A BUSINESS FOCUS FOR TECHNICAL SUPPORT STAFF

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Abstract

It has become the norm for nuclear power plants to be operated with a focus on achieving performance goals for safety and reliability of production. However, the business goal has to include the control of costs to ensure success in a competitive power market. While business managers accept that the three elements of production, safety and cost control are compatible, technical staff are often skeptical. The purpose of this paper is to examine the skepticisms and to give the technical basis for nuclear professionals' support in controlling the costs of production and safety. The management of financial risk and safety risk is related to selected performance areas to emphasize the importance of a professional approach to technical support work.

1. Introduction

For the last two decades the nuclear industry has focused on improving the performance of operating nuclear power plants. The stations are supported by both national and international industry organizations in the area of safety and reliability. They provide independent assessments, performance criteria and benchmarks. To date there has been a substantial improvement in safety and reliability. However, there are still opportunities for further improvement [1].

Another important evolution of the nuclear industry has been the move to deregulate power generation. This has exposed nuclear power plants to additional competitive pressures. Successful operators have to achieve safe and reliable production while controlling their cost of production. Indeed, the renaissance of the nuclear power industry is dependent upon the industry's effectiveness in controlling costs. There has not been as much industry cooperation on controlling costs because utilities are often left to fend for themselves after achieving a high level of performance in safety and reliability.

In this paper "cost control" does not mean the traditional "budget slashing" or "budget boosting" that is often imposed on organizations by managers who care more about today's budget figures than the continuous improvement of performance. Budget slashing is often done without understanding the effect on the organization which results in degraded performance. Budget boosting is often a case of using money as a solution to a problem without an improvement in performance. We use the term "cost control" to mean improving a station's performance in safety and reliability and at the same time maximizing efficiencies to extract the maximum value from each dollar spent.

With financial decisions being made at the utility's executive level, technical support personnel can be forgiven for being skeptical that the business goal of safety, production and cost control can be met; or, even that it is the correct goal for them. The reasons that many technical people give for this skepticism include their belief that:

1. Production and safety are incompatible; and,
2. Improving performance in production or safety requires larger O&M budgets.

A nuclear professional would not accept 'belief' as a basis for action. Correct actions (decisions) are based on a correct assessment of risk. Incorrect actions follow from incorrect assessments of risk. It is through risk analysis that we can provide the technical basis for effective decision making in support of the business goal.

As a business, a nuclear power plant owner operator faces three risk factors: production, safety and financial. The interrelationships among these three risk factors are discussed in Section 2. It addresses the skepticism of station staff with a technical basis for the role cost control plays in operating a high performance nuclear station. Section 3 will address impediments to effective cost control on the job.

2. Risk Management

An effective Risk Management program [2] is essential for a successful business operation that exposes the owner, the public and the environment to potential harm. Decision makers have to address two separate aspects as shown in Figure 1.

<u>Risk Assessment</u> – The engineering and business analysis has to be done to assure the risk of harm and financial loss is acceptable. This is for internal decision making and compliance with regulatory requirements.

<u>Risk Acceptance</u> – Those exposed to the risk from operation of the NPP have to accept the risk. The operator of the facility has to be effective in communication the risk, and its acceptability, to the public. A potential failure of risk acceptance is one of the larger financial risks to which the operator is exposed.

The devastation of the commercial airline industry after 9/11 is an example the extent of financial damage that can result from a failure of risk acceptance. The sensitivity of food business to public acceptance of risk is often in the daily news.

Earlier work [3] looked at using risk management methods to support the operating goal. The goal is to maximize daily production throughout the plant's life. This amounts to finding the optimum balance among: annual capacity factor, expected plant life, unit electrical cost and, safety and compliance.

