use the Control Chart?

- Provides a formal method to detect trends
- Provides credibility and rigor at minimum cost
- Balances false alarms and failures to detect
  (Type I and II Errors)
- Accepted industry standard with long history

Control Charts are analogous to the circuitry in your home's smoke detector.

Statistical Process Control – A Lens

Control Charting provides knowledge of variation. This knowledge is a lens, and provides a different way of viewing the world.

The Control Chart will give you a significantly different view of what is happening than will other methods.

Why Three Standard Deviations ?

- Many courses incorrectly teach that the control limits cover 99.7% of the normal distribution
- Not all data are normal, “real data” can cause the rate to be as low as 95% (Dr. Wheeler)
- The Tchebychev Inequality states up to 11% can be outside three standard deviations
- We use a suite of rules, and we want to avoid too many false alarms

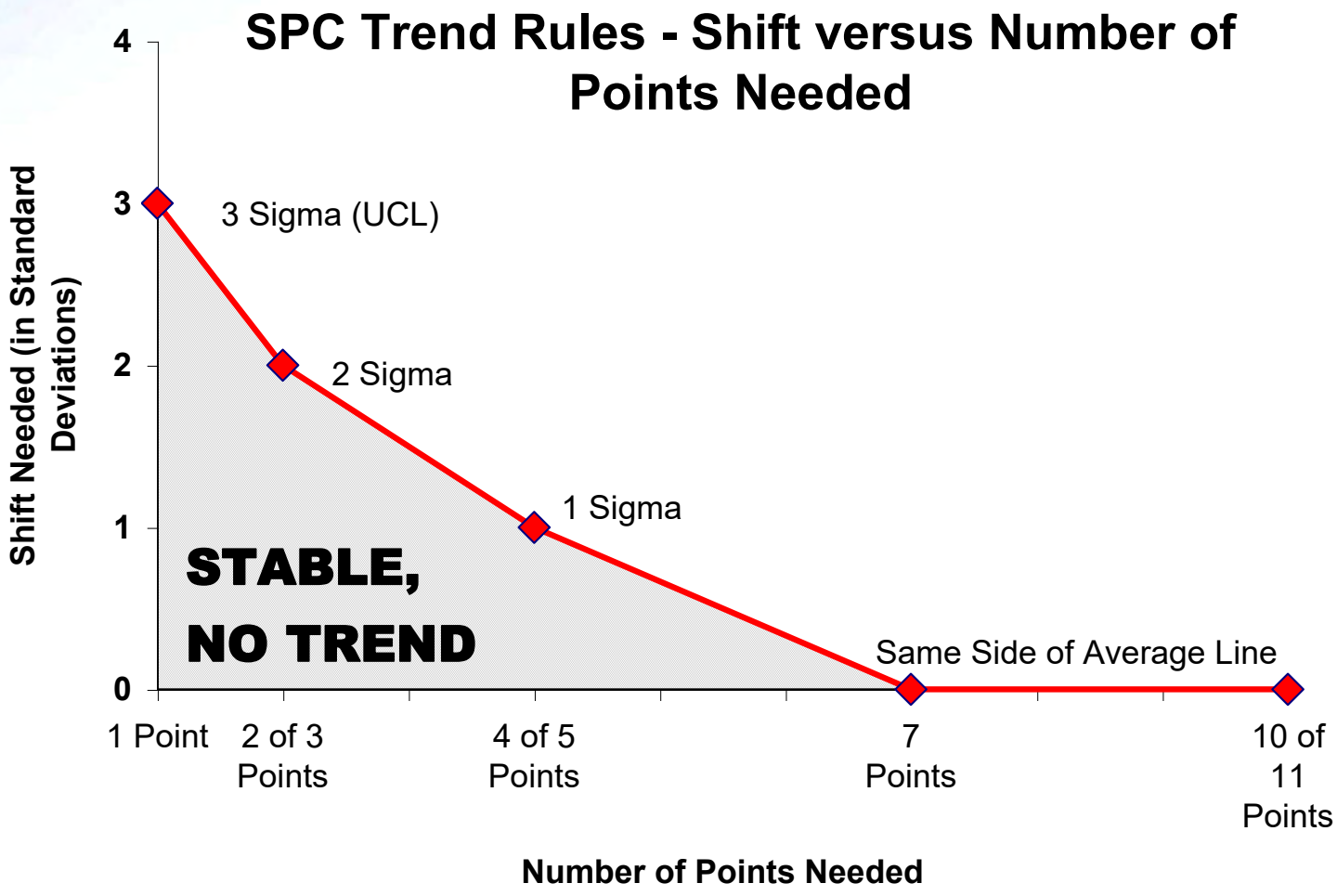
Why Three Standard Deviations (2)

- Dr. Shewhart established 3 standard deviations as an economic balance between failure to detect and false alarms.
- If you don't believe this, go home and make your smoke detector more sensitive. Is your house now more safe?

Definition of a Trend

- 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 Eleven points in a row all above/below average
- Seven points in a row all increasing/decreasing

Definition of a Trend



Let's Make a Control Chart

- I will make a C-chart Control Chart from a previous Red Bead Experiment
- The C-chart lends itself well to counting events, such as injuries or occurrence reports

- http://www.hanford.gov/rl/uploadfiles/VPP_cchart.pdf

The Data

Worker	Red Beads	Worker	Red Beads
Trial 1	11	Trial 13	7
Trial 2	12	Trial 14	10
Trial 3	6	Trial 15	7
Trial 4	12	Trial 16	12
Trial 5	9	Trial 17	4
Trial 6	13	Trial 18	11
Trial 7	11	Trial 19	6
Trial 8	7	Trial 20	11
Trial 9	8	Trial 21	9
Trial 10	6	Trial 22	12
Trial 11	13	Trial 23	12
Trial 12	10	Trial 24	6

Excel Spreadsheet Data

- Open Excel Spreadsheet and start a new file
- Column A will be Trial Number (Trial 1 – Trial 24)
- Enter the number of red beads for each trial in Column B
- Reserve Column C as the average, Column D as the Upper Control Limit, and Column E as the Lower Control Limit

Run Chart

- Highlight A2 to E25
- Hit F11. This will make a bar chart.
- Change chart type to line, delete the background, grid lines, and legend
- You now have a “run chart”, a line chart of the raw data

Calculate the Baseline Average

- We will use all of the data for our initial baseline
- =average(B2:B25) is the baseline average
- Copy and paste special (values) into the C column

Calculate the Standard Deviation

- The standard deviation for a c-chart is the square root of the average.
- This is a special case – the c-chart is used when counting Poisson events
- Poisson implies that we count individual events, and occurrence of one event does not affect any other likelihood of occurrence

Calculate the UCL and LCL

- In D2, type =C2 + 3 * sqrt(C2)
- Copy this down the column
- In E2, type =C2 – 3 * sqrt(C2)
- Copy this down the column
- Check the chart for any trends

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Clean up the chart

- I usually make the average line a heavy black line, and the control limits red and green
- Label the Average Line
- Add chart title and axis labels

New Data

- What do we predict the future results to be?
- How will we know if something changes?
- Let's do a few more days of "production" of white beads

Adding Data to the Chart

- Highlight the last row of data
- “Insert” a row
- Copy the row up into the blank row
- Replace the Trial Number on the bottom row, and replace the number of red beads
- Check the chart for trends

Did anything change?

- Have any trends developed?
- What do you think has happened?
- What is our new prediction for the future?

SPC Conclusion

- Statistical Process Control is not just a charting technique
- SPC is a way of doing business
- SPC approach saves money
- SPC has proven very successful at Hanford and Savannah River, allowing the workforce to make significant improvements

Choosing Performance Indicators

Managers who don't know how to measure what they want

settle for wanting what they can measure

Dr. Russ Ackoff at
http://www.f-laws.com/pdf/A_Little_Book_of_F-LawsE.pdf

Performance Indicator Introduction

- It is more important how the measure is used than what the measure is
- Self-fulfilling prophecies can prevent us from gathering any data
- We are drowning in data, but little knowledge is derived
- Context and Operational Definitions are crucial

Three Information Sources

- Worker and Customer Opinion
- Expert Review
- Process Measures

We will focus on Process Measures for this topic. Note that opinions can be converted to measurement data with survey analysis, and results can be converted to measurement data through grading criteria.

