USING LEADING INDICATORS TO AVOID MAJOR ACCIDENTS

STATEMENT OF THE HONORABLE JESSIE HILL ROBERSON, VICE CHAIR OF THE U.S. DEFENSE NUCLEAR FACILITIES SAFETY BOARD, AT THE U.S. CHEMICAL SAFETY BOARD'S PUBLIC HEARING ON *DEEPWATER HORIZON*

Good afternoon. I am Jessie Hill Roberson, and I am the Vice Chair of the United States Defense Nuclear Facilities Safety Board. My agency is an independent establishment within the Executive Branch of the United States government, and we are tasked with providing independent safety oversight of defense nuclear facilities operated by the Department of Energy that are covered by the Atomic Energy Act and have a function related to national defense. The Board's oversight mission covers all phases in the life of a defense nuclear facility: design, construction, operation, and decommissioning. In order to meet these obligations, my agency has spent an extensive amount of effort studying the history and nature of major accidents; the application of performance metrics as leading and lagging indicators; and the overarching role that organizational culture plays in determining the safety of high-risk operations. I would like to express my appreciation to Chairman Moure-Eraso and Members of the Chemical Safety Board for the opportunity to speak to you today about what we have learned and how we are using that information.

I want to be sure you understand what I mean when I use the word "oversight." In any high-risk or regulated industry, this word is often used and frequently abused. The dictionary definition captures my agency's approach very well – oversight is the act of providing "watchful and responsible care." This is not about auditing records for compliance with requirements; this is about technically challenging an industry to live up to its responsibilities, and to encourage that industry to continually improve itself. We believe that every organization conducting high-risk operations should have a good oversight program; effective oversight is a vital tool that helps the organization's leaders identify declining safety performance and problematic areas before the near misses and accidents begin to occur.

I'd like to talk a bit about our view on how major accidents occur. It has been observed that major accidents are usually characterized by coincidental breakdowns of multiple barriers rather than as a sequential progression of precursor events. The initiating event may be fairly minor, but as the successive barriers fail the resulting accident continues to grow in significance and consequence. The organization quickly becomes overwhelmed by the unfolding catastrophe and is unable to regain control of the situation. Accident analysts model this situation as an unfortunate alignment of the performance variability of the various operating elements (Hollnagel, 2004). Performance variation in physical systems may be due to design or construction deficiencies, inadequate maintenance, or environmental and aging conditions. Operator performance may vary due to production pressures, inadequate training, or inexperience. In the end, all high-risk operations are performed within the accumulated variability of these individual elements. In evaluating these performance variations, one cannot assume that the various elements are completely independent of each other. For example, a company facing financial challenges is probably postponing preventative maintenance AND taking shortcuts on operating procedures AND using suspect material and riskier technology, AND so on.

Clearly, safety in such an environment is achieved by minimizing the performance variability in each of the elements. In other words, we want to be sure that each barrier, whether it is a physical component, a computer system, an administrative procedure, or a human operator, is fully capable of performing its intended function whenever called upon to do so. Based on this consideration, we believe that any leading indicator program needs to, first and foremost, focus on monitoring and understanding the functionality of these barriers. Are systems receiving the appropriate surveillances and preventative maintenance? Are procedures being used, reviewed, and updated as expected? Are the operators and supervisors being trained, qualified, and exercised adequately to ensure that they have the appropriate level of knowledge and skills? Have sufficient staff and resources been provided to support the operations? In other words, leading indicators should not be viewed as predictors of accidents; rather, they are identifiers of accident-prone situations.

As we studied the various major accidents we noticed that in most cases there were strong, externally-driven pressures on the organization prior to the event. These pressures usually took the form of things like increased or decreased product demand, market instability, hostile takeovers, corporate mergers, public distrust, or conflicting priorities. While all organizations encounter these types of pressures periodically, in many of these cases the pressures were sufficient to challenge the wellbeing of the organization. Managers responded to the increased pressure by changing the organization or its operating mode. As a result, inconsistencies arose between the organization's current environment and the environment within which the organization learned to operate. Organizational behaviors that were once appropriate then became inappropriate or obsolete; the organization's priorities shifted and introduced a new bias into its collective decision-making and the level of risk it was willing to accept.

