Fukushima and the Role of Past Severe Accident Research

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City College of New York
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Yamadamachi, March 11, 2011

Associated Press

Fukushima – Daiichi, March 10 2011

American Nuclear Society

History of
Probabilistic Risk Assessments of
Severe Reactor Accidents

U.S. Severe Accident Documents

THEORETICAL POSSIBILITIES AND CONSEQUENCES OF MAJOR ACCIDENTS IN LARGE NUCLEAR POWER PLANTS

A Study of Possible Consequences if Certain Assumed Accidents, Theoretically Possible but Highly Improbable, W

in Large Nuclear Power Plants

WASH-740

UNITED STATES ATOMIC ENERGY COMMISSI

March 1957

WASH-1400
(NUREG 75/014)

REACTOR SAFETY STUDY

AN ASSESSMENT OF
ACCIDENT RISKS IN U.S. COMMERCIAL
NUCLEAR POWER PLANTS

EXECUTIVE SUMMARY

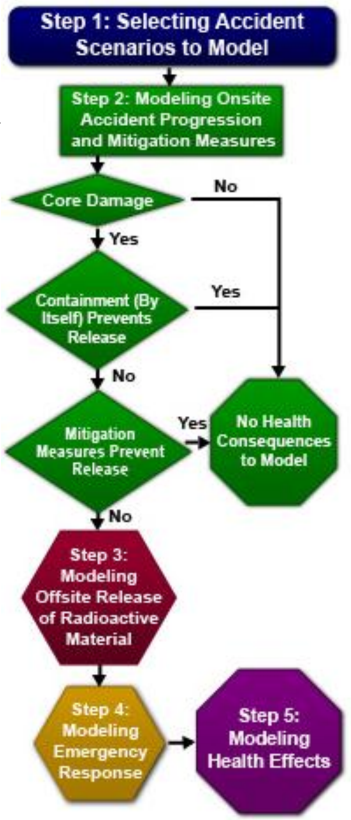
U.S. NUCLEAR REGULATORY COMMISSION
OCTOBER 1975