Survey Processing Sidebar

- Surveys usually are not analyzed well
- Most arithmetically average 1 to 5 Likert scale and don't asses for variation
  - This assumes people think linearly
  - This assumes each category is equal width
  - Can over-react to random variation
- For a better idea, see http://www.hanford.gov/rl/uploadfiles/VPP_AnaSurveyData.pdf

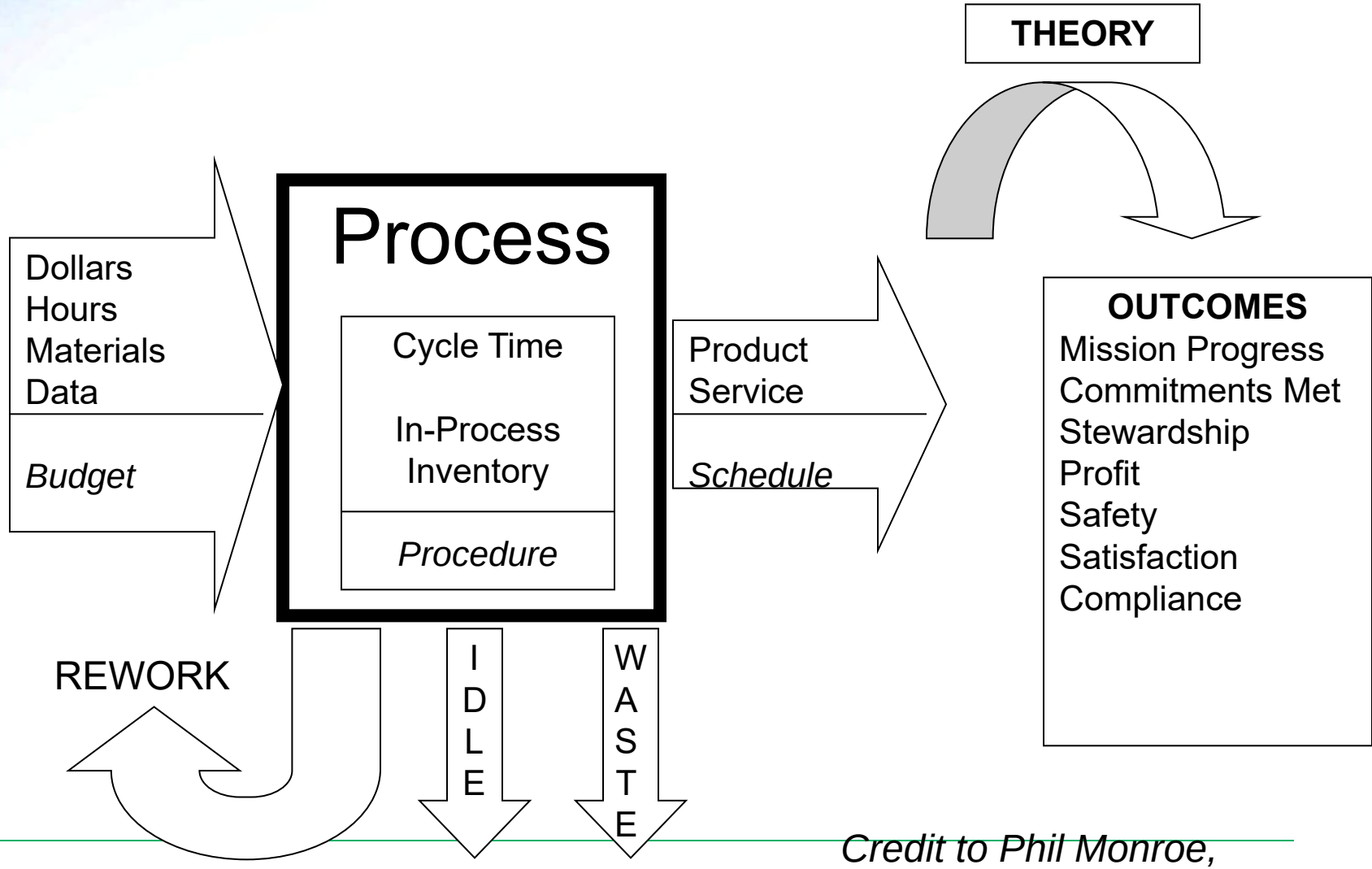
Some Approaches for Choosing PI's

- Top-Down
- Process Approach
- Bottom-Up
- Customer Focus
- Leading Indicators

Top-Down Approach

- Look at your Mission and Vision
- What are your Products, Services and Customers
- What is your Business Objective
- What are desired Outcomes
- What are the Processes that accomplish the above (drawing a flow chart may help)
- Decide on Measures (see next page)
- Go set up data sources, gather data

Process Approach



Credit to Phil Monroe, DEMCOM

Connection from Output to Outcome

- Outcomes are only achieved as a result of a process
- Focusing ONLY on outcomes is a sure path to failure
- Ignoring outcomes is a sure path to failure
- When I provide a Product or a Service, what is my THEORY that connects this to a favorable outcome?

Example – I provide statistical training to you. My product is you, as you leave this room. My theory is that you will apply the knowledge you have been provided, apply it to performance indicator work, which will cause continual improvement to occur and have a positive impact on accomplishing the Mission of your Organization.

Examples

Input Rate (units per time or Dollars, Hours)
Efficiency (Input vs. Budget, Input vs. Idle)

Cycle Time (Baldrige Criteria pushes cycle time)
Backlog (inventory)
Procedure Compliance, Completion without Stoppage

Output Rate (units per time of Product or Service)
Productivity (Output divided by Input)
Defect Rate (Waste + Rework vs. Output)

Effectiveness (Outcome measures, Outcome per Input, Percent Compliant, Output vs. Schedule)

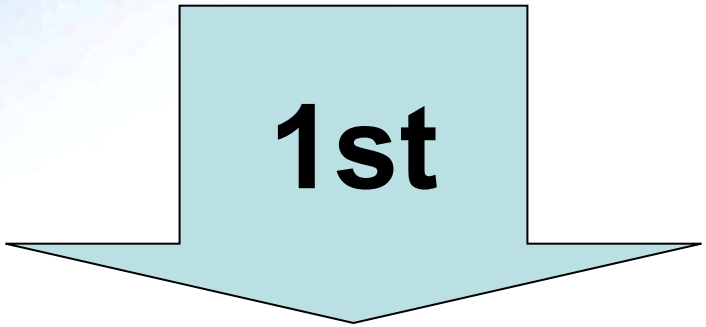
Bottom Up Approach

- Go find out what data you currently have
- Why are you collecting it?
- What could it tell you?
- Choose measures from available data
- Refine by trial and error

Advantage – Cost Effective, utilizes existing resources

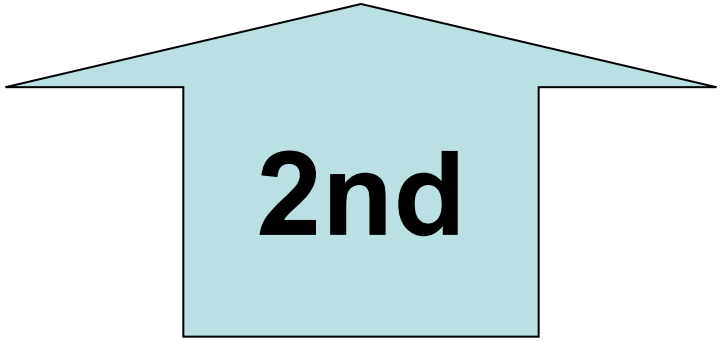
Disadvantage – Only focuses on "visible" data, is Reactive, Not "designed"

Combination Approach



Work down from the Aim of the Organization

3rd Meet in the middle, identify gaps



Work up from the data on hand

Customer Focus

- Put yourself in your customer's place.
- What is important to the customer?
- Customer Satisfaction, Loyalty
- Can it be measured or inferred?