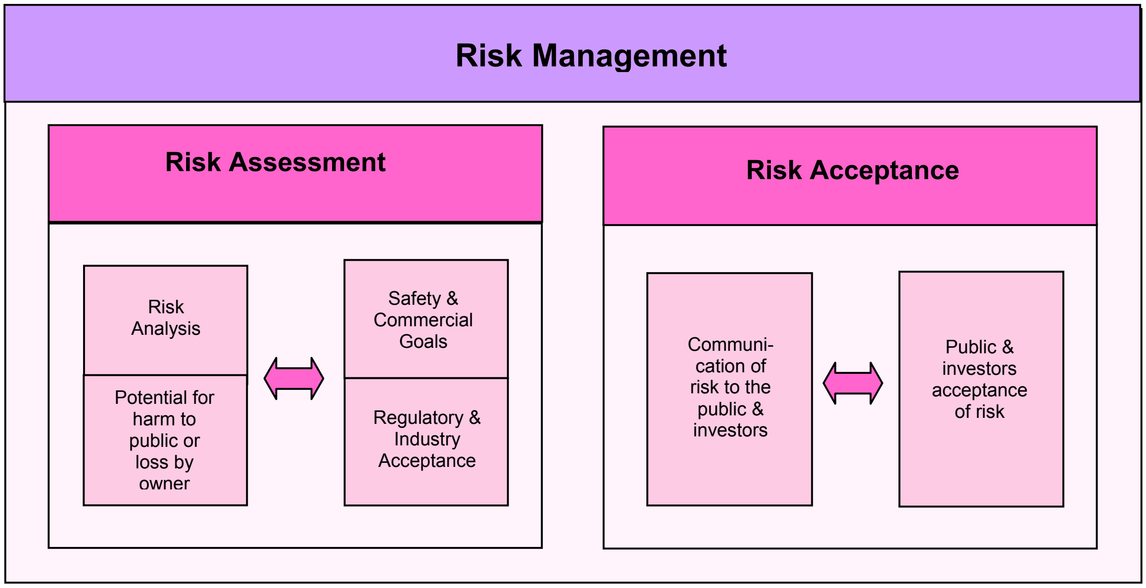

Figure 1. - The key elements of a Risk Management program

In order to analyze the convergence of safety, production and cost control, a model was adopted for the design basis and operation of an NPP. The model summarized in Table 1 which sets out the plant operating conditions, the operating objective of each condition, and the consequences of failing to provide the barriers associated with each operating condition. This is a standard model for a NPP that would be built today. [4,5,6] .

The frequency of plant operating conditions assumes a 90 percent capacity factor. This is the design basis for production to be used in the business model of the utility. It is the basis for a power purchase agreement and analysis of the return on investment. The frequency of abnormal operating conditions are the design basis for nuclear safety. These criteria are deemed to provide an acceptably low risk to the public from operation of the station.

The operating objectives for each of the operating conditions are the defence in depth layers of protection. It is these multiple independent layers that provide the risk reduction required for public safety. The station's management system incorporates the means to achieve the operating objectives. In Table 1 examples of the means to achieve the objectives are given for each operating condition. Consequences of a failure to achieve the operating objective are given for each operating condition. In all cases both production and safety are compromised.

	NOC	AOC	DBA	BDBA
Plant Operating Condition	Normal Operating Conditions • Configuration of SSCs intended for production of power. • Process system provide control/ cool/contain safety functions.	Anticipated Operational Conditions • Configurations of SSCs not intended for production of power • Corrective actions needed to restore process system capability for control/cool/contain functions.	Design Basis Accidents • Process systems not capable of providing safety functions. • Independent safety systems provide control/cool/contain functions.	Beyond Design Basis Accidents • Failures of process and safety systems not included in the design basis. • Safety systems not capable of providing control/cool/contain functions to protect the core.
Frequency	0.9 yr (production) 0.1 yr. (maintenance)	1-10^{-2} events/yr	10^{-2} -10^{-5} events/yr	<10^{-5} events/yr
Operating Objective	• Maintain NOC and production targets • Prevent precursors to operational events (AOC/DBA)	• Restore NOC • Detect and correct AOC	• Mitigate consequences of an accident • Safe shutdown state with independent control/cool/ contain functions	• Mitigate of consequences of a release of radioactivity • Emergency response
Means to achieve objective: Equipment and human perfor-mance	• Quality design/ commissioning/ operation/ maintenance • Knowledge and skills training • Procedure compliance • Preventative maintenance • Plant status & configuration control	• Surveillance programs • Availability of standby protective systems/features • Corrective maintenance program • Management of SSC ageing • Knowledge and skills training	• Preserve the design basis by plant status & configuration control • Availability of safety systems • Knowledge & skills training	• Emergency preparedness • Emergency planning • Communications • Knowledge & skills training
Consequen-ces of failures of equipment and human performance	• Reduced capability of SSCs from failures of plant status and configuration control • Increased frequency of precursors to operational events • Lost production.	• Reduced availability/ capability of protective features • Increased probability of an event challenging the safety systems • Lost production.	• Reduced availability/ capability of safety systems • Increased probability of fuel damage and radioactive release • Lost production.	• Reduced capability to mitigate radiological consequences • Increased health effects for staff and public • Lost production.