Severe Accident Risks:
An Assessment for Five
U.S. Nuclear Power Plants

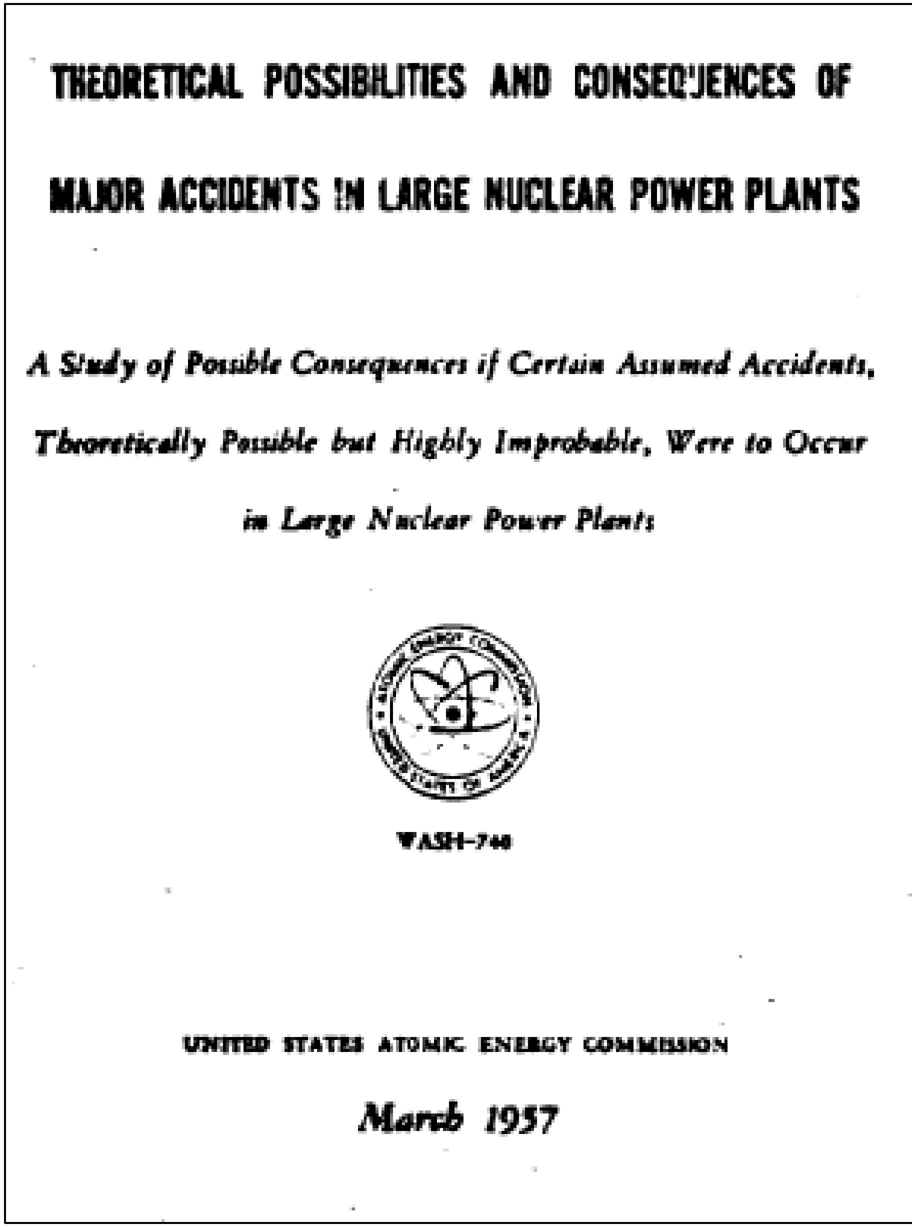
Final Summary Report

U.S. Nuclear Regulatory Commission

Office of Nuclear Regulatory Research



WASH 740, published 1957



THEORETICAL POSSIBILITIES AND CONSEQUENCES OF

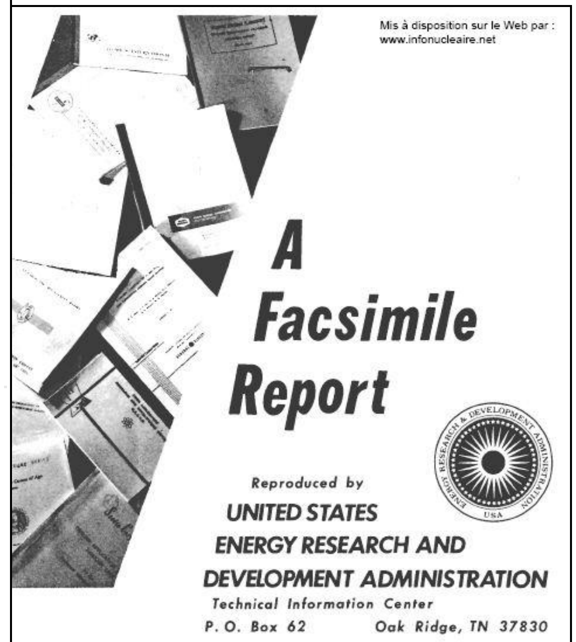
MAJOR ACCIDENTS IN LARGE NUCLEAR POWER PLANTS

A Study of Possible Consequences if Certain Assumed Accidents, Theoretically Possible but Highly Improbable, Were to Occur in Large Nuclear Power Plants

