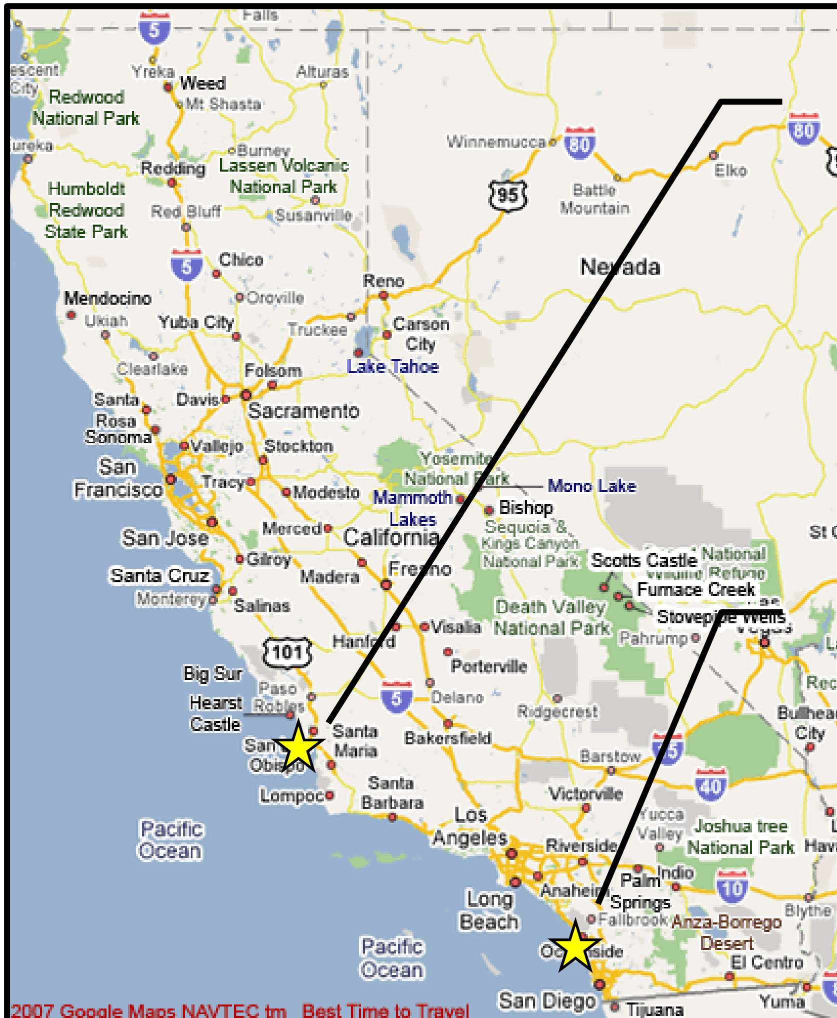
Assessing and Managing the Risk of Nuclear Power: Impact on California

California Council on Science and Technology
Meeting on "Risk, Uncertainty and Trust in Scientific Data and Analyses"

Edward Blandford, PhD
Center for International Security and Cooperation
Stanford University
June 1st, 2011

STANFORD UNIVERSITY

Nuclear Power in California



Diablo Canyon Power Plant (DCPP)

- 2 X 4-Loop Westinghouse PWRs (1,100 MWe each)
- Unit 1 commissioned in 1985 and Unit 2 commissioned in 1986
- Owned and operated by PG&E

San Onofre Nuclear Generating Station (SONGS)

- 2 X 2-Loop CE PWRs (1,100 MWe each)
- Unit 2 commissioned in 1983 and Unit 3 commissioned in 1984
- Owned and operated by SCE

Three major policy questions arise from the Sendai tsunami and the nuclear accident at Fukushima

- How should the nuclear accident at Fukushima affect our policies for existing reactors?
  - Policies for regulating safety (e.g., lessons learned)
  - Policies for license renewal (e.g., should existing nuclear plants be shut down before, or after, existing coal plants?)
- Are the new, Generation III reactor designs sufficiently safe to be built, considering lessons learned from the Fukushima accident?
- Are there broader lessons for protecting public health and safety?
  - The Japanese tsunami early warning system saved many lives
    - » compare the 2004 Sumatra tsunami, 230,000 fatalities, with Sendai ~28,000
  - The U.S. west coast from northern California to Alaska has thrust faults that can generate similar tsunamis