Do the same for your employees.

Low Frequency - High Impact Measures

- There are several “outcome” based measures such as Deaths, Bankruptcy, Property Damage, Environmental Damage which are infrequent occurrences but carry a high perceived risk and emotional reaction
- When one of these events occurs, we are susceptible to over reaction to the event itself

Jump Start with Leading Indicators

Just what are leading indicators, anyway?

Predictions of future?

or

A means to create a better future?

Creating a Better Future

Distracted by calls to predict future, we delay development of leading indicators

- At low injury rate, little information exists in outcome indicators
- Trending response time is long at low rates
- Use leading indicators to measure lower threshold data and activities
- Quickens trend response and improves outcomes

Choosing Leading Indicators

What are you doing to “Create a Better Future”?

What are your program elements, your grass-root efforts to improve?

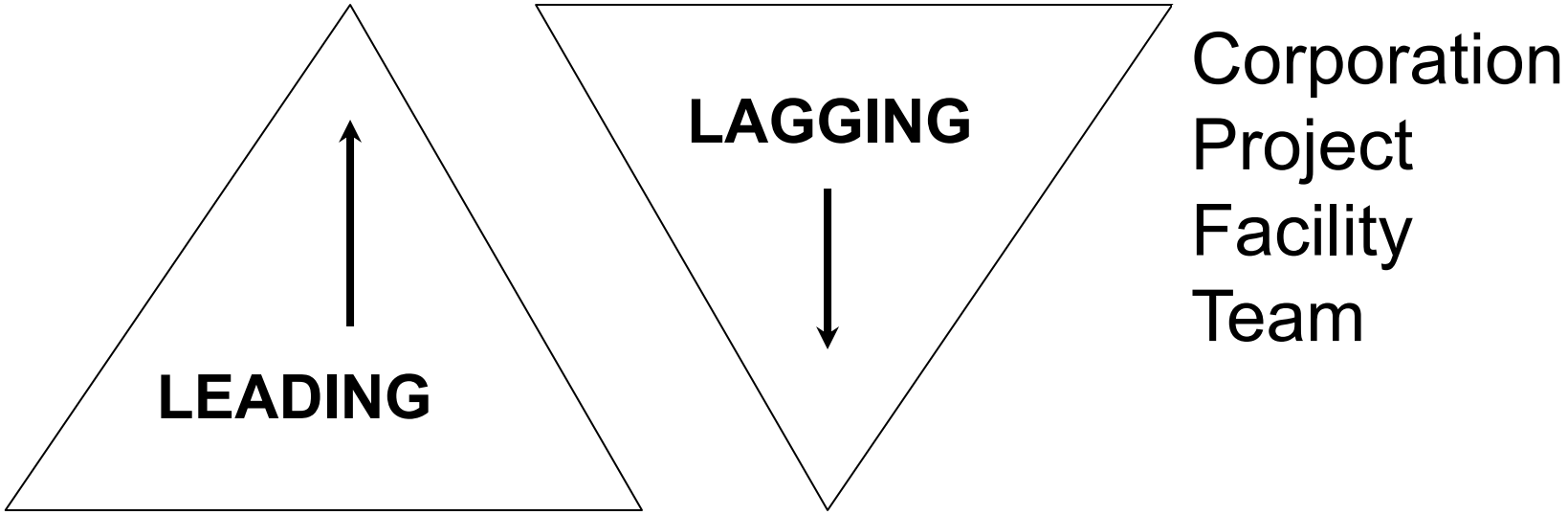
What are the activities you are conducting which you expect will lead to better performance on outcomes?

Leading and Lagging Indicators

- Lagging Indicators dominate at the higher levels, reflecting outcomes. Tend to be standardized and dictated from above.

- Leading Indicators dominate at the lower levels, reflecting processes that achieve the outcomes. Tend to be customized, and driven from the bottom-up.

Hierarchy of Indicators



Lagging indicators dominate at high levels, leading at lower levels.

Performance Indicator Evolution

As a process matures, one may end up evolving the indicators used. For example, if interested in completing actions by commitment dates, one may end up using (as the process matures):

- Percent of Actions completed by due date in effect at time of completion
- Percent of Actions completed without missing any due dates during their life
- Percent of Actions completed by the original due date
- Average days Actions completed ahead of original due date

The Search for the "Perfect" Indicator

- When committees get together and try to table-top the perfect indicator, paralysis often sets in.
- Realize all data are flawed, there is no "true value", indicators can always be "gamed."
- Putting the right culture of HOW to use performance indicators in place minimizes adverse impacts.
- Gain experience with simple indicators, then move on to more complex indicators if needed.
- With proper analysis, flaws with existing data can be detected and fixed. If you never look at the data, there will never be an incentive to fix the data.

Plan Ahead

- ***"It's absolutely vital for business that you settle this method of counting, measuring, definition of faults, mistake, defect, before you do business. It's too late afterwards"***

-Dr. W. Edwards Deming

How many initiatives have we embarked upon, without a clear set of indicators established up front, only to be left with, a year afterwards, trying to figure out "what happened"?

Operational Definitions

- “Clean the Table”

Context

- Do not look at a chart in a vacuum
- Reconcile any differences between the data and “gut feeling”
- Combine experience and the data
- Lessons from the data should lead to insight in the field, and vice versa

Just Do It

- All data are flawed
- Make good use of your data
- Endless conference table discussions won't cause any data to appear
- Initial prototype successes will lead to experience, and will further the spread of the use of indicators

Sentinel Events (Health Care)

- A sentinel event is an unexpected occurrence involving death or serious physical or psychological injury, or the risk thereof. Serious injury specifically includes loss of limb or function. The phrase “or the risk thereof” includes any process variation for which a recurrence would carry a significant chance of a serious adverse outcome.
- Such events are called “sentinel” because they signal the need for immediate investigation and response.
- The terms “sentinel event” and “medical error” are not synonymous; not all sentinel events occur because of an error and not all errors result in sentinel events.

http://www.jointcommission.org/SentinelEvents/PolicyandProcedures/

Sentinel Events

- The Joint Commission (formerly JCAHO, Joint Commission on Accreditation of Healthcare Organizations) provides a Sentinel Event Policy
  - Root cause analysis
  - Action plan to implement improvements
  - Monitoring effectiveness of improvements
  - Many parallels to ISMS and HPI