Table 1. – Model for the design basis for a NPP and its operation.

2.1 Production vs Safety

Mosey [7] identified five interrelated categories of institutional failures that lead to reactor accidents. They include priority of production, failure to recognize the importance of safety, and failure to provide adequate resources. This leads to the question, "Is it possible to be successful in achieving a business goal of safety, production and cost control?"

Poor equipment and human performance cause lost production and, at the same time, increase the risk of exposing the environment and the public to radiation. There is a general consensus on the synergy between the production and safety goals. However, the consensus is not universal because capacity factor and risk are, respectively, concrete and abstract performance measures.

It is possible to promote production to the detriment of safety. However, such decisions are incorrect and made in organizations that do not hold decision makers accountable for their actions.

2.2 Safety and Production vs Cost Control

The focus on station performance in achieving safe and reliable production of power has become the norm. In 1992 Pate [8] recognized the need to control costs as well as pursuing safety and reliability goals. There are three elements of the unit electrical cost that a station can control to some degree: O&M costs, forced outage losses and plant availability.

Pate compared O&M costs for plants to their performance level (INPO) in achieving safe and reliable operation. He found

- a wide variation in O&M costs (per kWh);
- lower cost plants at all performance levels; and,
- only lower cost plants at high performance levels.

The general pattern is illustrated in Figure 2. Of particular interest to us from Pate's analysis are the following observations:

1. The average O&M cost for low performing plants could be as much as twice that for high performing plants. This means that a significant part of the costs are independent of the safety and reliability performance.

2. Better performing plants in Europe and Japan were achieving lower O&M costs while having higher unit availability and lower forced outages losses.

The wide variation in costs for a given level of performance led the US utilities to introduce a standard nuclear performance model for work management process [1]. This model gives a reference management system for assessment and benchmarking. It has contributed to the dramatic improvement in capacity factors

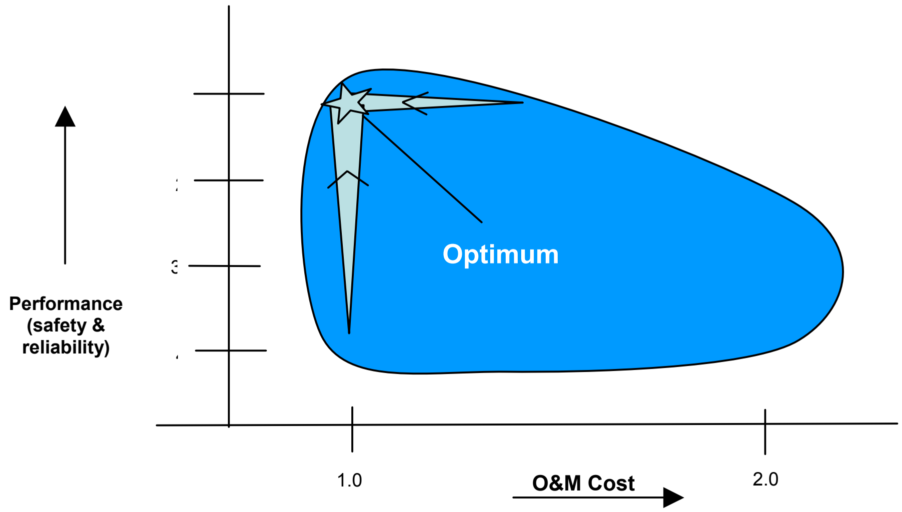

Figure 2. – The Cost-Performance envelope for nuclear power plants [8]

from 74% in 1994 to 90% in 2002 [9]. At the same time O&M costs dropped from 1.78 to 1.26 cents/kWh.

