Beware of the Assumptions: Decision Making and Statistics

Commissioner George Apostolakis

U.S. Nuclear Regulatory Commission

CmrApostolakis@nrc.gov

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Terminology

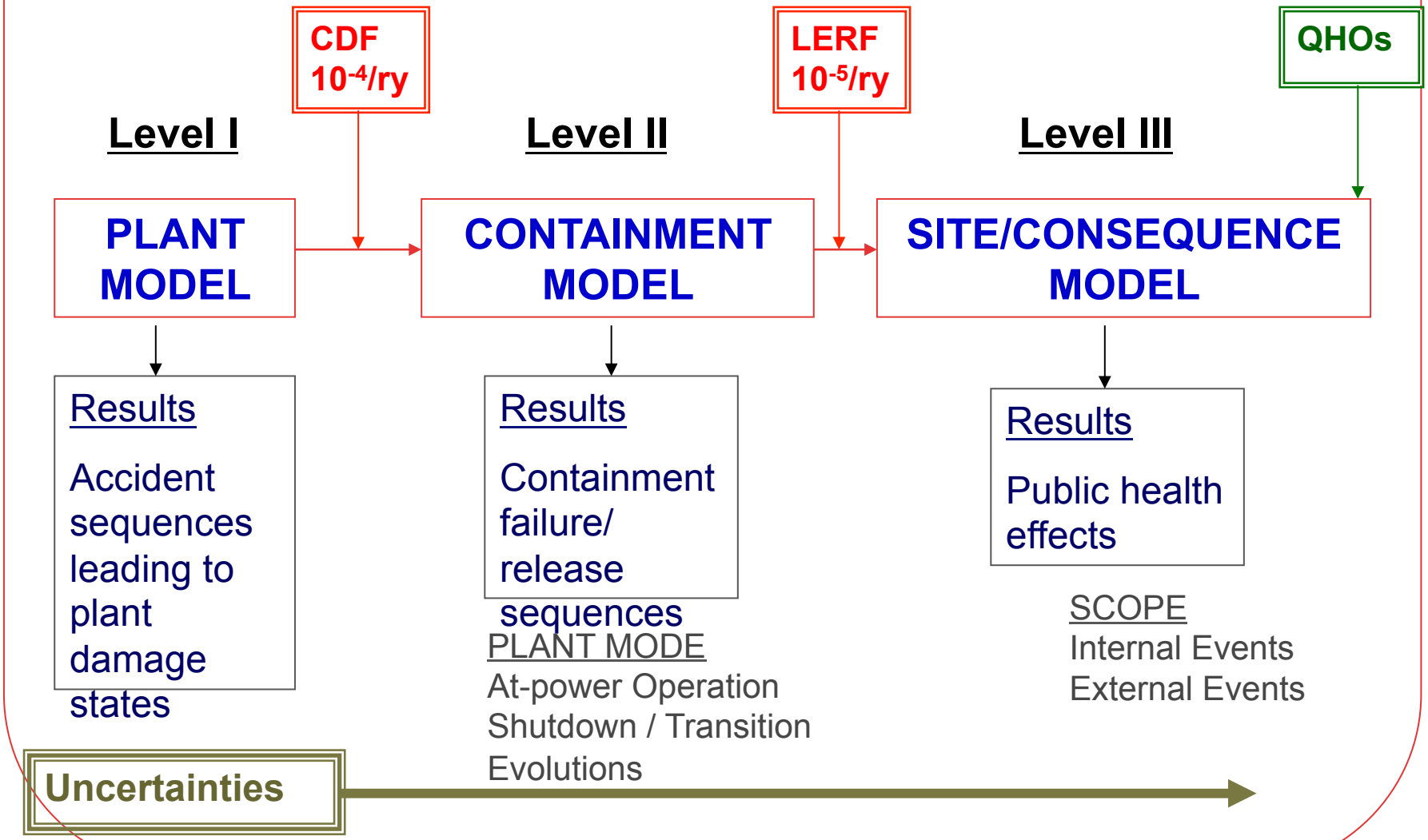
Global statistical analysis:

- Estimation of accident frequencies (CDF and LERF) based on historical core damage events and large early release events, i.e., events at the plant level

PRA:

- Estimation of accident frequencies (CDF and LERF) using identified accident scenarios and statistical evidence and models at the component level

PRA Model Overview and Subsidiary Objectives



Decision Making

- **Regulatory, like any other, decision making is based on the current state of knowledge.**
  - **The current state of knowledge regarding design, operation, and regulation is key.**
  - **The current state of knowledge is informed by science, engineering, and operating experience, including past incidents.**
  - **PRAs do not "predict" the future; they evaluate and assess future possibilities to inform the decision makers' current state of knowledge.**

A Little Knowledge of Probability Can Be Dangerous

If you live to be one hundred, you should rejoice.