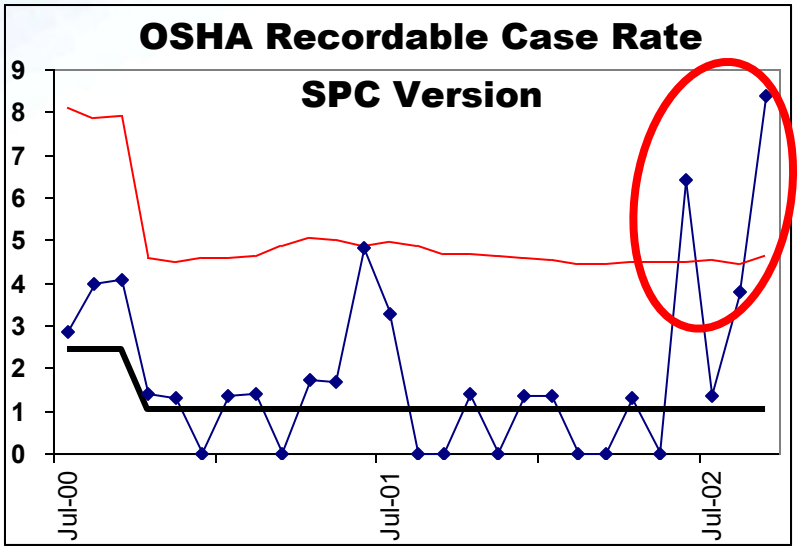
Example Sentinel Event

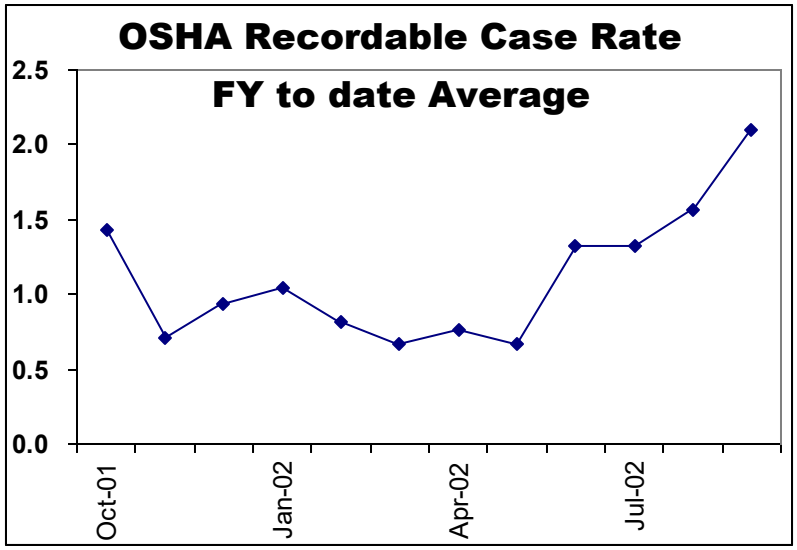
- Seven students die when a commuter train strikes a school bus stopped on the tracks for a traffic light.
- The school bus driver was a substitute driver
- Citizens had reported near misses for two years
- State D.O.T. and Railroad verified lights working properly
- Eye witness said bus never got green light before being struck.

Systems Failure

- Original design allowed for traffic to clear
- Engineer noticed that intersection had crosswalk, but not a 12 second delay for pedestrians
- Circuit was reprogrammed to add the delay and documented
- When problems arose, Railroad checked that its detector worked, and State DOT verified that the traffic lights cycled
- No one checked the real issue - was there sufficient time in the cycle to clear the tracks?

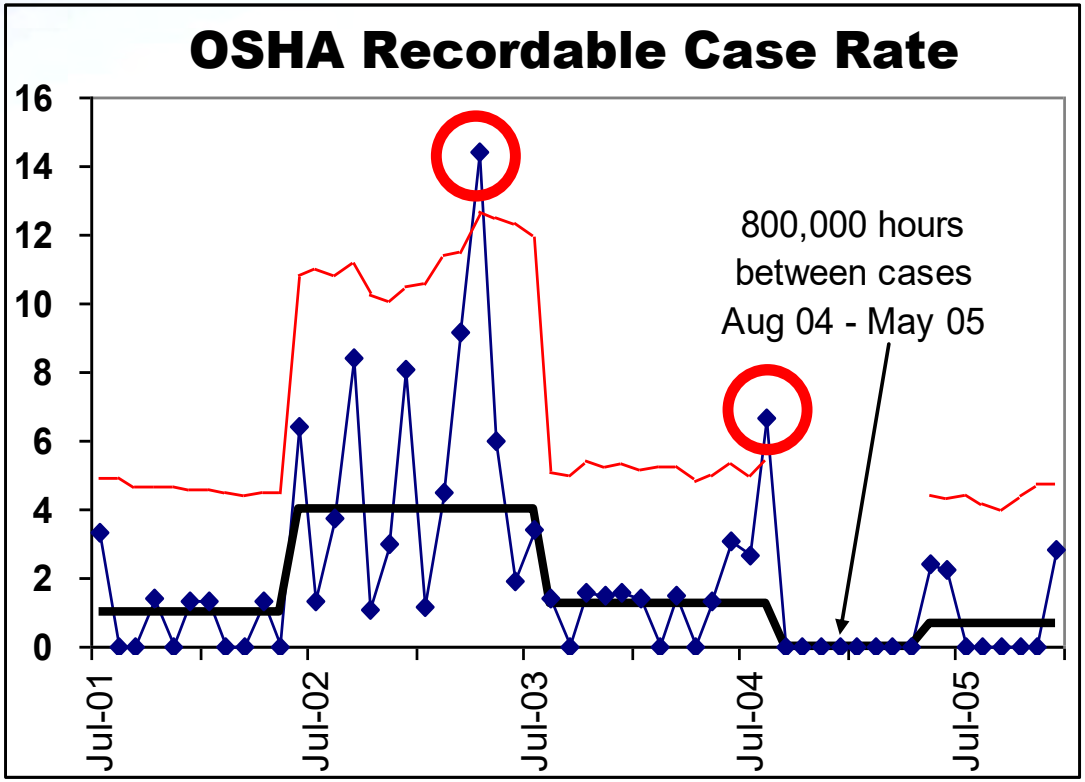
Case Study: Dueling Charts





A story from Hanford: Significant increase in injuries (which was due to a tool use change causing rotator cuff damage) detected on control chart, ignored by facility management due to use of Fiscal Year to date averaging.

The Alarm is Finally Heeded



Injuries continued at a higher rate much longer than necessary due to cumulative rotator cuff damage and lack of action. Very inexpensive ergonomic fixes led to significant reduction in injuries.

Results

K Basins' ergonomic improvements win safety award

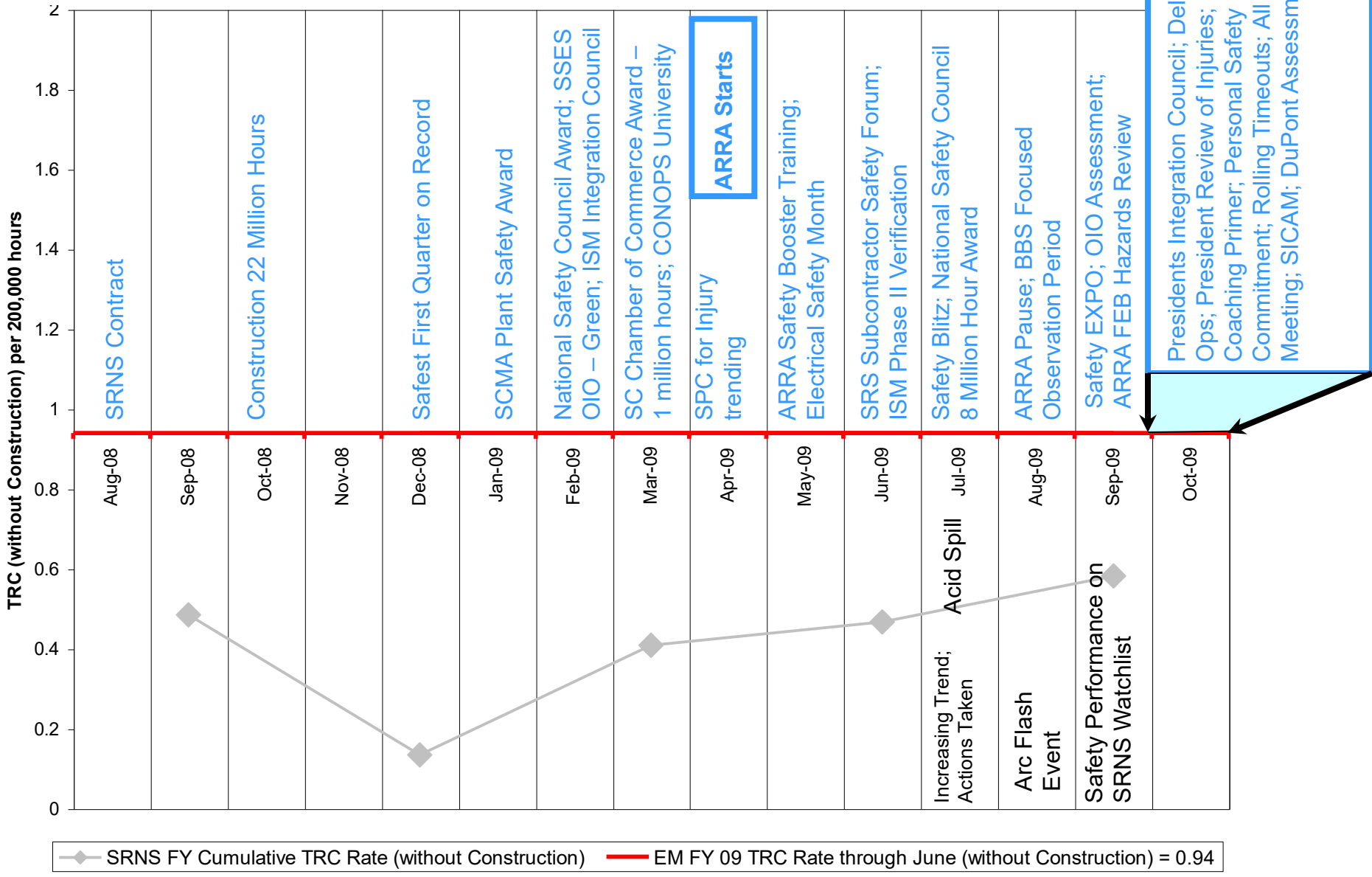
"Tooling and processes should fit the people, not the other way around."