Karns [1] has reviewed the success of the standard nuclear performance model in its application at US plants. To appreciate the success of the US utilities it is to be noted that their average capacity factor in 1980 was 56%. The programs in most other countries are now under performing relative to the US.

It is important to note that, while productivity was improving, safety performance was improving as well. The following safety indicators all showed substantial declines:
- unplanned automatic scrams
- safety system performance
- industrial safety accident rate.

Improved Performance Requires Bigger Budgets?

Pate provided the raw data in his 1992 “Excellence Versus Cost” speech to INPO executives. It showed the number of excellent plants tripled from 6 to 18 from 1986 to 1991, while average O&M costs for the excellent plants remained constant at 33% lower than US industry as a whole. If significant added O&M expenditures had been required to attain excellence, it would have reflected in, at minimum, a convergence of O&M expenditures if not significant higher average O&M costs. This was not the case.

Indeed, this is evidence that the highest levels of safety, reliability and economic performance go hand in hand. The focus for an under-performing plant should be to ensure changes in policy and improvement initiatives and programs are sensible- in that they do not cause the utility to spend money unnecessarily. If nuclear electric generation is not competitive in the marketplace, excellent performance by environmental, safety, or reliability measures will be a moot point.

2.3 Financial Risk and Station Performance

Station Staff are not as well versed in the financial risks associated with their performance as they are in the safety risk. This section looks at the financial risk associated with degraded equipment and human performance. It uses the design basis model from Table 1 supplemented by a financial model. The costs shown in Table 2 have been selected as representative of current CANDU technology. They are compatible with the models used in a recent study for the Canadian Nuclear Association [10].

Table 2. – Model for plant costs

Parameter	Cost
Output	1000 MWe
Capacity factor	90%
Life-time	30 yrs.
Plant cost	$3B
Fixed O&M	$13/MWh/yr
Replacement power	$1.5 M/day

The financial risk is modeled as the potential for lost production and unplanned equipment repairs or replacement. It is assumed that the business model would incorporate a contingency for five percent of the annual production being at risk. This corresponds to about $25M.

The cost of replacement power and repairs is estimated for five categories of events that would result in lost production. The estimates are shown in Table 3 with the estimated number of days of lost production. Category 5 events are life limiting and assumed to reduce life expectancy by one-half. The estimates are consistent with Canadian experience.

Assigning an equal risk tolerance for all categories of events, each category is then assigned one-fifth of the $25M contingency. To manage this risk, the frequency of events must be low enough that no more than $5M/yr is at risk for each category. This leads to the derived cumulative frequency for each category of events shown in Table 3.

To determine a derived frequency for each event within a category an arbitrary assumption is made that there are ten potential independent events in each category. It is not necessary to do a more refined analysis for our current purposes. The derived event frequency is shown in Table 3.

Cate-gory	Event	Production Loss	Cost of replacement power and repairs	Derived Cumulative frequency (all events/yr)	Derived Event Frequency (events/yr)
1.	NOC - Equipment fault, and corrective maintenance requiring forced/extended outage to repair	3 days	$ 4.5 M	1	10^{-1}
2.	AOC - Active system/ equipment failures requiring forced/extended outage for repairs and inspection	10 days	$ 15 M	$1\text{-}10^{-1}$	10^{-1} - 10^{-2}
3.	Active system failures that require major repairs before restart. DBA events including a small release of radioactivity to R/B.	30 days	$ 45 – 60 M	$< 10^{-1}$	$< 10^{-2}$
4.	Major equipment replacement and repairs DBA events with large release of radioactivity to R/B.	100 days	$ 150 - 250 M	$< 10^{-2}$	$< 10^{-3}$
5.	Remove plant from service - life limiting equipment and performance failures - severe accident	15 years (0.5 of life + 3 years replacement power)	$ 3 B	$< 10^{-3}$	$< 10^{-4}$

Table 3. – Derived frequency limits for events leading to lost production.

