Regulatory Decision Making and PRA

George Apostolakis

Head, Nuclear Risk Research Center

apostola@mit.edu

2nd JEA Nuclear Standards Committee Symposium

Tokyo

June 4, 2015

The Traditional Approach

Prior to Risk Assessment

- **Management of (unquantified at the time) uncertainty was always a concern.**

- **Defense-in-depth and safety margins became embedded in the regulations.**

- **"*Defense-in-Depth* is an element of the NRC's safety philosophy that employs successive compensatory measures to prevent accidents or mitigate damage if a malfunction, accident, or naturally caused event occurs at a nuclear facility." [USNRC White Paper, February, 1999]**

Problems with the Traditional Approach

- There is no guidance as to how much defense in depth is sufficient
- DBAs use qualitative approaches for ensuring system reliability (the single-failure criterion) when more modern quantitative approaches exist
- DBAs use stylized considerations of human performance (e.g., operators are assumed to take no action within, for example, 30 minutes of an accident's initiation)
- DBAs do not reflect operating experience and modern understanding
- Industry-sponsored PRAs showed a variability in risk of plants that were licensed under the same regulations.

Probabilistic Risk Assessment

- **Study the system as an integrated *socio-technical* system**

- **Probabilistic Risk Assessment (PRA) supports Risk Management by answering the questions:**

  - ➢ **What can go wrong? (thousands of accident sequences or scenarios)**
  - ➢ **How likely are these scenarios?**
  - ➢ **What are their consequences?**