Denise Brooks, ergonomics specialist

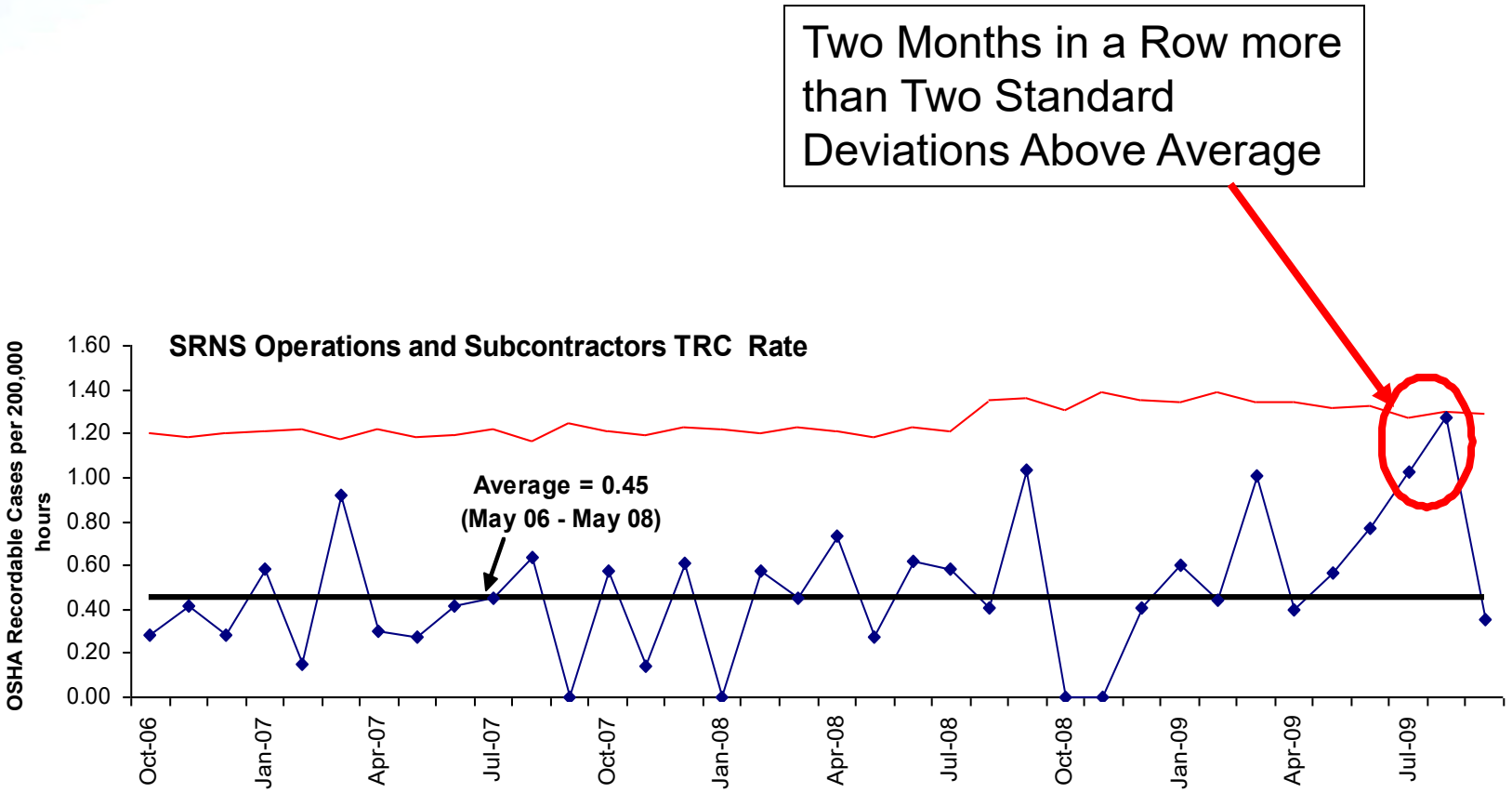
SRNS Challenges

- Some recent events hit the local newspapers and the Weapons Complex Monitor
- Increase in TRC and DART injuries
- Negative signals in the Leading Indicators that are being developed

SRNS Safety Performance Timeline-October 2009



Adverse Trend in TRC



Actions

- Presidents Integration Council
- Deliberate Operations
- President Review of Injuries
- BBS Management Coaching Primer
- Rolling Timeouts;
- SICAM – review of work packages;
- DuPont Assessment

SRNS Trending Vision

- Statistical Process Control (SPC) / Control Charts for trending.
- Effective detection of adverse trends, leading to action.
- SPC monitoring of responses, such as BBS and Field Observations.
- Detection of improving trends for feedback.

SRNS Commitment

Garry Flowers, CEO SRNS:

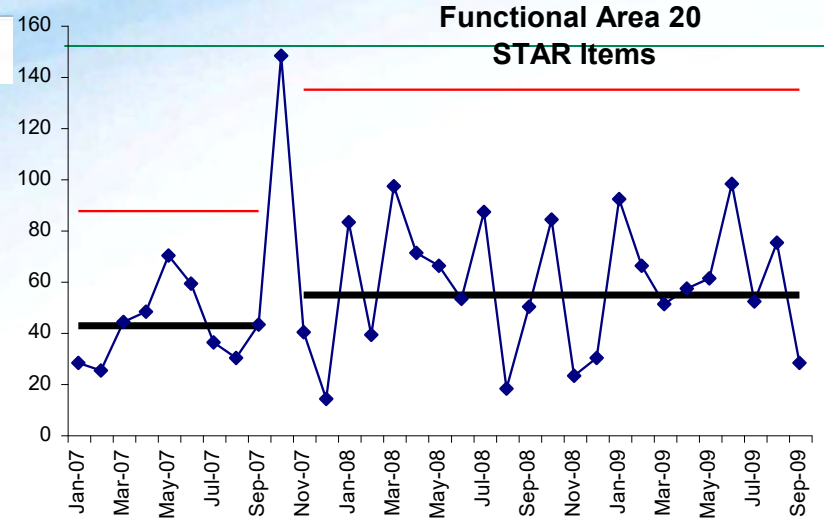
"We are implementing formal Statistical Process Control to more comprehensively assess events and root causes. We are using the SPC process to focus on leading/lagging indicators for feedback and continuous improvement"