The event frequencies derived to manage financial risk at an acceptable level are essentially the same as those for safety risk in Table 1. The first order model used here for financial risk has a higher event frequency for loss of plant events. However, the public does not have equal risk tolerance for low consequence and high consequence events. Neither do investors. If the tolerable event frequency for the loss of plant events is reduced by another factor of ten the financial and safety risk limits line up.

This model leads us to the conclusion that the same plant Management System would be developed for managing financial or safety risk.

3. A Skeptical Enquiry

Nuclear professionalism is being emphasized within the industry as a necessary ingredient for successful plant operations. A business focus is now considered one of the 'soft skill' competencies of a nuclear professional [11]. In this section we look at some aspects of technical performance from the perspective of the business goal. The following are examples of attitudes that skeptics hold in conflict with a culture of professionalism and the business goal.

- The quality of performance can be ‘elastic’;
- It is a job and not a profession;
- The use of technical ‘standards’ is voluntary;
- Corrective actions are a burden; and,
- Safety margins can be used to improve production.

The following discussion is based on the risk model discussed in Section 2 and elements of a plant Management System.

3.1 “*The quality of performance can be elastic*”

The attitude that the, ‘*quality of performance can be elastic’*, assigns some work activities greater significance towards achieving the business goal. The importance of quality in performing tasks associated with the different safety barriers is shown in Figure 3. Examples of programs and activities from the Management System are shown for each barrier.

Figure 3 illustrates the importance human performance in maintaining the safety provisions. The normal perception is that a high standard of performance is required for the systems to mitigate the consequences of an accident and a lower standard is acceptable for the other barriers. This is consistent with the normal perception, ‘*nuclear power plants are safe because they have safety systems*’.

The design basis model in Table 1 specifies performance requirements for all barriers. A failure to maintain them as fully effective is to expose the station to a greater risk of an accident and its consequences. A nuclear professional, who is trained to understand risk management, places equal importance on maintaining all barriers as intended by design. That is, ‘*nuclear power plants are safe because of the way they are operated*’.

It is a common perception that safety provisions for beyond design basis accidents are not as important as for design basis accidents. This is seen in the failure of emergency response efforts for disasters such as severe hurricanes. However, a nuclear professional understands the safety provisions for beyond design basis accidents are an integral part of the plant’s design basis as well.

An effective Management System supports and promotes a professional work culture. This compensates for the perceived lower importance of activities related to preventing accidents. The result is all safety management programs and work activities are seen as being equally important in achieving the business goal.

