Probabilistic Safety Assessment and Risk Management

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CRIEPI Central Research Institute of Electric Power Industry

Risk Management

- "Deterministic" approach
  - Design basis accidents
  - Defense in Depth
  - Safety margins

- Risk-based approach
  - What can go wrong? (thousands of accident sequences or scenarios as opposed to the limited number of DBAs)
  - How likely are these scenarios? (identify risk-dominant scenarios and manage them)
  - What are their consequences?

Risk-Informed Framework

Traditional "Deterministic" Approach

- Unquantified probabilities
- Design-basis accidents
- Defense in depth and safety margins
- Can impose unnecessary regulatory burden
- Incomplete

Risk-Informed Approach

- Combination of traditional and risk-based approaches through a deliberative process

Risk-Based Approach

- Quantified probabilities
- Thousands of accident sequences
- Realistic
- Incomplete

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Deliberative Decision Making

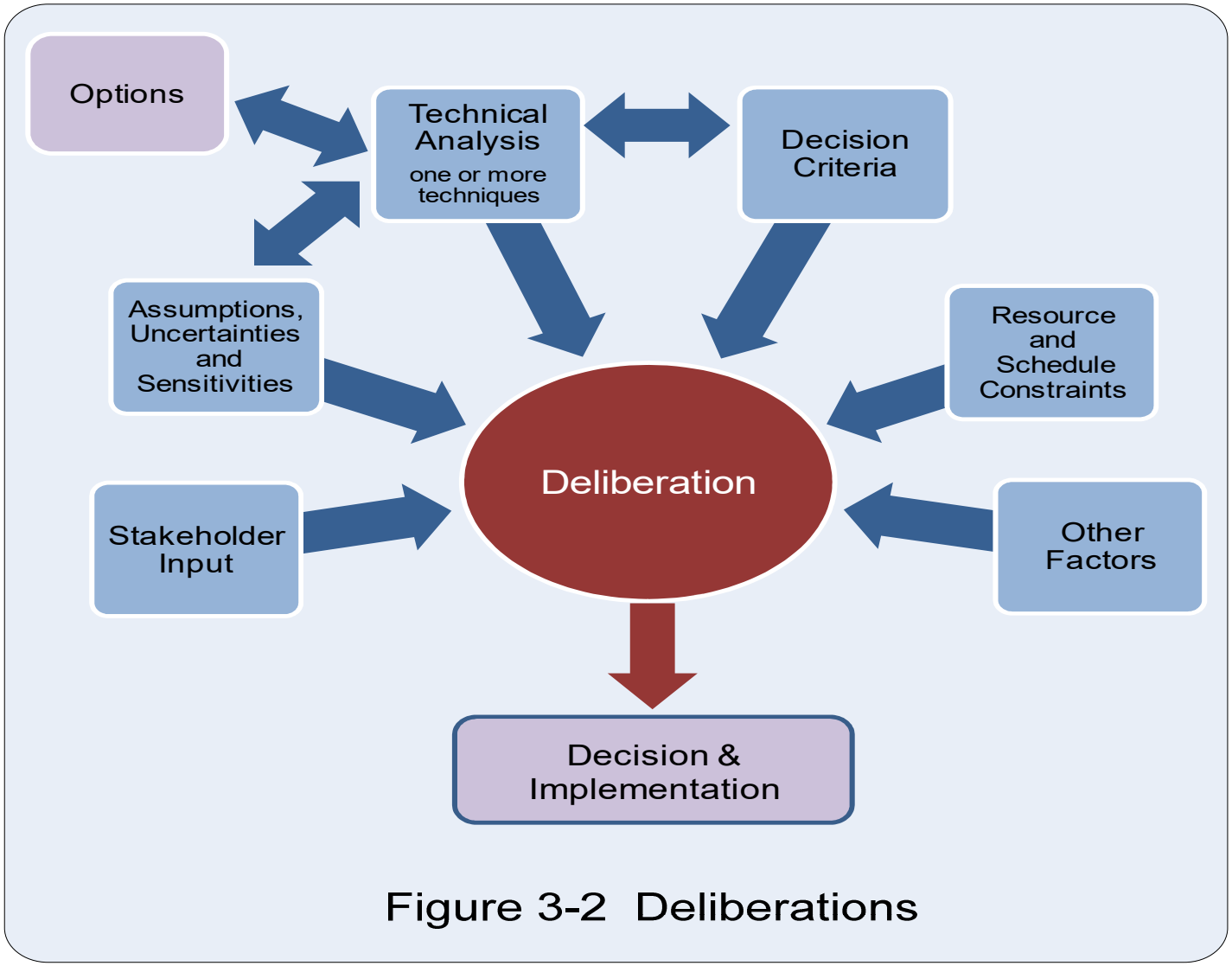

Figure 3-2 Deliberations

NUREG-2150, *A Proposed Risk Management Regulatory Framework*

Risk-Informed Decision Making (1)

- **USNRC**
  - **RIDM: Insights from PRA are considered with other engineering insights in decision making.**
  - **Regulatory Guide 1.174 (1997) provides guidance.**

- **Industry**
  - **Ensure that the Safety Goals and applicable regulations are met.**
  - **A PRA may reveal credible vulnerabilities to the utility staff.**

Early Applications (before RG 1.174)

- **Industry (1981)**
  - Plant-specific PRAs provide insights.
  - A seismic initiated interaction of adjoining buildings could lead to the collapse of the main control building. A simple structural modification was implemented to damp the interaction between the two buildings.
  - The fire contribution to CDF was deemed to be too high. A simple plant modification reduced this contribution.