WASH-740

UNITED STATES ATOMIC ENERGY COMMISSION

March 1957



WASH 740 Table of Contents

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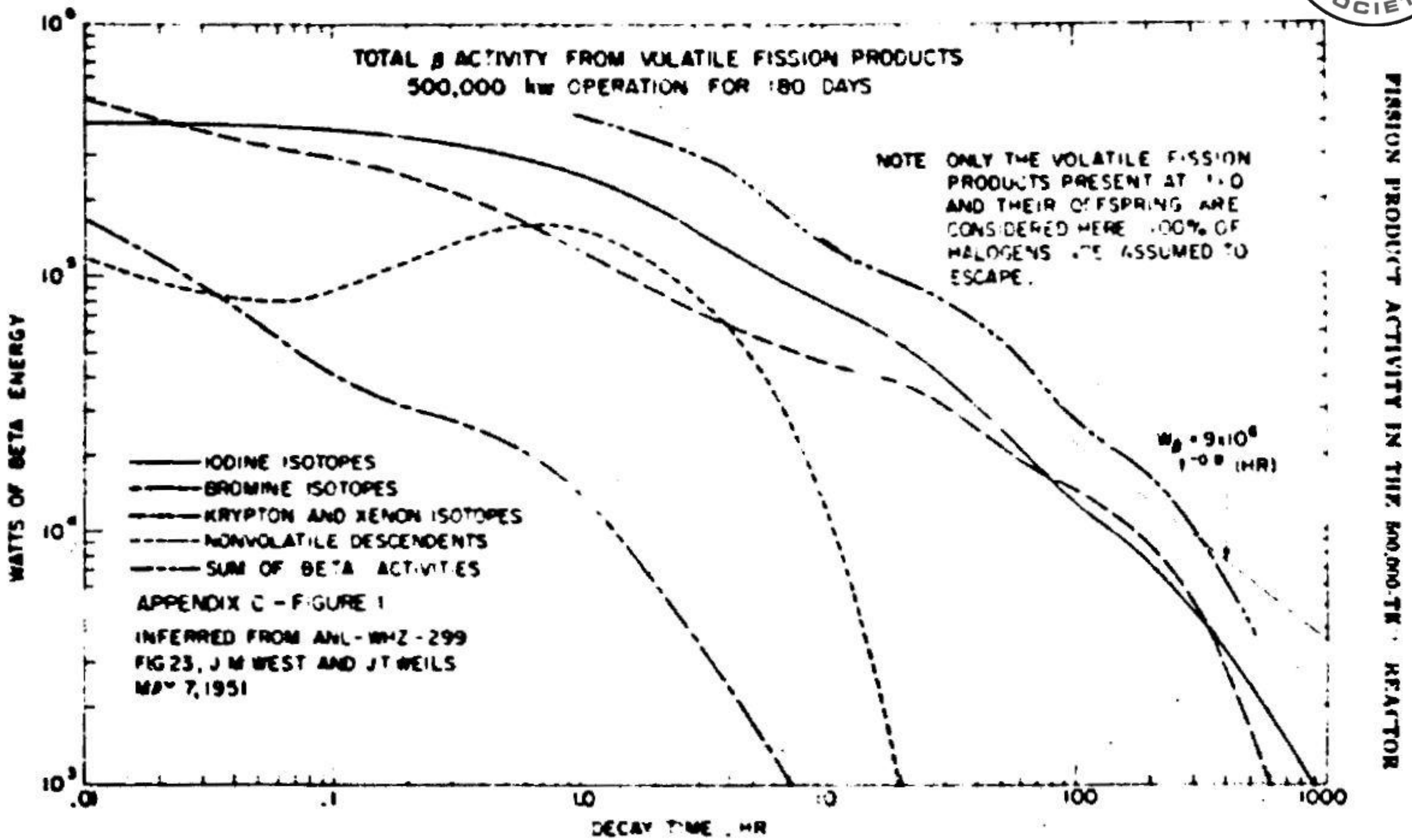
WASH 740 Appendix C - Fission Product Activity in a 500,000 tkw Reactor