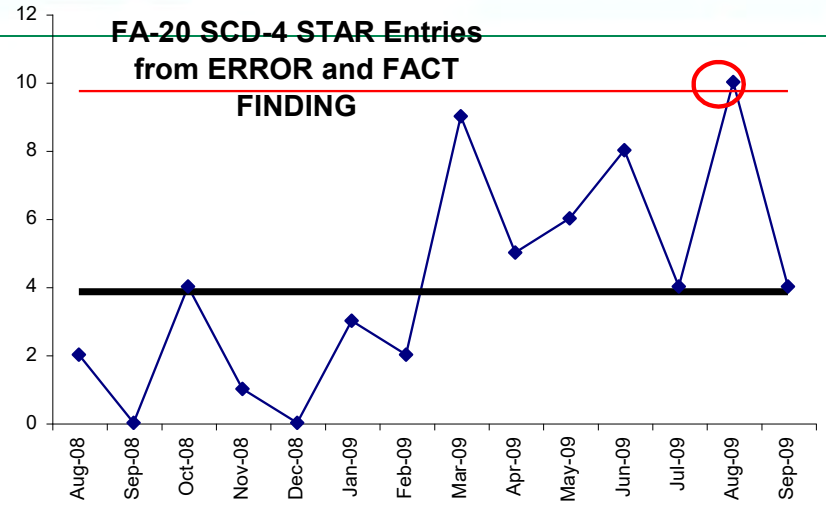
SRNS-A0000-2009-00079

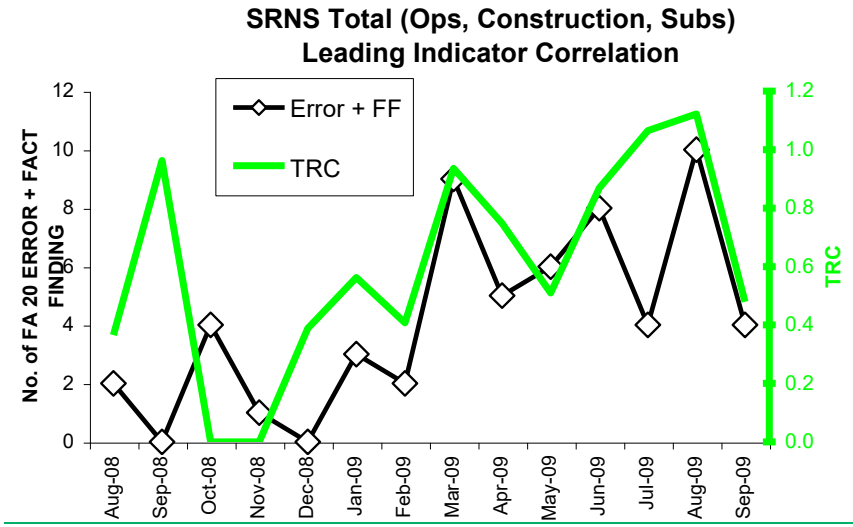
SRNS FY 10 POMC Extract

SRNS FY10 ISMS Performance Objectives, Measures and Commitments		
Objectives	**Measures**	**Commitments**
Enhance and improve environment,safety and health performance through various measures and commitments	Develop use of and fully utilize Statistical Process Control (SPC) techniques for monitoring and improving SRNS safety performance	Demonstrate full utilization of SPC through presentations and regular trend charts by 9/30/2010
	TRC Rate for OSHA Recordable Cases per 200,000 hours for SRNS Operations and Service Subcontractors	Maintain or improve performance as monitored by Statistical Process Control methodology
	DART Rate for OSHA Recordable with RWA or DAFW Cases per 200,000 hours for SRNS Operations and Service Subcontractors	Maintain or improve performance as monitored by Statistical Process Control methodology
	Reportable Personnel Contamination Events per 200,000 RWP hours	Maintain or improve performance as monitored by Statistical Process Control methodology
	Environmental Compliance Index calculated monthly	Maintain or improve performance as monitored by Statistical Process Control methodology
	Safeguards & Security Incident (1/8 hour reportable) Rate	Maintain or improve performance as monitored by Statistical Process Control methodology
	ORPS Normalized Score per DOE-EM calculations	Maintain or improve performance as monitored by Statistical Process Control methodology
	Average number of Emergency Drill cancellations per month	Maintain or improve performance as monitored by Statistical Process Control methodology
	Communicate complexwide to obtain "Best Practices" and other lessons learned for ARRA-specific worker safety.	Develop a communication forum to obtain ARRA Best Management practices by 9/30/2010
	Develop and monitor a set of leading performance indicators to enhance preventative actions and avoid reactive initiatives	Establish implementation of OS&H Leading Indicator Scorecard for use by data owners by 2/1/2010

SRNS LEADING INDICATOR - STAR CTS SCD-4 FROM ERROR AND FACT FINDING



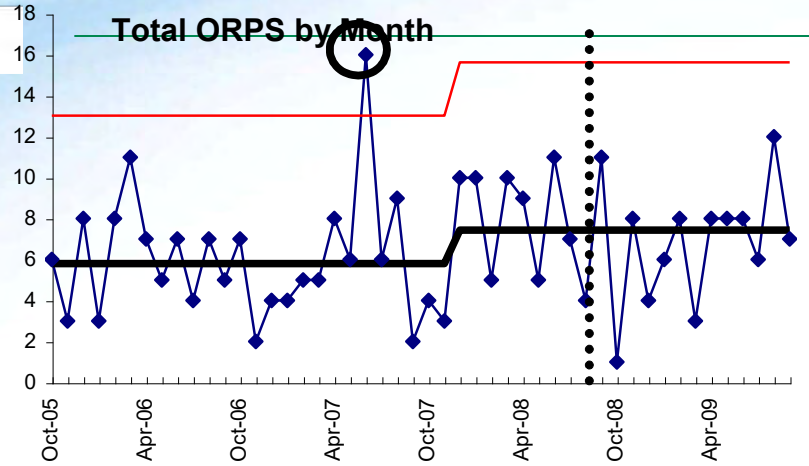


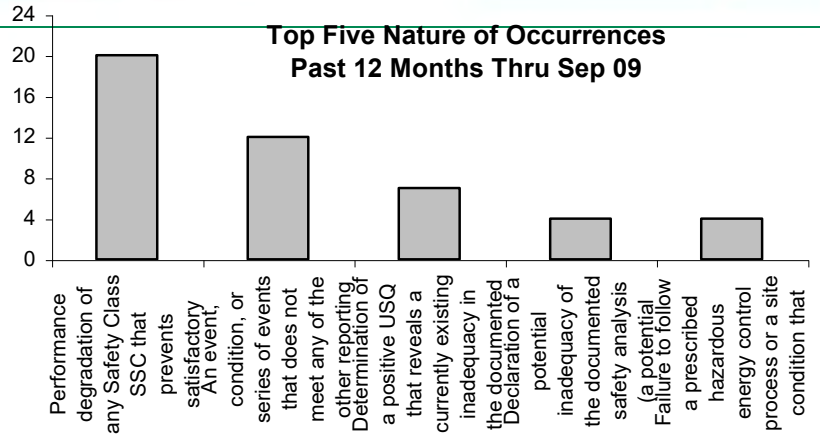


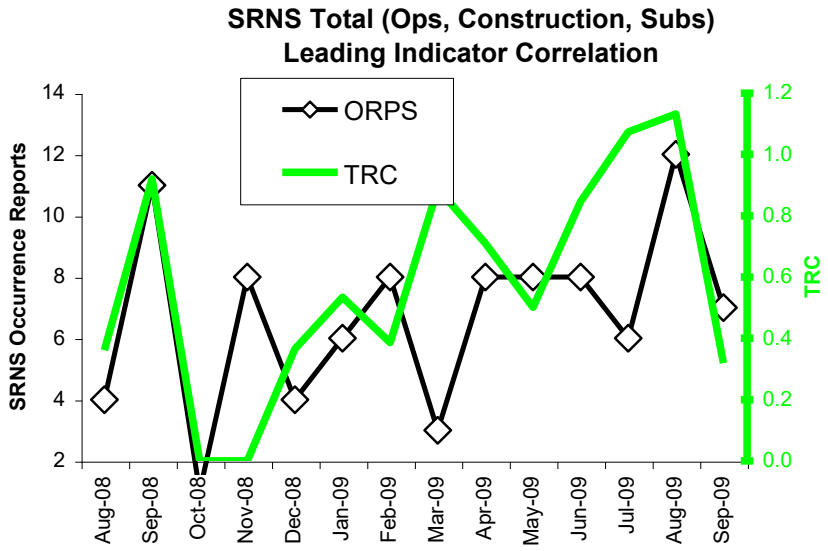
Occupational Safety and Health STAR Functional Area 20

Rate of use of STAR by OS&H has been stable since November 2007. Error and Fact Finding Entries appear to correlate to the TRC. Some Error and Fact Findings do originate with injuries, but many are from non-injury events.