Most major accidents and near misses fit this model. NASA's major accidents, *Apollo 1*, *Challenger*, and *Columbia*, all occurred while the organization was under significant external budget and mission pressures. In the United States' nuclear power industry, the Three Mile Island accident, two near-misses at the Davis-Besse nuclear power plant, and regulatory interventions at other plants occurred during times of significant market deregulation and industry upheaval. The chemical, oil, and natural gas industries undergo frequent market instabilities, corporate restructuring, and societal pressures for environmental concerns; within that turmoil you will find the roots of Bhopal, Texas City, Prudhoe Bay, Exxon Valdez, and San Bruno, among other disasters.

We usually talk about organizational behaviors, but in reality constant tradeoffs between production and safety occur in the mind of each individual worker. In a world of incessantly changing demands, workers simply cannot do everything expected of them at all times (Hollnagel, 2004). The workers ask themselves, "can I do this thing quickly, or is it important enough to do it exactly correct?" Their answers to these questions are based on their values, training, prior experience, peer pressure, and their individual perception of the risk involved. When the organization is under duress, the workers may respond in unpredictable ways, and are likely to accept riskier behaviors. At one time or another we have all probably rushed through a yellow light, texted while driving on the highway, or jaywalked in traffic; actions we know we should not do but have justified to ourselves due to the pressures of the moment either without consideration of the risk or with a perception that the risk was low. One of the primary goals of the current focus on safety culture is to influence attitudes and behaviors so that these tradeoffs more often lean to the side of safety rather than production.

Consequently, we believe that it is important that any organization conducting high-risk activities needs to be watching for those external influences and regularly monitoring the collective decisions the organization is making. Are backlogs accumulating in training and preventative maintenance? Are we demanding more from less staff? Are sick leave, turnover, and employee concern trends suggesting that the workers are under duress? Has the balance changed between resources committed to safety and resources committed to production?

Earlier I mentioned that major accidents are characterized by coincidental breakdowns of multiple barriers; once the initiating event occurs there is no way to reliably predict the final outcome of the accident. Therefore, when it comes to avoiding major accidents during high-risk operations, safety must be based on completely avoiding the accident's precursor events. This is in contrast to the traditional approach to accident reduction, where the rates of precursor events are considered to be primary indicators of the safety program's effectiveness. This is not to say that an organization should not be watching for the occurrence of precursor events. Instead, the implication is that the organization needs to set an action threshold based on the occurrence of a single precursor event rather than the frequency at which precursor events are occurring. However, regardless of our intention to avoid major accidents, it is important to remember that we must still be prepared to react and mitigate the accident should it occur anyway.

We believe that when looking at performance measures and leading indicators, context is everything. The absolute value of a metric rarely conveys sufficient meaning from which one may draw a conclusion. Instead, only when the metric is normalized and placed into the proper context can one recognize the significance of the value. This can be illustrated with a simple example. Staffing levels can be easily measured by a direct count of the people within the organization; however, that value is meaningless until it is compared against the optimal staffing level derived from the anticipated work load and an appropriately designed staffing plan.

To fully understand context one needs to do more than just calculate a ratio between a measured value and a derived value. There will be times when an organization's decisions may appear to be contradictory to safety when in fact they are completely consistent with safety, and vice versa. The organization may be undergoing changes in mission or production, it may be transitioning to a different mode of operations, or it may simply be responding to changing market conditions. All of these changes may induce what appear to be negative changes in the safety metrics, but in reality those changes may mean that safety performance is actually stable or improving.

The key to putting the safety metrics into the proper context is to understand that operating organizations must maintain a balance between the priorities and resources committed to safety and those committed to production. In a simple model, the organization could spend all its resources on safety and go bankrupt, or it could spend all its resources on production and suffer disaster (Reason, 1997). In this model, companies drift through a safe zone between the two extremes. If they move too far to either side they experience an unacceptable consequence. But in reality, organizations do not float through a safe zone, they intentionally seek to operate at the edge between safe and unsafe in order to minimize the safety investment and maximize the production investment. This may seem like a risky proposition at first, but making a marketable product at a reasonable cost is what business is all about.

