Nuclear Risk Research Center

On the significance of nuclear regulatory research

George Apostolakis

Head, Nuclear Risk Research Center

apostola@mit.edu

http://criepi.denken.or.jp/en/nrrc/index.html

Presented at the

Regulatory Information Conference

Session W16: Role of Research in Transforming the Nuclear Regulatory Environment

March 13, 2019

A Broader View: PRA Evolution

- **Reactor Safety Study: Establishes basic structure**
  - **A major NRC achievement**
- **Zion/Indian Point PRAs: External events are important**
- **French studies: LPSD risk is comparable to that at power**
- **Fukushima: Multi-unit issues are important**
- **PRAs do not include management attitudes, organizational factors, and failure of digital and passive systems**
- **Traditional defense-in-depth expected to compensate for limitations and uncertainties in RIDM**

Number Evolution

- Following the RSS (1975), a mindset of using negative powers of 10 for probabilities without serious thought prevails
- At the PSA conference in Newport Beach (1978), safety system unavailabilities were reported to be about 10^{-6} per demand
- Now, they are in the region of 10^{-3} - 10^{-4} per demand
- Swain & Guttmann set a lower bound for human error at 10^{-5}
- NUREG-1150: “core damage frequencies below 1E-5 per reactor year should be viewed with caution because of the remaining uncertainties in PRA (e.g., events not considered)”

The Problem with Low Frequencies (1)

- PRAs for advanced reactors (not yet built) report CDF and LRF estimates in the range of 10^{-7} to 10^{-9} per reactor year
- Return periods of 10^{7} to 10^{9} years
- Age of the earth: 4.6×10^{9} years
- Age of the earth's crust: 2×10^{9} years
- Low numbers are credible when supported by statistics
  - Asteroids with diameter 3 miles strike the earth every 20 million years (5×10^{-8} per year)
- PRAs involve assumptions and judgments; they are incomplete: what should we do with very low numbers?

The Problem with Low Frequencies (2)

- The CDF and LERF estimates do not include digital I&C failures, management attitudes, safety culture, operating experience, errors of commission
- The issue is the completeness of PRA
- Events that have occurred have not been of incredibly low frequency (Chernobyl, Fukushima)
- Is it worth expending resources pursuing incredible accident sequences?

Analysts are concerned

- **NUREG 1150 (Peach Bottom): "Core damage frequencies below 10^{-5} per ry should be viewed with caution because of the remaining uncertainties in PRA (e.g., events not considered)."**
- **NEI 18-04 (LMP): "Event sequences with frequencies less than 5×10^{-7}/plant-year are retained in the PRA results and used to confirm there are no cliff edge effects. They may also be taken into account in the RIPB evaluation of defense-in-depth."**
- **French researchers: "practically eliminated"**

NuScale Claims

- **"The most significant change in NuScale's new accident source term methodology is that overly conservative source terms based on "incredible" core damage events will be excluded from use as the MHA source term used in the design basis of the NPM."**
- **The NuScale approach employs a 10^{-6} per year threshold for identifying incredible core damage events.**
- **Core damage sequences with frequencies below 10^{-6} per year in the NuScale design are judged to have sufficient safety margins to account for uncertainties.**

Questions

- **Should RES establish a project to address PRA limitations due to incompleteness, very low frequencies, their meaning, and their regulatory treatment?**
- **Should we establish a *de minimis* frequency level and how would it affect the reporting of PRA results and the regulations?**
- **Note: *de minimis,* "lacking significance or importance: so minor as to merit disregard," *Merriam Webster***

With thanks to

- **Karl Fleming, KNF Consulting Services LLC**