Very few people die past that age.

George Burns

Assumptions Underlying Global Statistical Estimates

- **All of the reactors in the population are nominally identical and are operating under the same regulatory system (*exchangeable* events).**

- **A simple formula:**

$$F = \frac{N}{T}$$

F = frequency (events/reactor year)

N = number of events

T = total number of operating reactor years

How Exchangeability Affects Decision Making

A NASA astronaut is about to fly his first mission. There were five previous similar missions.

- **Scenario 1: The previous five missions were all successful.**
- **Scenario 2: The first four missions were successful, the fifth was a failure.**
- **Scenario 3: The first mission was a failure and the second through fifth missions were successful.**

How would the decision-making process be different in each case and why?

An Example: Occupational Risks (Probability of Death per Year)

- President of the United States: 0.019
- Fire Fighter: 0.00040 (factor of 48)
- Police Officer: 0.00032 (factor of 59)

- Four Assassinations (1865; 1881; 1901; 1963)
- Years (1789-2000): 211

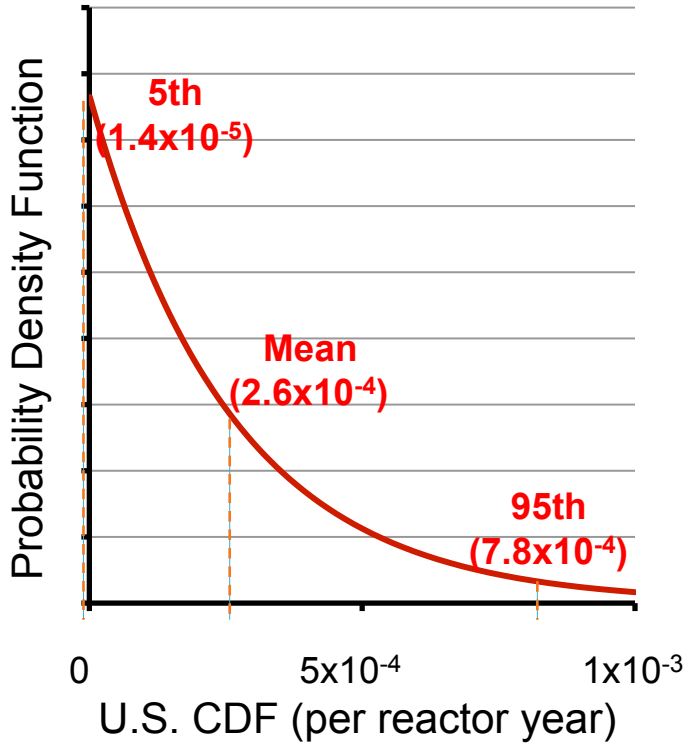
$$F = \frac{4}{211} = 0.019$$

- Is 0.019 a modern President's risk?
  - ➢ No. Exchangeability is not valid.

Data from: Wilson and Crouch, *Risk-Benefit Analysis*, Harvard University Press, 2001

Global Statistical Estimates of CDF

- **U.S. Experience**
  - 1 core damage event (TMI-2)
  - 3,839 LWR reactor years
- **Exchangeability is assumed between TMI-2 and current reactors (PWRs, BWRs, all sites).**
- **Exchangeability is invalid.**