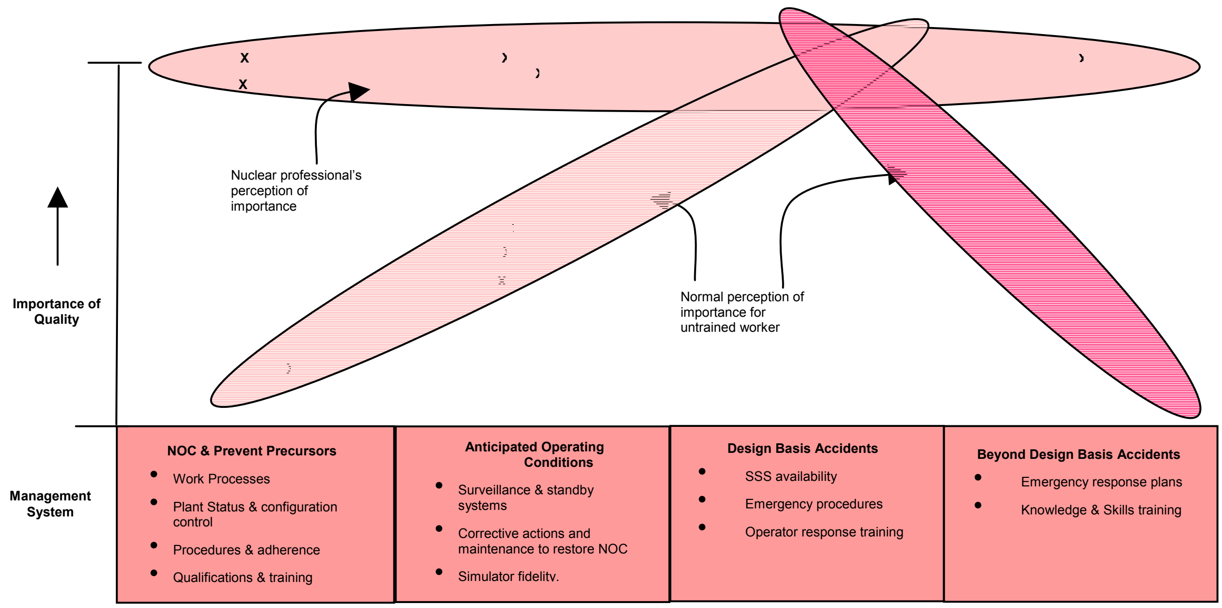

Figure 3 – The perception of the importance of the quality of human performance vs the type of safety barrier

3.2 "*Corrective Actions are a burden*"

The attitude that , '*corrective actions are a burden',* leads to assigning them a lower priority than normal work in achieving the business goal. The categorization of events for corrective actions is illustrated in Figure 4. The triangle shows the number of events that would be the performance targets for an effective Management System in achieving the business goal.

Operational safety programs are put in place so that the plant is operated as intended by design for safety. That is, there must be programs to control the operating configuration and to maintain the status of the plant and equipment. To achieve the operational safety objective the management system includes a Corrective Action Program. This program provides a means of addressing deficiencies in the performance of the station's work activities. It also provides a means to prioritize the work needed to correct the deficiencies.

If the Corrective Action program is not effective, the station's performance degrades. The degraded performance generates more corrective actions requiring more resources to address them. This spiral downward requires major interventions to restore performance levels.

An effective Corrective Action program is an important tool in cost control. As performance degrades the width of the event/deficiency triangle in Figure 4 increases. A high standard of performance in all work activities will narrow the pyramid. Optimizing performance and cost is based on optimizing the effectiveness of the corrective action program.