- **USNRC (1980s)**
  - Generic regulations.
  - Two rules (ATWS and SBO) based on WASH-1400 findings and operational experience.

Risk-Informed Decision Making (2)

- **PRA insights are considered with other engineering insights to inform decision making.**
  - **Key word: "considered"**
  - **The decision is based on judgment**
- **What shapes this judgment?**
  - **The credibility and acceptability of PRA and other engineering insights**
  - **Individual PRA results can be credible and acceptable**
- **Fire PRAs for power operations are used by the NRC and industry to make risk-informed decisions**
  - **This use indicates that FPRA is credible and realistic enough for decision making**

Safety Goals

- High-Level qualitative and quantitative objectives for single units.
- Subsidiary goals for CDF and LERF.
- PRA Standards are developed.

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ACRS Letter, April 2004 (1)

- The Quantitative Health Objectives (QHOs) apply to the site as a whole. The sum of the contributions from each reactor on the site to acute and latent fatalities should be bounded by the QHOs.

- The Committee has not reached consensus on the approach that should be taken to determine the core damage frequency (CDF) goal. Two views are presented in the discussion below.

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ACRS Letter, April 2004 (2)

- **Option 1**
  - The site goal (e.g., 10^{-4} per ry) is divided by the number of units at the site.
  - The risk from and the likelihood of a core damage accident at all sites cannot be precisely equal. However, there is the expectation that they be comparable.
- **Option 2**
  - CDF is an accident prevention goal and its value should be the same for each reactor at every site.
  - Requiring each module to have a CDF value given by the overall CDF goal divided by the number of modules introduces a new Safety Goal concept, a site CDF. Such a concept was never intended to be part of the Safety Goals.

My View

- The Qualitative and Quantitative Health Objectives are a statement of the societal acceptability of NPP risks.
- They should be met including all hazards at the site.
- CDF and LERF (or similar metrics) balance accident prevention and mitigation for any given site (defense-in-depth).
- LERF or any other metric of release should be a site goal.
- CDF should still be per reactor year.

The IAEA MUPSA Methodology

- A significant step forward.
- As expected at this stage of development, further improvements and refinements will occur.
- The methodology is not ready to be used in generic regulatory decision making.

PRA Evolution

- Reactor Safety Study, 1975: Establishes basic structure
- Zion/Indian Point PRAs, early 1980s: External events are important
- French studies, mid 1980s: LPSD risk is comparable to that at power
- Fukushima, 2011: Multi-unit issues are important
- The current state of MUPSA methodology is at a stage similar to that for single units in the 1970s and early 1980s.

Multi-Unit Risk Management: Industry

		Initiating event				
		SLBO	Fire in the turbine hall	LOOP (SFT approach)	LOOP (MET approach)	Seismic events
CDF for Units 1&2 ("old" units)	Unit 1	2.56E-08	7.65E-07	1.13E-06	1.13E-06	1.58E-04
	Unit 2	9.84E-08	2.98E-06	1.13E-06	1.13E-06	1.58E-04
	Units 1&2	1.87E-10	6.46E-09	1.68E-08	1.68E-08	1.32E-04
	R_2("old")	7.30E-03	8.44E-03	1.49E-02	1.49E-02	8.35E-01

IE	Base case	Sensitivity case
CD12 for seismic events	1.32E-4	9.65E-5

From: IAEA, "MUPSA for New and Existing Reactor Facilities," Vienna, 2019.

- **The plant-specific numbers for seismic failure are high and exceed the safety goal for CDF.**
- **They should prompt plant management to explore further these results and, possibly, take action.**

My Numbers Concern

Case Description	Unit 1	Unit 2	Units 1 and 2 (old)	Unit 3	Units 4	Units 3 and 4 (new)	Units 1, 2, 3 and 4
LOOP (SFT Method)	1.17E-06	1.17E-06	3.64E-08	7.47E-07	7.47E-07	3.67E-09	8.02E-15
LOOP (MET Method)	1.17E-06	1.17E-06	3.64E-08	7.47E-07	7.47E-07	3.67E-09	8.02E-15

From: P. Hlavac, "Results of quantifications of the MUPSA model," presented at the Third Meeting on Phase II – MUPSA Case Study Vienna International Centre, August 06 to 09, 2018.

- **What does 10^{-15} mean?**
- **Age of the earth: 4.6×10^{9} years**
- **Low numbers are credible when supported by statistics and acceptable models**
  - **Asteroids with diameter 3 miles strike the earth every 20 million years (5×10^{-8} per year)**
- **This is not the case with PRA.**

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."
- The NuScale approach employs a 10^{-6} per year threshold for identifying incredible core damage events.
- French researchers: "practically eliminated"

Questions posed at RIC 2019

- **Should the USNRC Office of Nuclear Regulatory Research 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 regulations and the reporting of PRA results?**
- **<u>Today's addition</u>: Should the IAEA undertake a similar initiative?**

- Note: *de minimis,* "lacking significance or importance: so minor as to merit disregard," *Merriam Webster Dictionary.*