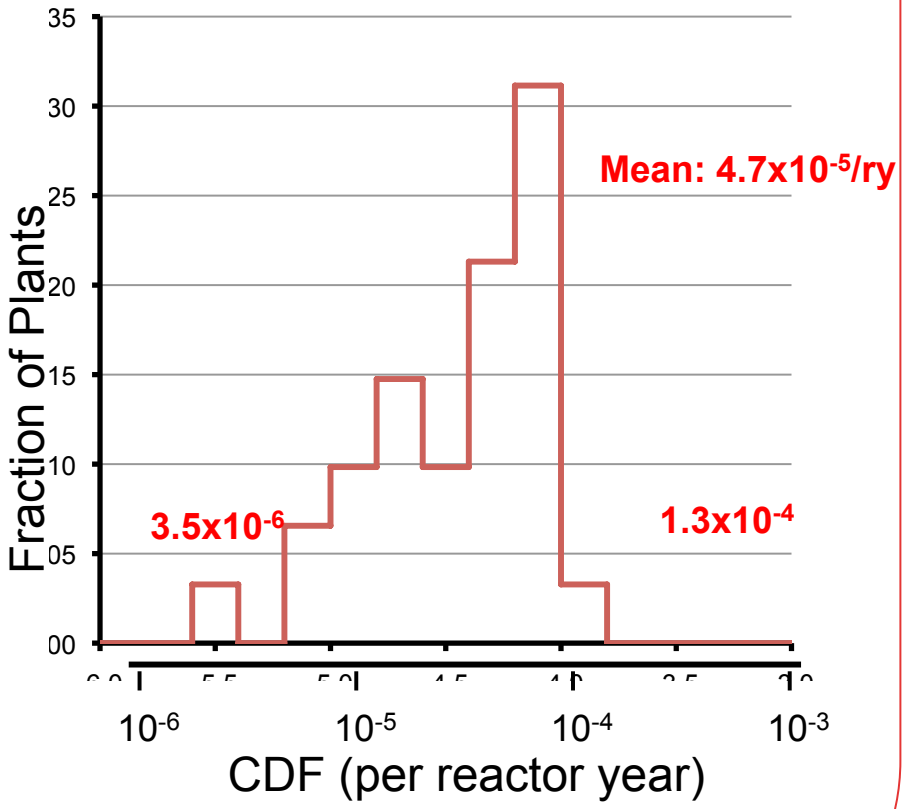
Why is Exchangeability Invalid?

Major changes are instituted after accidents:

- **Regulatory changes after TMI and Fukushima**
- **Establishment of INPO after TMI**
- **IPE and IPEEE programs after TMI**
- **FLEX after Fukushima**

PRA CDF Estimates for U.S. Plants*

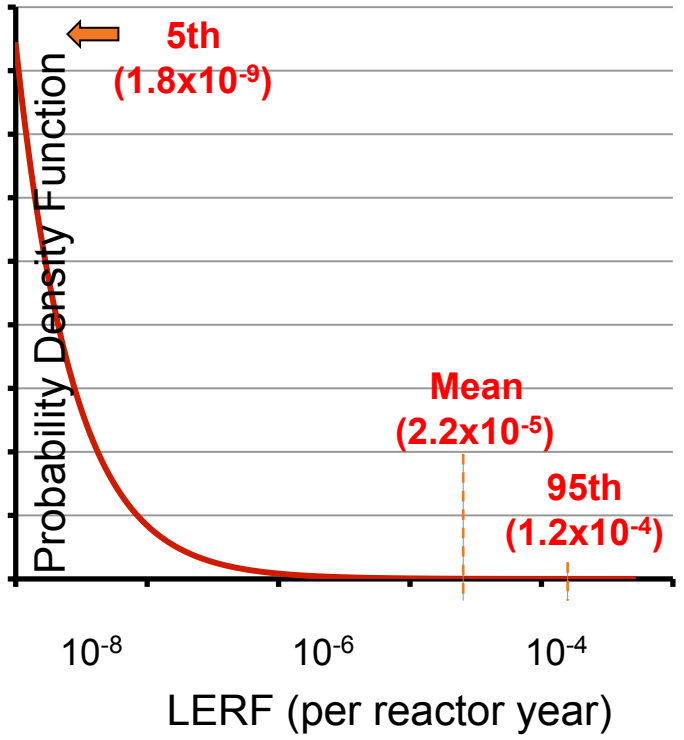
- **Current point estimates including internal and external events (61 units)**
  - **Post 2000 (90% after 2005)**
  - **Plant-to-plant variability reflects differences in designs and modeling**



*From License Amendment Requests (LAR) and Severe Accident Mitigation Alternative (SAMA) analyses