Given this perspective, it is clear that any leading indicator program needs to consider the functionality of both the safety programs and the production programs. By trending the data with time and comparing the results between the production and the safety programs, one monitors the organization's collective decisions regarding its priorities and its allocation of resources. One would expect that as production is increased, more resources should be devoted to the safety programs; as production decreases, the safety resources might also decrease unless maintenance work conducted during non-production periods will place an equal or higher demand on the safety resources than during production. By combining this information with the normalized results of individual metrics, the organization's leaders can make adjustments to the organization to ensure the continued balance of safety and production without waiting for the next accident to happen.

As I mentioned in the beginning, we have studied various approaches to leading indicators. There is no clear process by which one may identify the leading indicators most appropriate to a particular operation. Therefore, we developed a 5-step process for discovering a set of leading indicators tuned specifically to each organization's needs based on the models I've discussed.

1. Select appropriate production goals to be achieved and associated detriments to be avoided

2. Identify the key elements (i.e., people, processes, equipment) essential to achieving the goals as well as the key elements essential to avoiding the detriments

3. Determine metrics that will monitor functionality of those key elements

4. Track and trend relative changes between production-based metrics and safety-based metrics

5. Take prompt action when indications of imbalance exist between production and safety metrics or when any single metric falls below a predetermined action level

We have also identified the basic set of essential attributes that a leading indicator program should have:

- The selected leading indicators must facilitate an understanding of the organization's collective decisions about priorities and resources

- There must be a direct logical link between individual leading indicators and the functions they are monitoring

- The leading indicator process must allow the users to monitor relative trends between production-related and safety-related functionalities

- A leading indicator process augments but does not replace other oversight practices

- Some leading indicators need to monitor for potential external influences on the organization

- The occurrence of a precursor event needs to trigger an immediate evaluation and corrective action

- Individual leading indicators need to have defined trigger levels for prompting evaluation and corrective actions; the trigger levels should be derived from the logical link between the metric and the function it is monitoring
- Leading indicators must be “actionable”
- A small set of meaningful, actionable leading indicators that bears direct relationship to the work and the organization is more useful than a multitude of metrics without clear focus

This concept looks simple, but in reality each organization will have multiple production goals to achieve and multiple detriments to avoid, so this process will quickly evolve into a hierarchy of goals. For example, one production division may need to produce X kilograms of explosives per year while avoiding a serious explosion; a second may need to paint Y components per year while avoiding a serious fire; and a third may need to generate Z gallons of chemicals per year while avoiding a serious toxic gas release. Each of those production divisions has different goals and different detriments.

It can seem challenging at first to figure out what metrics should be employed to monitor the functionality of a program or component that you hope you never have to use, but it really isn’t that hard. If you are monitoring the functionality of a physical system, there should always be periodic inspections, surveillances, functional tests, and preventative maintenance work that need to be conducted; is that work getting done properly and on time? Do the results of the inspections, surveillances, and tests indicate full functionality? If you are monitoring the functionality of a group of people, there should always be ongoing training, routine assignments, staffing levels, turnover rates, and other indications of the ability of the group to perform the needed function when called upon.

There is one important caution. We often observe metrics being used inappropriately. The value of a leading indicator is in how close it relates to the barrier or function that it is monitored. The linkage must be clear and logical or else the organization can deceive itself into believing that conditions are better than they really are. One of my favorite examples is the use of personal safety metrics to infer that an organization has a good nuclear facility safety posture. These metrics may imply that the organization has a good personal safety program, but it says essentially nothing about that organization’s nuclear facility safety program. I know you have seen the same thing in the chemical industry.

In conclusion, I would like to say that my agency has always understood the need for balancing the priorities between production and safety. We have long believed that this concept must be one of the overriding principles of managing high-risk operations, but we have found that it was a difficult principle to put into practice. With this approach to leading indicators, we hope to see the next step in the implementation of that concept. We believe strongly that a leading indicator program focused on ensuring the functionality of the barriers designed to prevent the occurrence and mitigate the consequences of major accidents is essential to the successful conduct of high-risk operations.

