Facilitating Regulatory Transformation through an Understanding of the Current Levels of Safety

Background

The NRC has established Safety Goals that set forth a measure of "How Safe is Safe Enough" for the commercial nuclear power industry. These Safety Goals were established via a Policy Statement in 1986[1]. Since that time, the NRC, the U.S. industry, and the global nuclear community have performed extensive research and analyses aimed at understanding the true level of safety in the operating fleet of reactors. These include hundreds of millions of dollars in research into severe accidents and many additional millions of dollars in plant-specific analyses and targeted safety studies. A recent EPRI White Paper[2] provides a technical summary of recent NRC and industry work and documents the substantial margin that is now understood to exist between the NRC's subsidiary safety objectives and the prior definition of "How Safe is Safe Enough." This enhanced understanding, obtained under NRC leadership and based in large part on state-of-the-art work performed by the NRC staff[3,4] has demonstrated that not only has the US nuclear industry improved safety over time, but that the perceived margins to the NRC's quantitative Safety Goals are far greater than originally expected.

This important insight is valuable in the NRC's on-going effort to evaluate opportunities to transform the regulatory processes. The purpose of this paper is to outline the nature of the technical and regulatory implications and recommend areas where these implications can be used in transforming key regulatory processes.

Technical Implications

For the past 20 years, the NRC has been a global leader in pursuing a risk-informed regulatory environment. By using a risk-informed decision making process the NRC and the industry have focused their attention on issues commensurate with their safety significance. This focus has largely been built on the perception that meeting the core damage frequency (CDF) and large early release frequency (LERF) subsidiary safety objectives of $1x10^{-4}$/rx-yr and $1x10^{-5}$/rx-yr, respectively, met the overall Safety Goals for nuclear power. The state-of-the-art work performed by the NRC over the last decade has shed light on the actual margin that exists between the CDF/LERF objectives and the Safety Goals as shown in Figure 1 below:

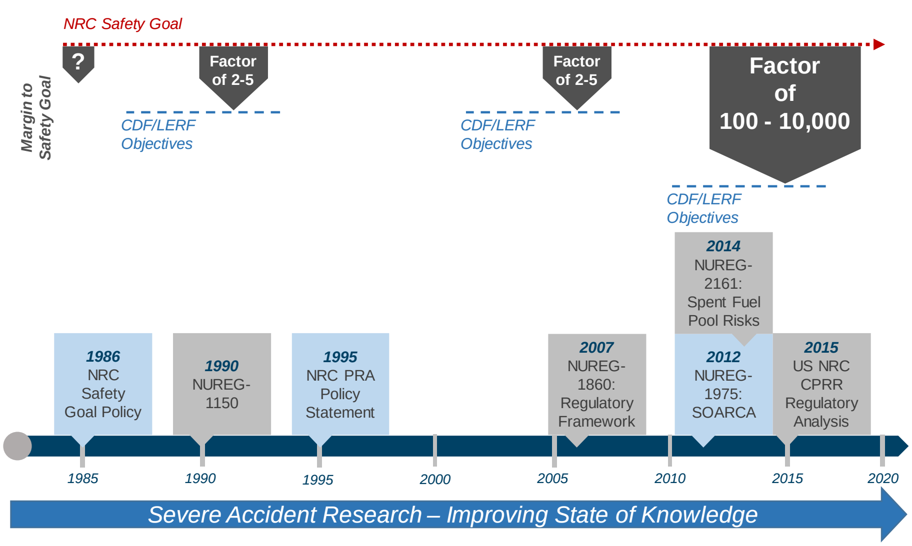


Figure 1 – Change in Perceived Safety Margin

This improved understanding of the margin of safety provides a new perspective on safety significance. That is, something once thought to be critical to maintain adequate safety may now be understood to have much lower actual safety significance. The additional information on site to site variability provided in the EPRI White Paper diminishes the need for site-specific analyses to support the broad applicability of these technical implications for all sites.