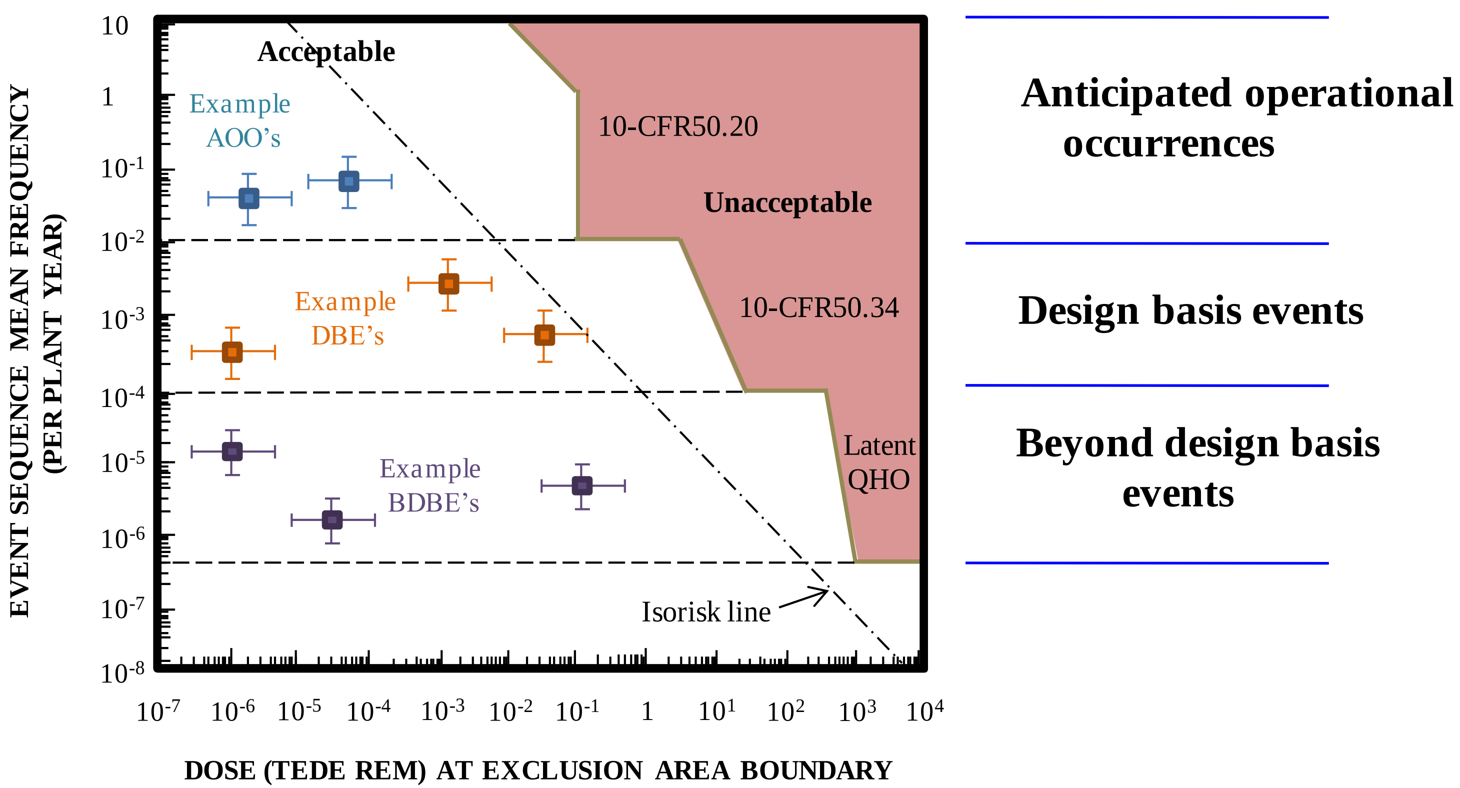
The U.S. Nuclear Regulatory Commission published safety goals for nuclear power in 1986

- "The risk to an average individual in the vicinity of a nuclear power plant of prompt fatalities that might result from reactor accidents should not exceed one-tenth of one percent (0.1 percent) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed."

- "The risk to the population in the area near a nuclear power plant of cancer fatalities that might result from nuclear power plant operation should not exceed one-tenth of one percent (0.1 percent) of the sum of cancer fatality risks resulting from all other causes."

No comparable requirements exist for fossil fuels

The USNRC safety goals can be displayed on a frequency/consequence chart



Deterministic vs. Risk-informed vs. Risk-based

Traditional
"Deterministic"
Approaches

Risk-informed Approach

Combination of traditional and risk-based approaches

Risk-based or
"Probabilistic"
Approaches

USNRC relies heavily on Defense-in-Depth philosophy where an appropriate balance between protection, mitigation, and emergency preparedness must be established

G. Apostolakis (2000)

STANFORD UNIVERSITY

The United States response to Fukushima

- Major ongoing activities:
  - US NRC Task Force 90 day review
  - DOE reviewing critical nuclear installations
  - INPO independent review
  - US NRC and DOE monitoring situation in Japan and providing support

Major questions raised surrounding risk analysis and management of current fleet

- Is there adequate protection from natural phenomena within the design basis?
- Is there sufficient consideration of natural phenomena that falls outside of the design basis?
- Are US nuclear facilities adequately prepared for mitigation for long-term station black outs?
    - Multiple unit sites?
- Do US nuclear facilities have adequate emergency preparedness measures?
- Does the US NRC have adequate programs in place to deal with similar issues?