SRNS LEADING INDICATOR - Occurrence Reporting (ORPS)





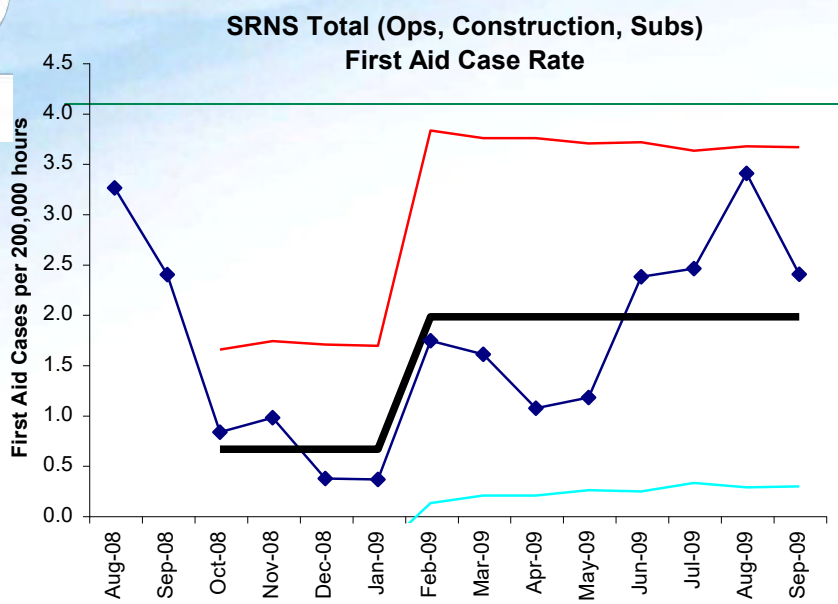


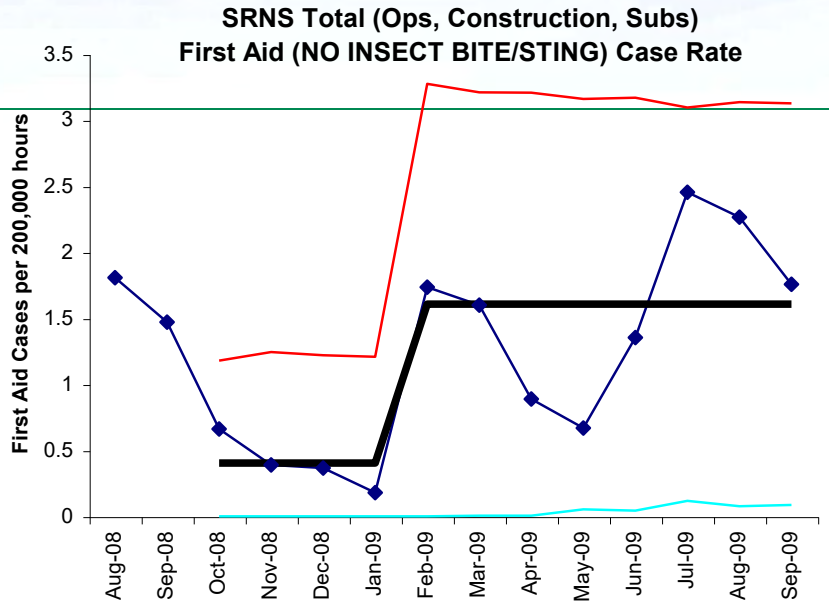
SRNS Occurrence Reporting and Processing System (ORPS)

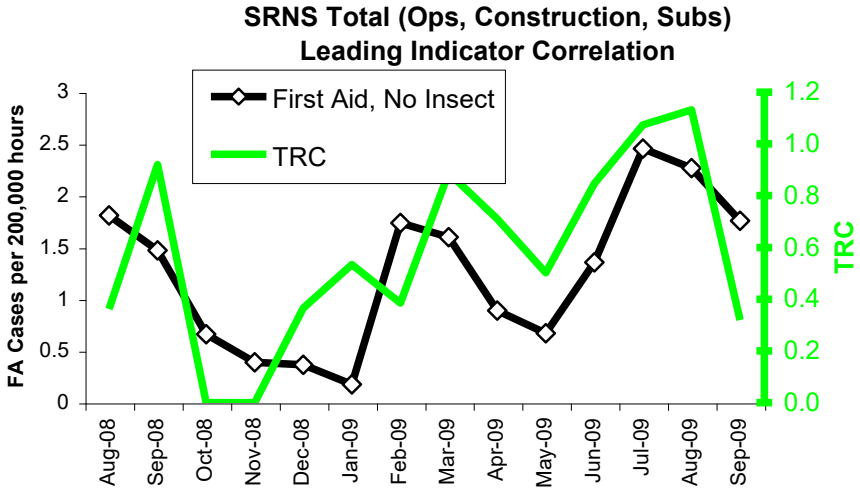
Total number of occurrence reports per month did spike in June 2007, then the baseline increased from 5.8 per month to 7.4 per month in 2008.

ORPS and TRC do not appear to be well correlated, but will be included in this package. Leading Indicators for ORPS reports may also be developed.