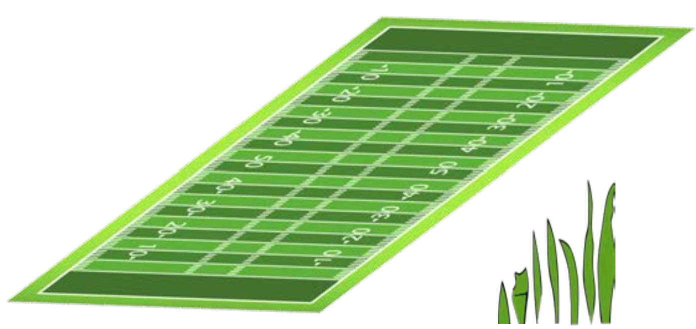
This new understanding of margin allows the NRC and industry to take a fresh look at the role of uncertainties in decision-making. Typically, risk analyses have focused on mean values with additional considerations of uncertainty and the relationship to the CDF/LERF acceptance guidelines. This focus on mean values is further substantiated by the large margins between these acceptance guidelines and the Safety Goals demonstrated by NRC's work. Further, these margins should expedite decision-making by lessening the emphasis on the uncertainties about the mean values for most applications.

Importantly, prior designation of "small" changes in risk based on the prior understanding of margin may have overstated the safety significance in many risk-informed applications.

What is truly "Significant"?

The EPRI White Paper shows that the CDF/LERF subsidiary objectives of $1x10^{-4}$/rx-yr and $1x10^{-5}$/rx-yr have a minimum margin to the Safety Goals of a factor of ~70 [Table 3 of Ref. 2], based on the <u>worst case</u> from NRC's SOARCA analyses. Most risk-informed applications utilize change in CDF/LERF or the integrated probability of core damage/large early release to characterize significance.

For example in the implementation of NFPA 805, self-approval is allowed for plant changes that result in a change in CDF/LERF of $1x10^{-7}$/rx-yr or $1x10^{-8}$/rx-yr, respectively, or 1/1,000th of the CDF/LERF objectives. The significance of these change criteria with respect to the Safety Goals is infinitesimal, even using this bounding result from SOARCA. If the $1x10^{-4}$/rx-yr CDF objective is a factor of 70 below the Safety Goal, then these self-approvals are quantitatively evaluating changes that are 1/70,000th of the Safety Goal. To put this in perspective, if this margin is considered with respect to where on a football field a marker might be placed, the level of resolution would be roughly 1/20 of one inch, or essentially the thickness of a blade of grass (100 yards*36 inches/yard = 3,600 inches * 1/70,000 = ~1/20th of an inch). The NFPA 805 self-approval process is essentially measuring how many additional blades of grass are added to the length of a football field.



Football Field vs Blade of Grass

Figure 2 – Safety Significance of NFPA 805 Self-Approval

Another example applies to a significant resource sink for the industry: potential non-Green findings under the Significance Determination Process (SDP) portion of the Reactor Oversight Process (ROP). If over the life of a plant, it operated at exactly a risk level of a CDF equal to = $1x10^{-4}$/rx-yr, the total accrued risk would be a more than a factor of 70 below the Safety Goals. The total calculated risk would be $8x10^{-3}$ ($1x10^{-4}$/rx-yr * 80 years of life) with a factor of 70 margin to the Safety Goal. In a typical SDP evaluation, the plant condition being evaluated is considered in terms of the level of risk times the duration. A greater than green finding is one that has a risk increment of >$1x10^{-6}$. Thus, a comparison of such a finding to the Safety Goals would show that each 10^{-6} finding is approximately 1/560,000 over the life of the plant (total lifetime risk at the QHO level divided by risk at Green-White threshold = [$8x10^{-3}$*70]/$1x10^{-6}$). Said another way, if we consider the Green-White threshold to be the thickness of a single piece of paper, the margin to Safety Goals would be equivalent to over 1,000 reams of paper (560,000 sheets), or a stack of paper over 15 stories high, and the industry and NRC expend undue resources trying to assess the significance of an issue equivalent to the thickness of the sheet of paper.