Recent US NRC findings at DCPP and SONGS

- NRC inspectors focused on what licensees were doing with respect to the capabilities and strategies they had to respond to large fires/explosions, station blackout events, and flooding events
- No major safety-related findings but examples of findings:
  - Lack of a written agreement for fuel oil supply to support emergency diesel generators when operation was required for more than 7 days (SONGS)
  - Extension cords used to connect power from portable generator to plant equipment were not re-verified to be of an adequate length (SONGS)
  - Licensee identified that the memorandum of understanding was not in place with the California National Guard for the contingency to supply diesel fuel to the site when the main road is unavailable (DCPP)

Cannot overstate the importance of having effective self-assessment and corrective action program

The accident at Fukushima provides important lessons learned

- Severe natural events are possible
  - U.S. west coast is likely underprepared for protecting coastal residents from tsunamis
  - The nuclear accident at Fukushima is an important contributor to the overall costs of the disaster
    - » Likely greater than $100 billion from a total cost of ~$300 billion
    - » But public health impact from accident is much smaller
- The most important lesson for managing beyond-design-basis events in existing infrastructure is to have planned ahead
- Some key remaining questions:
  - Ability to cope with multiple unit accidents
  - Clear line of command (less of an issue in the United States)
  - Mutual aid agreements

Backup Slides

Station Blackout: Assessing Coping Time

"The reactor core and associated coolant, control, and protection systems, including station batteries and any other necessary support systems, must provide sufficient capacity and capability to ensure that the core is cooled and appropriate containment integrity is maintained in the event of a station blackout for the **specified duration**."

Based on four factors:

1. The redundancy of the onsite emergency ac power sources;
2. The reliability of the onsite emergency ac power sources;
3. The expected frequency of loss of offsite power; and
4. The probable time needed to restore offsite power.

In summary, the US NRC evaluates the overall design of onsite and offsite electrical system reliability and determines an appropriate coping time

- Coping time varies from plant to plant and can range from 4 to 36 hours

Source: 10 CFR Part 50.63 Loss of all alternating current power

February 2002 USNRC Order: Section B.5.b

- Following 9/11, USNRC developed strategies that required plant licensees to "maintain or restore core cooling, containment, and spent fuel pool cooling capabilities under the circumstances associated with loss of large areas of the plant due to explosions or fire"
- Originally intended for coping with fires and explosions, NRC contends strategies would help protect against natural hazards such as severe earthquakes and floods
- USNRC will review adequacy of B.5.b strategies for dealing with non-security severe events by end of 90-day review

History of PRA in the nuclear industry

1932: James Chadwick discovers the neutron

1945: Atomic bombings of Hiroshima and Nagasaki by the United States

Atomic Energy Act of 1954 passed allowing for commercial reactor development

1957: WASH-740, the first comprehensive look at the consequences of a large nuclear accident, was published by the AEC focusing on LOCA

Seminal papers by Reg Farmer and Chauncey Starr provide strong foundation for PRA

1974: Reactor Safety Study (RSS) initiated

1975: Results from RSS, better known as the Rasmussen Report (WASH-1400) published

NRC undertakes two sets of follow-up PRA studies: RSSMAP and IREP* improving PRA methods

1986: NRC introduces two safety goals stated in terms of public health risk (individual and societal)

1988: NRC issues Generic Letter 88-20 acknowledging that each nuclear power plant is unique and may have plant specific vulnerabilities

NRC introduces concept of risk-informed regulation through PRA policy statement

1998: NRC published a series of key Regulatory Guides (RGs) 1.174-8

NRC begins preparation for Next Generation Nuclear Plant (NGNP) license review

1940 | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2010

1941: Enrico Fermi and his team achieve first demonstration of a nuclear chain reaction with the Chicago Pile experiment

Establishment of the Atomic Energy Commission (AEC) as part of the Atomic Energy Act of 1946

First formal textbook addressing risk in nuclear power plants written by MIT professor Ernst Frankel

Emergency Core Cooling System (ECCS) integral effects test, LOFT, casts doubt on safety system performance

1974: Congress abolishes AEC and sets up the Nuclear Regulatory Commission (NRC)

PRAs for Zion and Indian Point are published showing risk-significance of fires and earthquakes

1979: Accident at TMI occurs resulting in significant core damage sparking significant public fear

NRC endorses surrogate objectives known as CDF and LERF *

NRC starts work on NUREG-1150, 'Severe Accident Risks: An Assessment for Five US Nuclear Power Plants'

NRC in the process of reviewing several new COL applications for Gen III+ plants

2002: NRC issues guidance on performance-based regulation

1998: NRC introduces its Reactor Oversight Process (ROP)

RSSMAP = Reactor Safety Study Methodology Application Program
IREP = Interim Reliability Evaluation Program

CDF = Core Damage Frequency
LERF = Large Early Release Frequency

STANFORD UNIVERSITY