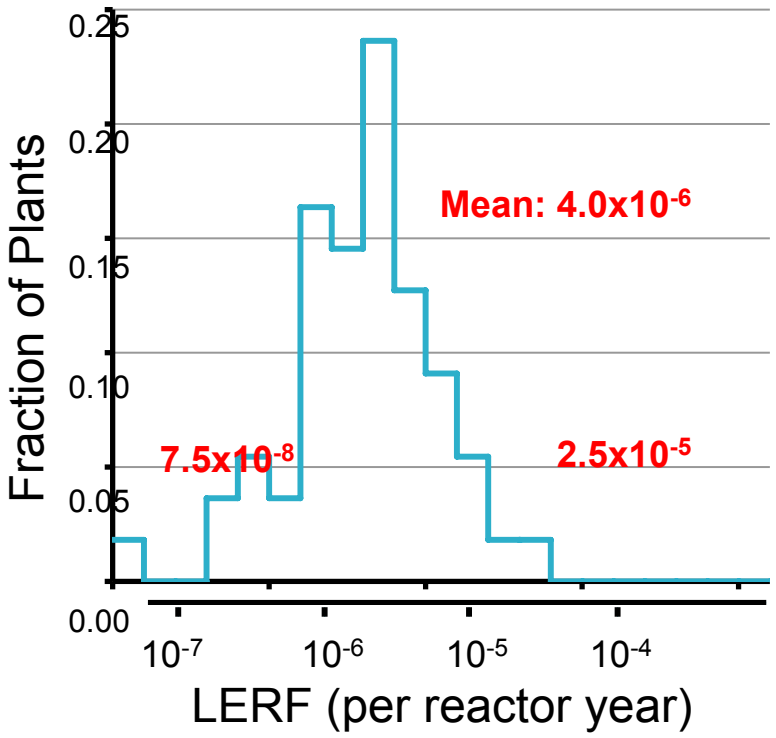
Global Statistical Estimate of LERF for the U.S.

- **U.S. Experience**
  - **0 large early releases**
  - **3,839 LWR reactor years**
- **Exchangeability is still assumed, but is invalid.**



PRA LERF Estimates for U.S. Plants*

- **Current point estimates including internal and external events (55 units).**
  - **Post 2000 (90% after 2005)**
  - **Plant-to-plant variability reflects differences in designs and modeling.**



*From License Amendment Requests (LAR) and Severe Accident Management Alternative (SAMA) analyses

A Continuous Learning Process: TMI Accident

- Upgraded requirements for auxiliary feedwater systems, containment building isolation, and reliability of pressure relief valves, among others
- Upgraded emergency planning regulations
- Added requirements related to hydrogen control
- Revamped operator training and staffing requirements
- Established fitness-for-duty programs

A Continuous Learning Process: Fukushima Accident

- Requiring mitigation strategies for beyond-design-basis external events
- Requiring consideration of multi-unit accidents
- Mandating severe accident capable containment vents for BWRs with Mark I and II containments
- Requiring integration of emergency operating procedures and procedures for coping with severe accidents

A Continuous Learning Process: Analysis

- **Significance of small LOCA, human error, and support systems** (Reactor Safety Study)
- **Significance of seismic and fire risk** (Zion and Indian Point PRAs)
- **Significance of low power and shutdown operations** (French PRA)
- **Risk contributors are plant specific, even for sister units** (Indian Point PRAs)

What is the Message?

- **Global statistical analysis requires the assumption that TMI-2 is exchangeable with current reactors. It is not.**
- **It is the qualitative insights from operational experience that are useful in regulatory decision making, not the frequencies of core damage and release derived from this experience.**
- **PRA results represent current design, operation, and regulation.**

Concluding Remarks

- **Regulatory decision making must be based on the current state of knowledge.**
  - **The current state of knowledge regarding design, operation, and regulation (as reflected in the PRAs) is key.**
  - **The current state of knowledge is informed by science, engineering, and operating experience, including past incidents.**
  - **The need for the assumption of *exchangeability* between past, present, and future reactors makes global statistical estimates of little value in regulatory decision making.**

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

Words of Wisdom

Facts are stubborn things, but statistics are pliable.

Mark Twain

Acronyms

BWR	Boiling Water Reactor
CDF	Core Damage Frequency
FLEX	Diverse and Flexible Mitigation Capabilities
INPO	Institute of Nuclear Power Operations
IPE	Individual Plant Examination
IPEEE	IPE for External Events
LERF	Large Early Release Frequency
LOCA	Loss of Coolant Accident
LWR	Light Water Reactor
PRA	Probabilistic Risk Assessment
PWR	Pressurized Water Reactor
QHO	Quantitative Health Objectives
TMI	Three Mile Island