WASH 740 Appendix D – Effects of Fission Product Release on Humans And Land Use

For Strontium-90: maximum permissible body dosage maintained over a "working lifetime… the average amount over 40 years would be…"

$$\frac{1}{40}\int_0^{40} \exp\left(-\frac{0.693}{6}t\right)dt = \frac{1}{40}$$

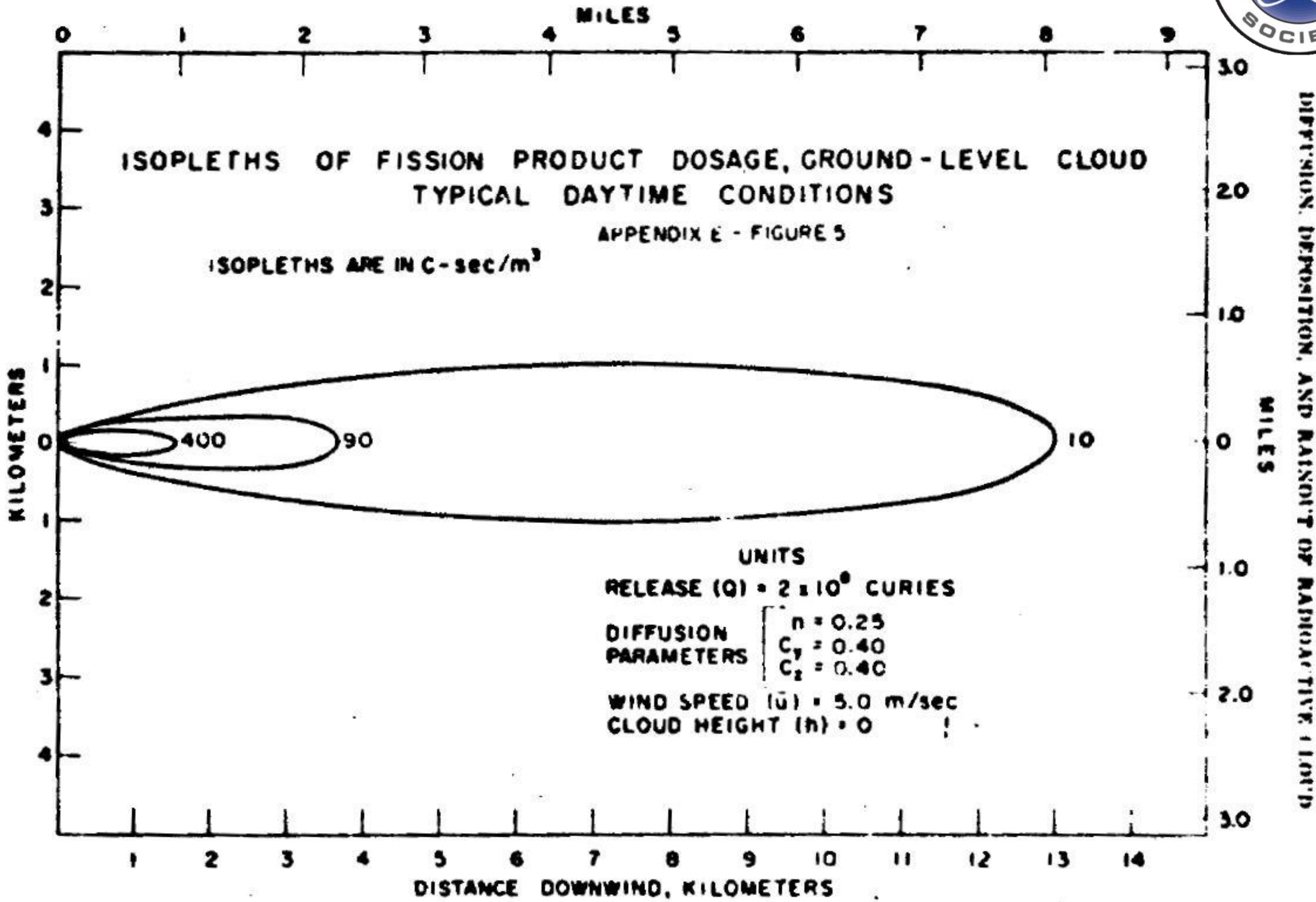
$$- \frac{6}{0.693} \exp\left(-\frac{0.693}{6}t\right)\Big]_0^{40}$$

$$= [-6/(0.693 \cdot 40)] \left(e^{-4.6} - 1\right)$$

$$(1/4.6)\left(1 - e^{-4.6}\right) \simeq 0.21$$

"…of that originally present"