Q and A's on the Defense Nuclear Facilities Safety Board's Leading Indicator Program:

1. *What is the role of the regulators in the collection and use of indicators for major accident prevention?* My agency is not a regulator, we conduct external oversight. We do not write the regulations, rather we ensure that DOE and its contractors are implementing the requirements that DOE has established. In that regard, what my agency does is collect information in a variety of forms that we then put into the context of the operation being reviewed and draw conclusions about the safety of the operation. When we see a potential decline in safety posture then we decide if action is necessary, and we bring the problem to the attention of DOE. In other words, we function as a leading indicator program for DOE. As for the role of a regulator in a leading indicator program, we believe that regulators should ensure that the organizations under their jurisdiction have established viable performance metrics systems; that they have identified which of those metrics will be used as leading indicators; and that they are proactively incorporating that information into their management strategies and daily operational decisions. We also believe that regulators should have their own leading indicator program. By going through a process similar to what I have described here, the regulator should be able to identify the key organizations and functional areas where they need to focus their main attention.

2. *Ideally, who is involved in the development of effective process safety indicators?* First, government and industry groups should work together in developing consensus guidance and a pool of subject matter experts to assist in designing and implementing performance and leading indicator programs for use in their industries. Once that is accomplished, however, the organization that will be using the performance indicators is the group that should develop them; no other party understands the workplaces and the processes as well. Remember, context is everything, and only the user can fully appreciate the context. An effective leading indicator program is a multi-tiered system of linked goals, essential functional elements, and associated performance metrics. Different people are involved at the different tiers; leaders should decide the goals to be achieved and the detriments to be avoided; program managers should identify the key functional elements relied on to satisfy the goals and avoid the detriments; and first-line supervisors and technical experts are in the best positions to identify the metrics that can be used to measure the functionality of those key elements.

3. *How does one know that a particular indicator is predictive of a major accident event?* This is one of the more common misunderstandings about the use of leading indicators for accident avoidance. There is no way to identify a metric that can reliably predict a particular future outcome; don't even try. Instead, the goal is to avoid accident-prone situations, and those can be predicted fairly reliably. The presence of conditions such as untested barriers, poorly maintained equipment, outdated procedures, insufficient or unqualified staff, inadequate quality control, uncontrolled hazards, overly-stressed workers, or ill-prepared supervisors are all widely recognized harbingers of accidents. The situation gets even worse if several of these conditions are present at the same time. That is why the focus of the leading indicator program should be on the functionality of elements relied on to assure safe operating conditions. Those elements are people, processes, and equipment, which are things that can be readily monitored. There is one other point that is very important to remember: organizations change, people change, goals change, and hazards change. The metrics you are

using also should be changing as necessary to ensure that they are still providing you with a valid indication of the status of the key functions you are monitoring.

4. *Can you provide some examples of the linkage between metrics and the functionality they are designed to monitor?* Let us start with an example of a bad linkage between metric and function. In DOE, contractors are expected to measure and report two parameters for worker safety programs: DART (Days Away, Restricted, or Transferred), and TRC (Total Reportable Cases). These two metrics may be effective for measuring the quality of a site's worker safety program; however, we often see them being used as an indication that the site's nuclear facility safety program is effective. In reality, there is little if any direct linkage between DART or TRC and the elements that one relies on to ensure the safe operation of a nuclear facility. Nuclear facility safety depends on elements such as radiation protection, criticality safety, nuclear safety analysis, conduct of operations, quality assurance, issues management, maintenance, and training and qualification. Appropriate metrics for these elements might be staffing levels, completion of routine workplace monitoring, currency of procedures and safety documents, frequency of procedure violations, satisfaction of training/qualification requirements, timeliness and effectiveness of corrective actions, and so on. A direct link between a metric and its associated functional element makes it clear what action is necessary when the metric falls below its trigger levels.

5. *Are there any pros or cons to allowing individual facilities or groups to collect their own performance data?* Yes, there are both pros and cons. The most obvious advantages are that the individual groups are in the best position to identify the appropriate metrics and to understand the meaning and the context of each metric, as applied to their operation, and they are also in the best position to take appropriate and quick action when a negative trend has been identified. This attention to detail and willingness to respond to new information are essential attributes of a successful learning organization. The most obvious disadvantage is that the system can be intentionally abused by inserting false data; but more likely the system could be inadvertently misused if managers did not design the system properly or if they focus too much attention on the numbers and not enough attention on the context. In any regulatory system, there needs to be a level of checks and balances between the regulator and the party being regulated such that intentional abuse is discouraged and inadvertent misuse is unlikely.

Suggested Reading List

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