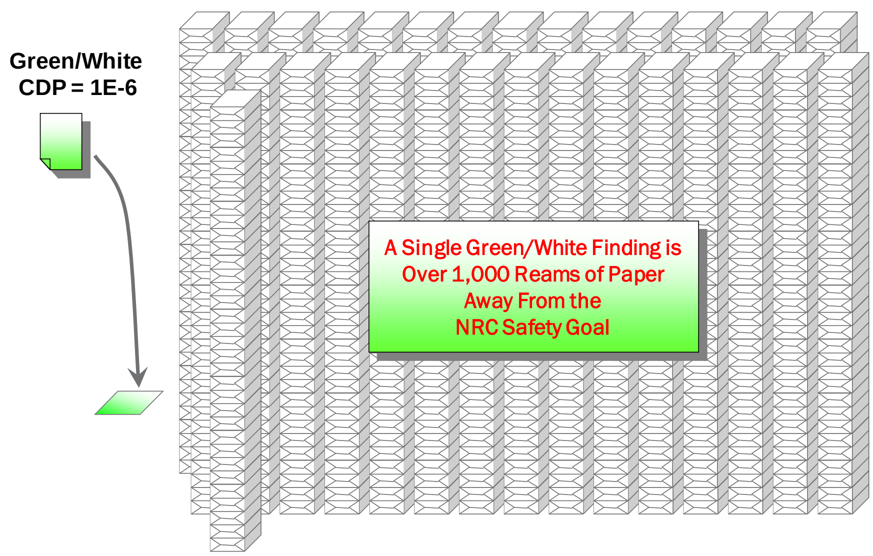


Figure 3 – Safety "Significance" of a Green Finding

Regulatory Implications

The improved technical understanding gained on the margin to the Safety Goals can serve as a foundation for regulatory change. The improved understanding of the actual margin to the Safety Goals can enable change to numerous regulatory processes to preclude unnecessary diversion of resources to items of low safety significance. Such changes can include:

Licensing and Oversight of Operating Reactors

1) Integrate a risk-informed decision making (RIDM) process within the current regulatory structure to bring an understanding of safety significance to the front of regulatory processes. This process should focus resources on safety significant issues and should restrict detailed regulatory review on low risk issues. This process could be applied to license amendment requests, generic safety issues, and regulatory inspection and oversight activities.

2) Implement changes to the regulatory use of risk significance thresholds. Examples include:

    a) Reconsider regulatory actions taken in the SDP in response to performance deficiencies found to be in the White regime based on their low level of safety significance.

b) Limit actions to expend significant NRC resources on inspections of Alternate Treatments for systems, structures and components (SSCs) found to be of Low Safety Significance (LSS) under 10 CFR 50.69.

c) Obtain full advantage of the inherent plant features, capabilities and operator response to optimize security response.

Licensing and Oversight of Advanced Reactors

1) Reflect the improved level of safety provided by advanced reactor designs by focusing and streamlining the licensing process for these designs.

Application of Probabilistic Risk Assessment (PRA) Insights and Metrics

1) Reduce the perceived need to bound fire risks as the significance of these contributors to overall safety is less than previously perceived.

2) In light of the greater safety margins, limit the need to quantify all risk contributors with detailed Regulatory Guide 1.200 PRAs, if they can be shown to be low risk.

3) Given the greater margin available, RIDM guidance should be developed for the interpretation and application of Regulatory Guide 1.174 acceptance guidelines and other derivative guidelines, rather than effectively treating these as hard limits.

Conclusions

The state-of-the-art work performed by the NRC staff and other industry organizations has demonstrated that there is greater margin to the Safety Goals than previously perceived. As the NRC and industry look for ways to improve safety focus and enhance efficiency, these insights provide a foundation to enable a reconsideration of many past practices and conventions. It is clear that safety is best ensured when the NRC and the industry focus attention on the matters according to their safety significance. To recall the analogy, assessing and constraining safety down to the width of a blade grass on a football field is counter to this philosophy.

References

[1] "Safety Goals for the Operation of Nuclear Power Plants: Policy Statement." U.S. Nuclear Regulatory Commission, 51 FR 30028, August 4, 1986.

[2] "Insights on Risk Margins at Nuclear Power Plants: A Technical Evaluation of Margins in Relation to Quantitative Health Objectives and Subsidiary Risk Goals in the United States," Electric Power Research Institute White Paper 3002012967, May 2018.

[3] State-of-the-Art Reactor Consequence Analyses (SOARCA) Report. U.S. Nuclear Regulatory Commission Report NUREG-1935, Vol. 1, November 2012.

[4] State-of-the-Art Reactor Consequence Analyses (SOARCA) Project: Sequoyah Integrated Deterministic and Uncertainty Analyses. U.S. Nuclear Regulatory Commission Draft Report, November 2017.