PRA Model Overview and Subsidiary Objectives

CDF 10^{-4}/ry

LERF 10^{-5}/ry

QHOs

Level I

PLANT MODEL

Results
Accident sequences leading to plant damage states

Level II

CONTAINMENT MODEL

Results

Containment failure/release sequences

PLANT MODE
At-power Operation
Shutdown / Transition Evolutions

Level III

SITE/CONSEQUENCE MODEL

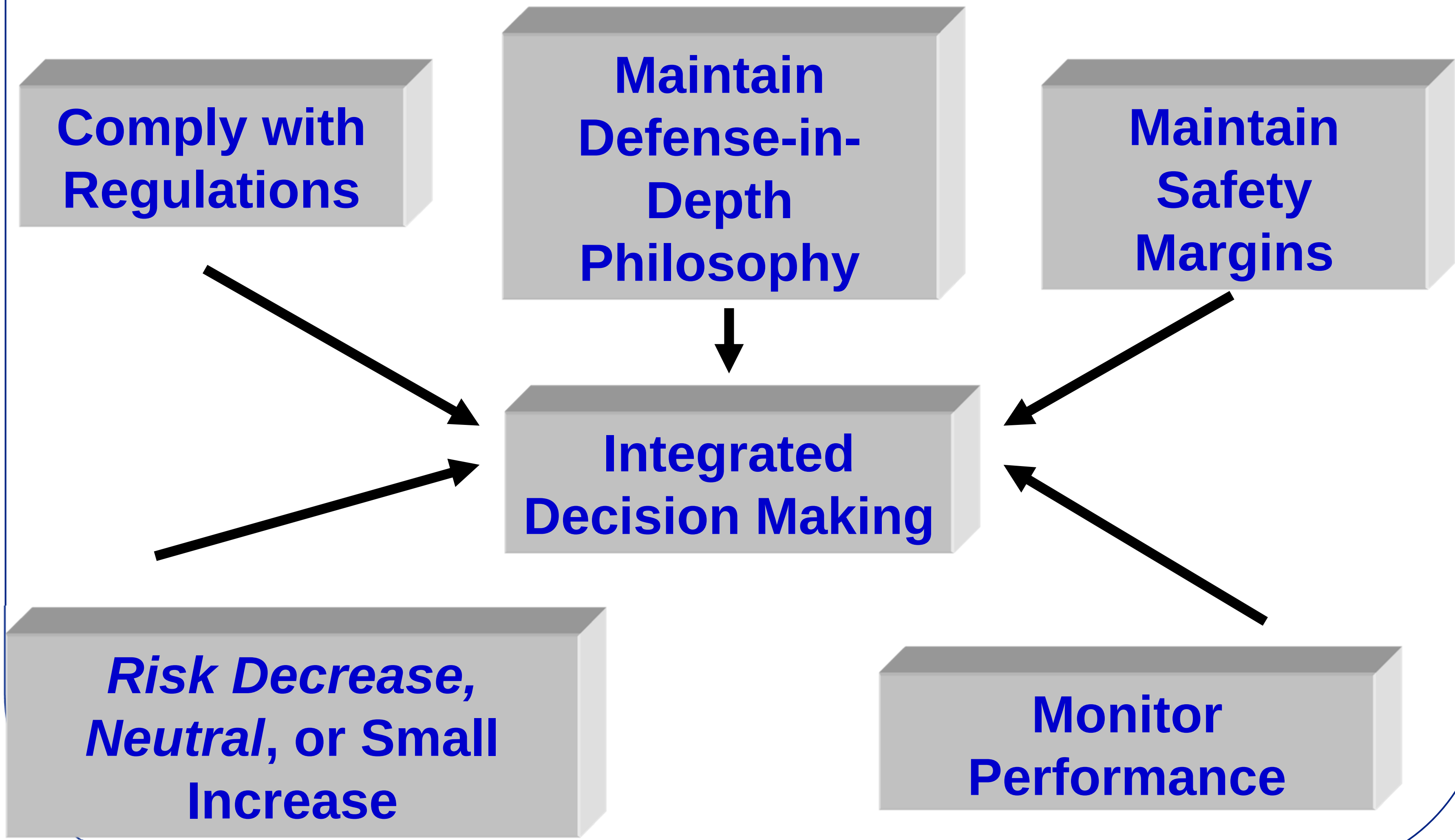
Results

Public health effects

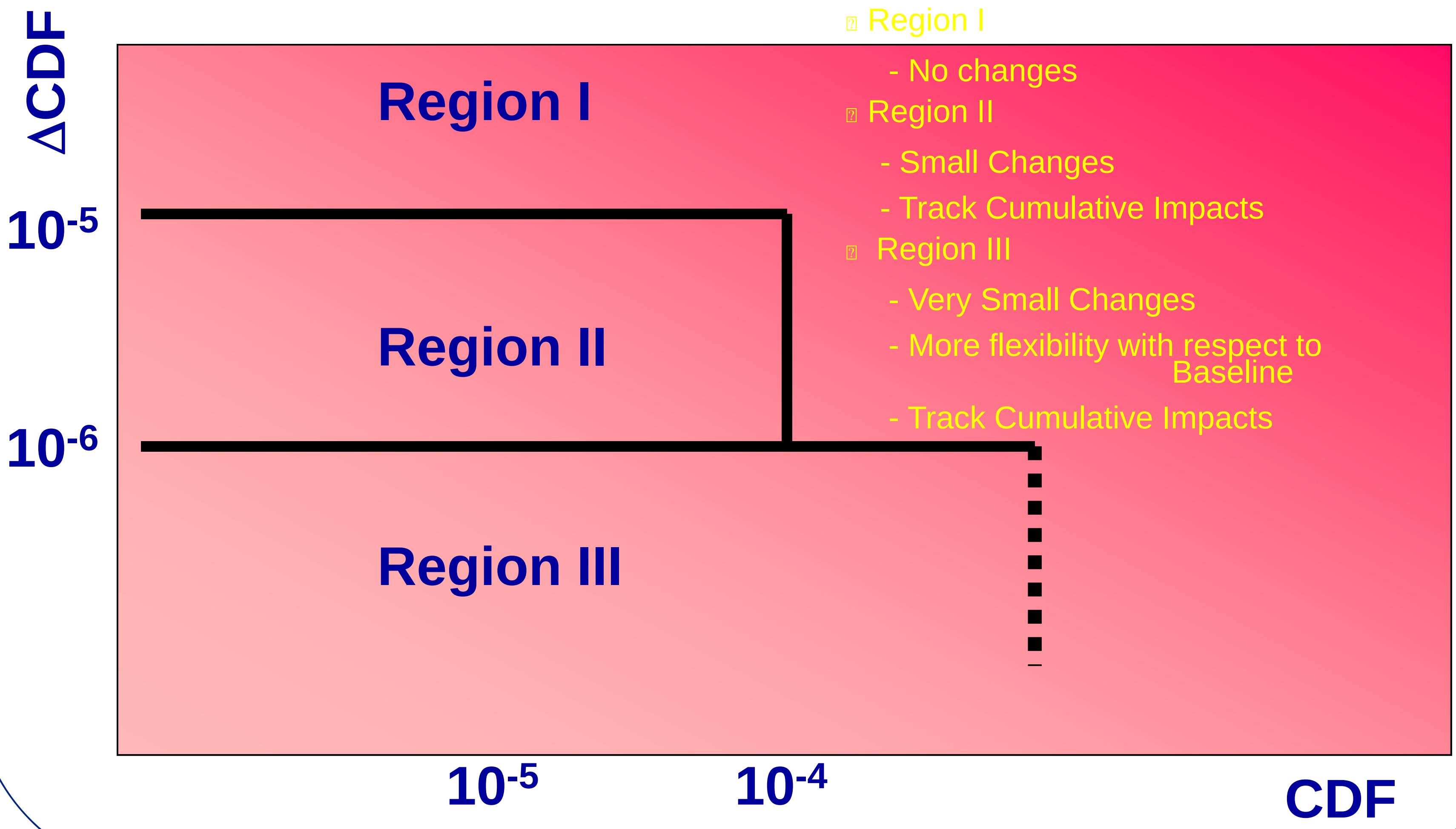
SCOPE
Internal Events
External Events

Uncertainties

Risk-Informed Changes to the Licensing Basis (RG 1.174; 1998)



Acceptance Guidelines for Core Damage Frequency



Decision Making

- **Regulatory decision making (like any decision) should be based on the current state of knowledge and should be documented**

  - **The current state of knowledge regarding design, operation, and regulation is key.**

  - **PRAs do not "predict" the future; they evaluate and assess future possibilities to inform the decision makers' current state of knowledge.**

  - **Ignoring the results and insights from PRAs results in decisions not utilizing the complete state of knowledge.**

PRA Adequacy

- A full-scope PRA includes all operating modes, internal and external initiating events and estimates of the core damage frequency, large early release frequency, release categories, and health effects
- Most regulatory decisions utilize Level 1 PRAs and Large Early Release Frequency
- Many regulatory decisions do not require a full-scope Level 1 PRA
- The level of detail of the PRA is determined by its intended use

PRA Quality

- PRA models are ambitious in scope (socio-technical system model)
- Many diverse models are employed (systems, human reliability, earthquakes, etc)
- Expert judgment is important, just as it is important in "deterministic" analyses
- Regulators must have confidence that the quality of risk information is sufficient to justify its use in decision making

Regulatory Guidance

USNRC Regulatory Guide 1.200, "AN APPROACH FOR DETERMINING THE TECHNICAL ADEQUACY OF PROBABILISTIC RISK ASSESSMENT RESULTS FOR RISK-INFORMED ACTIVITIES"

- ➢ **Scope of a PRA**
- ➢ **Technical elements of a full-scope Level 1 and Level 2 PRA and their associated attributes and characteristics**
- ➢ **Level of detail of a PRA**