SRNS LEADING INDICATOR - Total (Ops, Construction, Subs) First Aid Rates



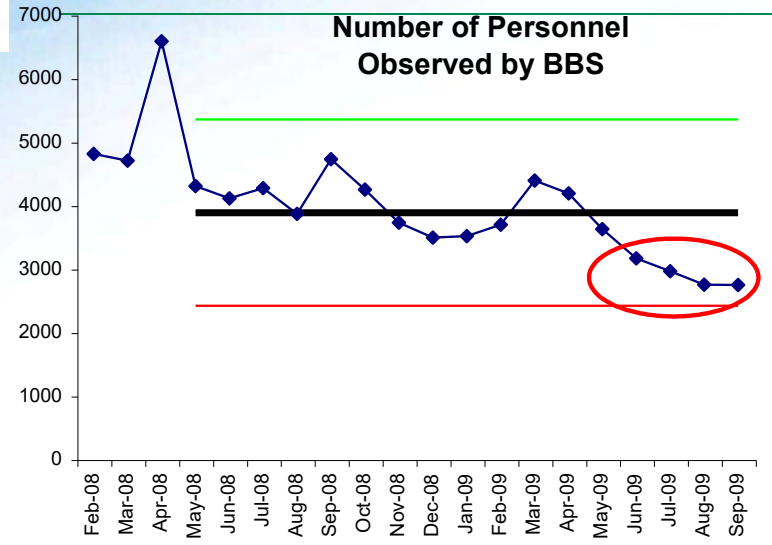


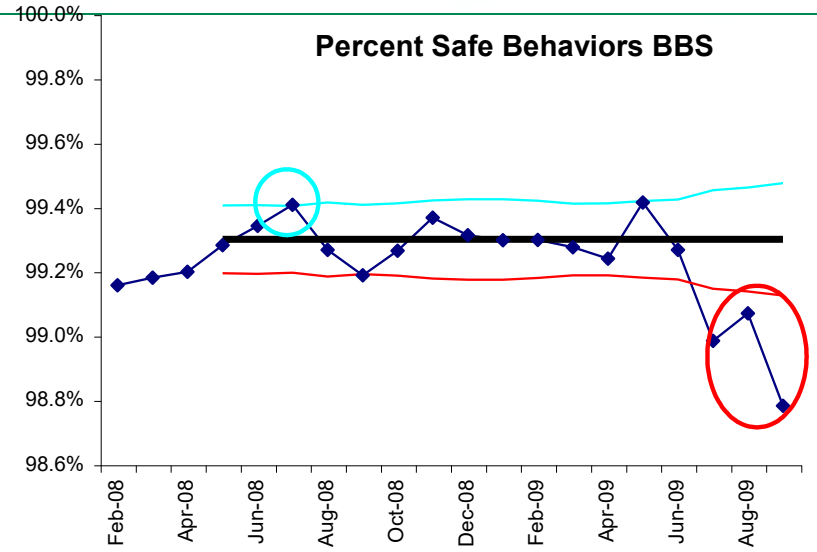


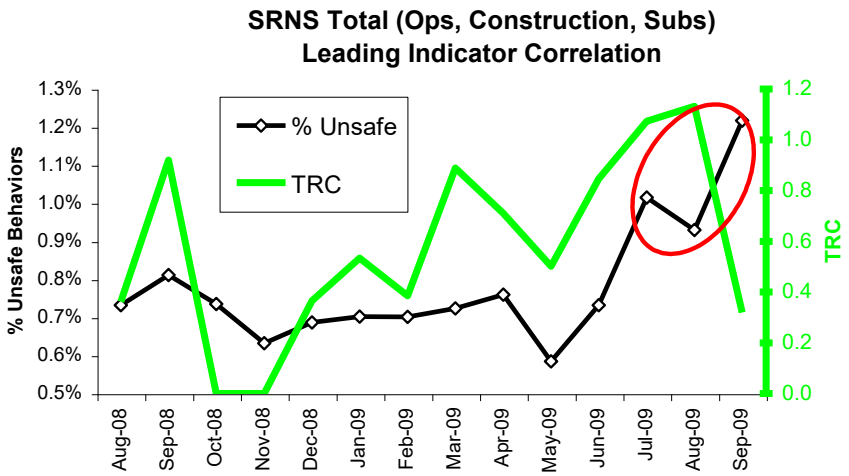
SRNS Total (Ops, Construction, Subs) First Aid Rates

There is a definite seasonal cycle in First Aid Cases, with increases in the summer. Most of the increase is in Insect Bites and Stings. From August 2008 through July 2009 there were 30 Insect Bites and Stings First Aid Cases, and only 1 MTC case. When Bites and Stings have been removed, the data correlates well to the OSHA Recordable Case Rate and may be used as a Leading Indicator.

SRNS LEADING INDICATOR - BEHAVIOR BASED SAFETY OBSERVATIONS







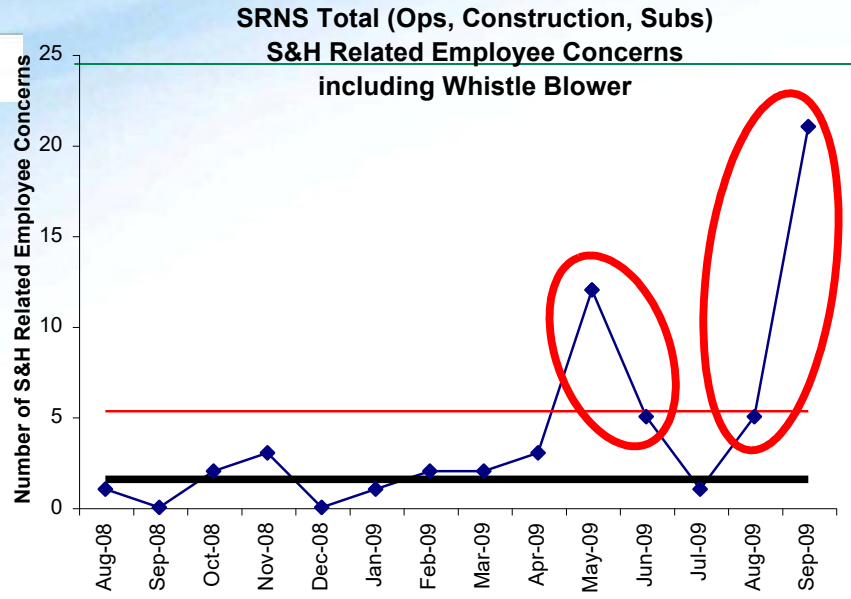
Behavior Based Safety Observations

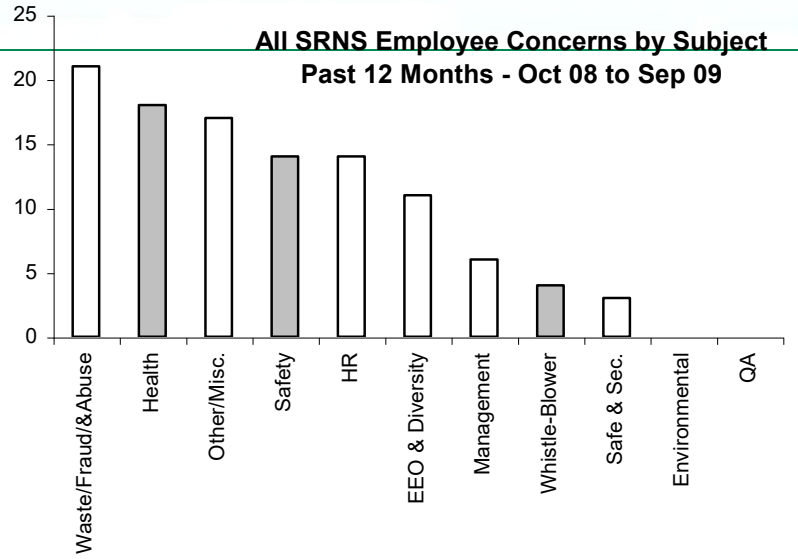
The new STAR BBS data source has been incorporated into these charts. Data prior to July 2009 are from Lotus Notes, data for July 2009 are from both Lotus Notes and STAR,

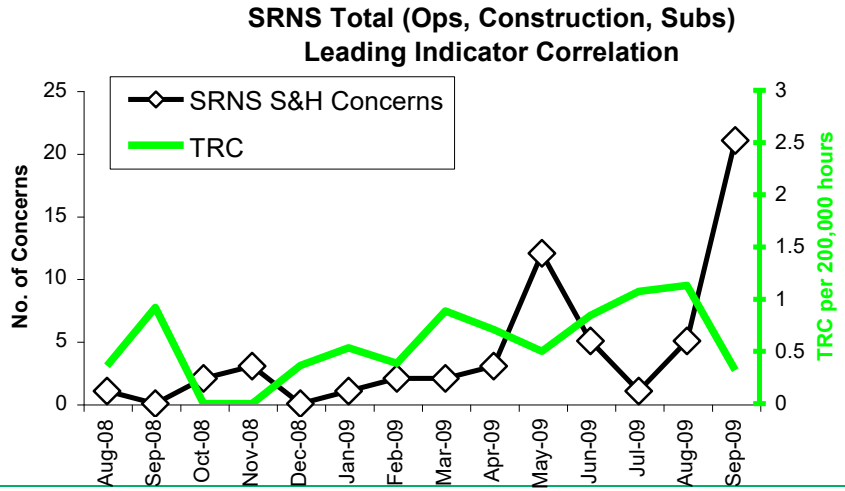
There has been a significant drop in Percent Safe Behaviors for July, August and September 2009. The number of personal observed is now a decreasing trend.

Percent Unsafe Behaviors appears to correlate well with the TRC rate, though they did diverge considerably in September.

SRNS Leading Indicator - S&H Related Employee Concerns







SRNS Total (Ops, Construction, Subs) S&H Related Employee Concerns, including Whistle Blower

S&H Related Employee Concerns took an extremely sharp increase in September.

Lessons Learned

- Formal criteria for “what is a trend”.
- Time savings due to standardization of charting (making and reading).
- Credibility with stakeholders.
- Minimize false alarms (knee jerks).
- Maximize detection of real changes.
- Timely response.

Note

- “Stable” does not imply “good”.
- Currently taking actions on a changing condition, an adverse trend.
- When actions take effect and we become stable, we will ask – are we stable where we want to be?

Improvement Model

- Identify trends and take appropriate actions to correct or reinforce.
- When stable, determine if results need improvement.
- Involve all employees in improvement.
- Use Leading Indicators to show timely results.
- Publicize the results.

Vision and Success

- Methods built upon valid theory
- Rigor, standardization, and low expense
- Statistical Process Control for trending
- Trends provide basis for action
- Trends show effects of action
- Resources are available
- Implementation is underway at SRNS

Contact

Steve Prevette

Steven.prevette@srs.gov

803-392-7684