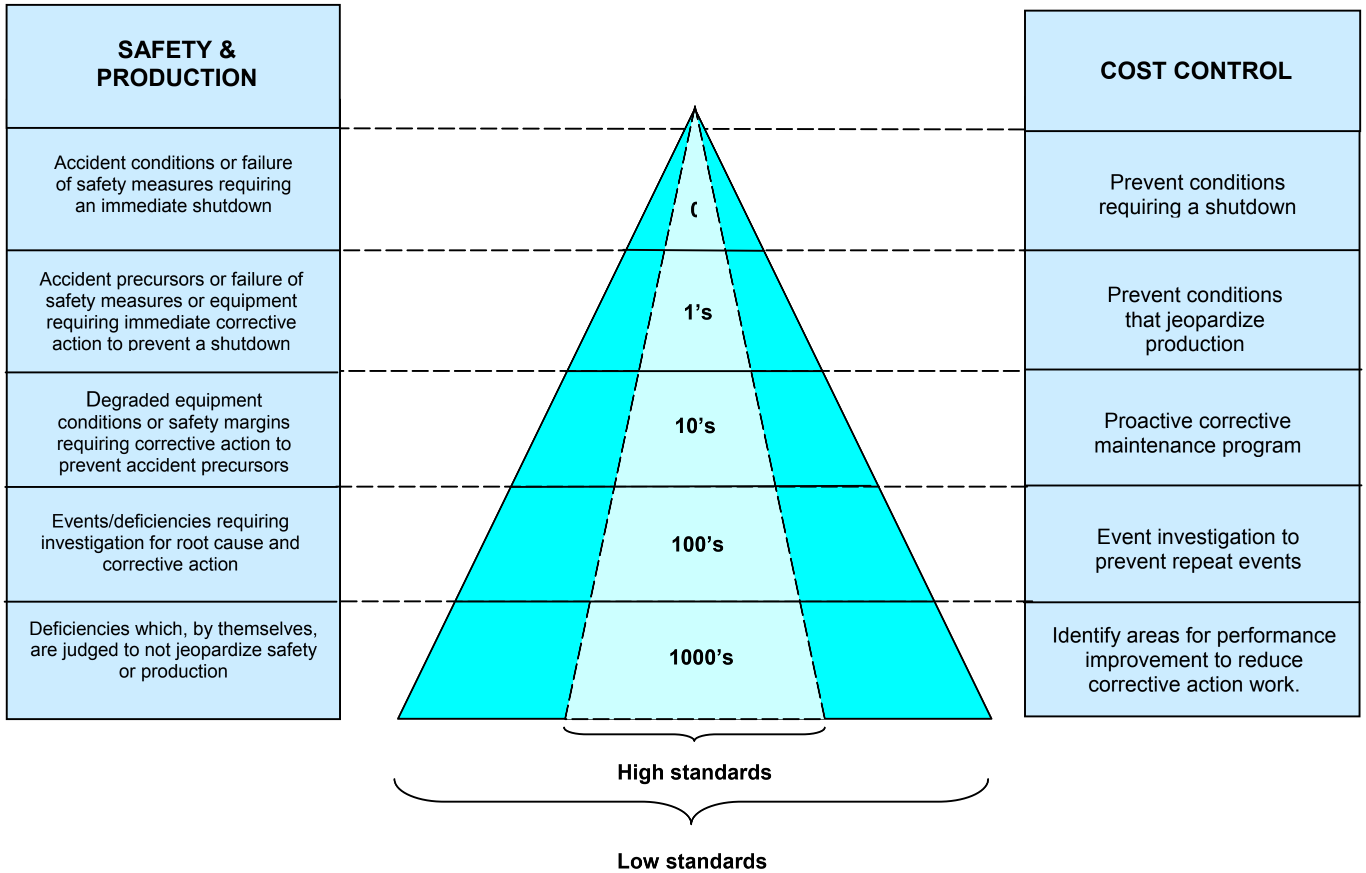

Figure 4. – Corrective Action Program in support of the business goal

3.3 "The use of technical standards is voluntary".

The attitude that, '*the use of technical standards is voluntary*', leads to the substitution of personal standards for the consensus standards of experienced professionals. The result is a lower quality of performance because it is the most error prone of human performance modes [12].

A technical standard is subjected to a very thorough review and acceptance by a panel of technical experts. The use of the standard is a readily available means to perform work according to current best practices.

The use of personal knowledge and judgment, when solving problems, seems to be a way of saving time and effort. However, it presumes that the individual has the knowledge and capability equivalent to the professional consensus that is embodied in a technical standard. Moreover, the station's Management System must include checks and balances to ensure the work is performed to the level it would be if a technical standard were adopted.

The challenge for the Management System is seen by comparing the two approaches. The adoption of a standard is a rule based performance mode which would have a success/failure rate of 100:1. The reliance on personal skills only is a knowledge based performance mode with a success/failure rate of 2:1. In this latter case, the Management System has to compensate for the more error prone work.

The voluntary adoption of standards is a means for achieving a higher level of performance at a lower cost. It is one element of an effective Management System that achieves high performance while controlling costs. This use of standards as a cost control tool is overlooked in the skepticism about their value.

3.4 "Safety margins can be used to improve production"

The attitude that, '*safety margins can be used to improve production*', tolerates operation outside the design basis. This increases both the financial risk and the safety risk. The operating ranges for the different operating conditions included in the design basis (Table 1) are shown in Figure 5.