- ➢ **Development, maintenance, and upgrade of a PRA**

- **The documentation must be sufficient to facilitate independent peer reviews**

Peer Review

- **Qualifications of the experts**
  - independent with no conflicts of interest (i.e., have not performed any work on the PRA)
  - collectively represent expertise in all the technical elements of a PRA including integration
  - expertise in the technical element assigned to review
  - knowledge of the plant design and operation
  - knowledge of the peer review process
- **Guidance for reviews**
  - NEI 00-02, "Probabilistic Risk Assessment Peer Review Process Guidance."
  - NEI 05-04, "Process for Performing Follow-On PRA Peer Reviews Using the ASME PRA Standard."
  - NEI 07-12, "Fire Probabilistic Risk Assessment (FPRA) Peer Review Process Guidelines."

PRA Standards

- "The peer review is to be performed against established standards" (RG 1.200)

- Examples
  - ASME/ANS RA-Sa-2009, "Addenda to ASME/ANS RA-S-2008 Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications,"
  - ASME/ANS RA-S-1.4-2013: Probabilistic Risk Assessment Standard for Advanced Non-LWR Nuclear Power Plants (for trial use)

- Concern about stifling methodological progress

ASME/ANS RA-Sa-2009 Requirements

- **High-Level Requirements**
  - The HLRs set forth the minimum requirements for a technically acceptable baseline PRA, independent of an application.
- **Supporting Requirements**
  - For each Capability Category, the SRs define the minimum requirements necessary to meet that Capability Category
- **Capability Category II**
  - Resolution and specificity sufficient to identify the relative importance of the significant contributors at the component level
  - Use of plant-specific data/models

Example: Initiating Events

- **HLR-IE-A The initiating event analysis shall provide a reasonably complete identification of initiating events.**

- **Supporting Requirements**
  - **IE-A2 INCLUDE in the spectrum of internal-event challenges considered at least the following general categories: transients, LOCAs, SGTR, ISLOCAs, support system failures**
  - **IE-A4 REVIEW generic analyses and operating experience of similar plants to assess whether the list of challenges included in the model accounts for industry operating experience**