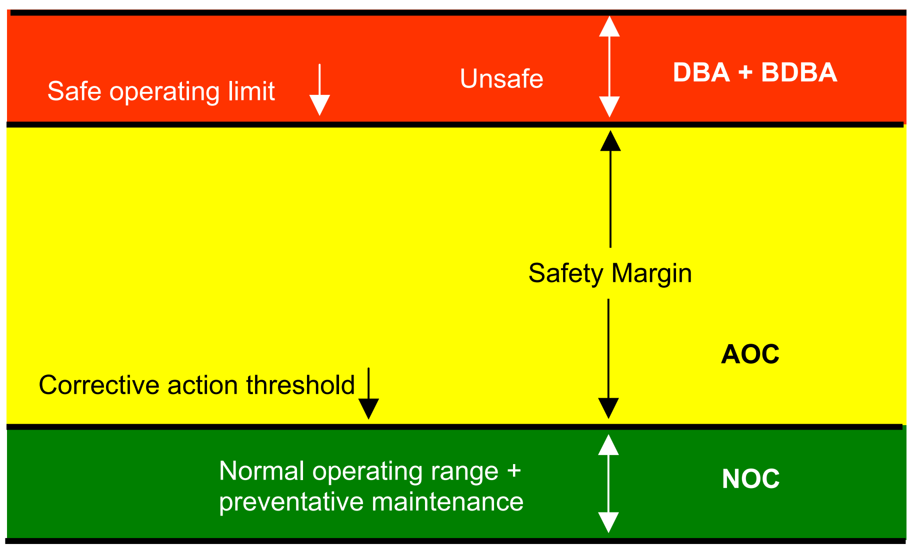

Figure 5. – Implementation of operating limits for safety and production

The operating goal is to stay within the normal operating range intended by design. It's boundary is the threshold for corrective actions to restore operating conditions to their normal range. At the other extreme, the safe operating limit is the boundary of operating conditions where safety systems would intervene to protect the plant and the public.

The safety margin is provided by the design for two purposes:

- to provide the ability to correct anticipated transients before they challenge the safe operating limits and result in lost production; and,
- to provide extra confidence the plant is not being operated unsafely due to errors and uncertainties.

Expanding the normal operating range by reducing the safety margin has two effects:

- an increase in safety risk because level 2 of defence in depth is weakened; and,
- an increase in the financial risk because it is more likely a transient could not be corrected before a shutdown would be required leading to lost production.

A proactive pursuit of the operating goal maximizes capacity factor at the same time it maximizes the margin of safety. Thus, a professional pursuing a high standard of performance in maintaining the design basis is working to achieve the business goal.

3.5 "*It is a job not a profession*"

The attitude that , '*it is a job not a profession*', removes personal commitment from the effort to achieve the business goal. Technical support staff need specialized education and training to be an 'expert' in performing their work. Beyond that they need the professional's commitment to high standards and continuous improvement of their personal performance.

The forward of "Principles for Enhancing the Professionalism of Nuclear Personnel" [13] states the following:

> *The nuclear professional is thoroughly imbued with a great respect and sense of responsibility for the reactor core- for reactor safety- and all his decisions and actions take this unique and grave responsibility into account.*

The need for professionalism becomes self-evident when the individual recognizes that

- one's performance has the potential to jeopardize the business, the public and the environment; and,
- no one has the right to place another at risk through deliberate action or negligence.

This brings us back to the beginning of the paper – correct decisions and actions are based on a correct understanding of risk.

As operators have adopted conservative decision making, the number of high performing stations has increased. The risk to operating a nuclear power plant has decreased as the economic and safety performance increased.

Once professionalism is instituted, the nuclear utility needs a strong nuclear safety culture, one that prevents operators from slipping back into complacency, overconfidence and a basic lack of respect for the nuclear reactor. Professionalism is (still is) the tool to counter non conservative decision making and thus protecting the public AND the investment of the shareholder.

4 Summary and Conclusions

The business goal of production, safety and cost control is essential for a renaissance of the nuclear industry. To achieve this goal technical staff need to have a business focus in their decisions and actions. The 'buy-in' to the business goal will not be effective without a strong commitment to professionalism.

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