WASH 740 Appendix E – Diffusion, Deposition, And Rainout of the Radioactive Cloud



Chernobyl, May 1986

WASH 1400, published 1975

(NUREG 75/014)

REACTOR SAFETY STUDY

AN ASSESSMENT OF
ACCIDENT RISKS IN U.S. COMMERCIAL
NUCLEAR POWER PLANTS

EXECUTIVE SUMMARY

U.S. NUCLEAR REGULATORY COMMISSION
OCTOBER 1975

Professor Rasmussen

Frequency of Fatalities due to Man-Caused Events

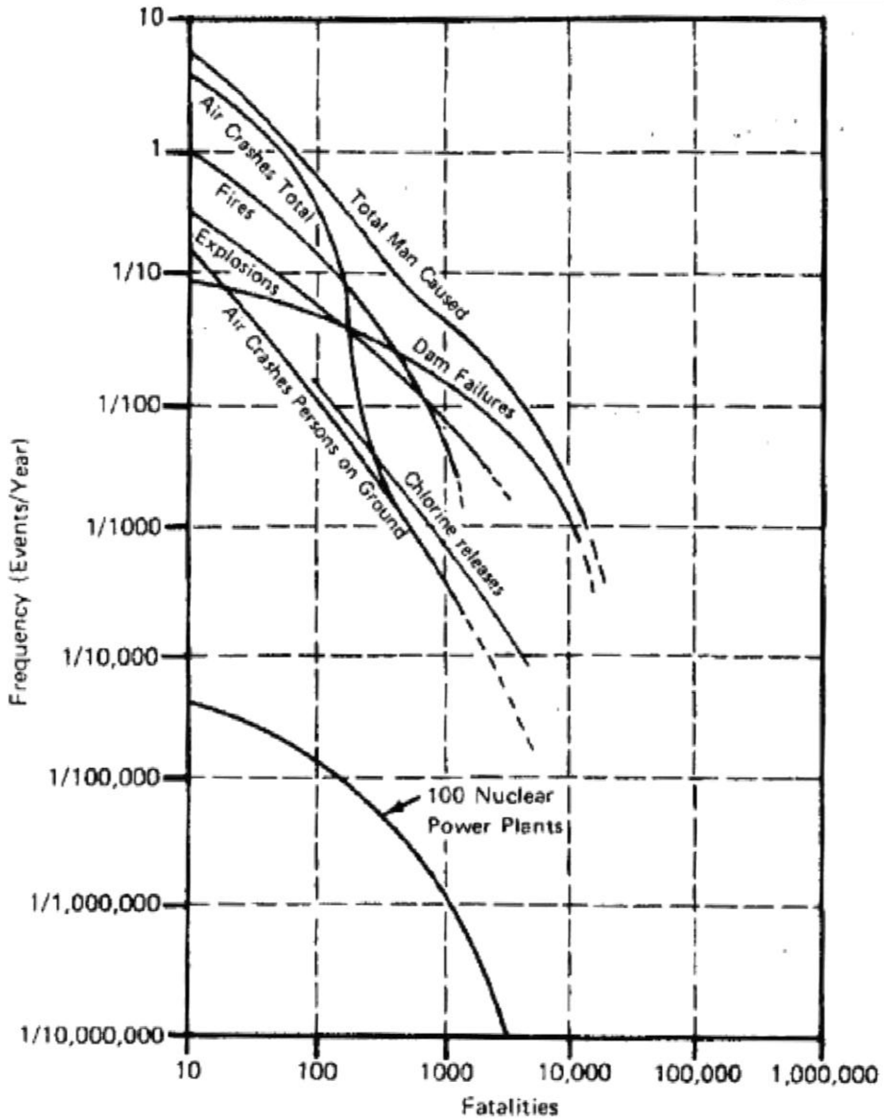


FIGURE 1-1 Frequency of Fatalities due to Man-Caused Events

Frequency of Fatalities due to Natural Events

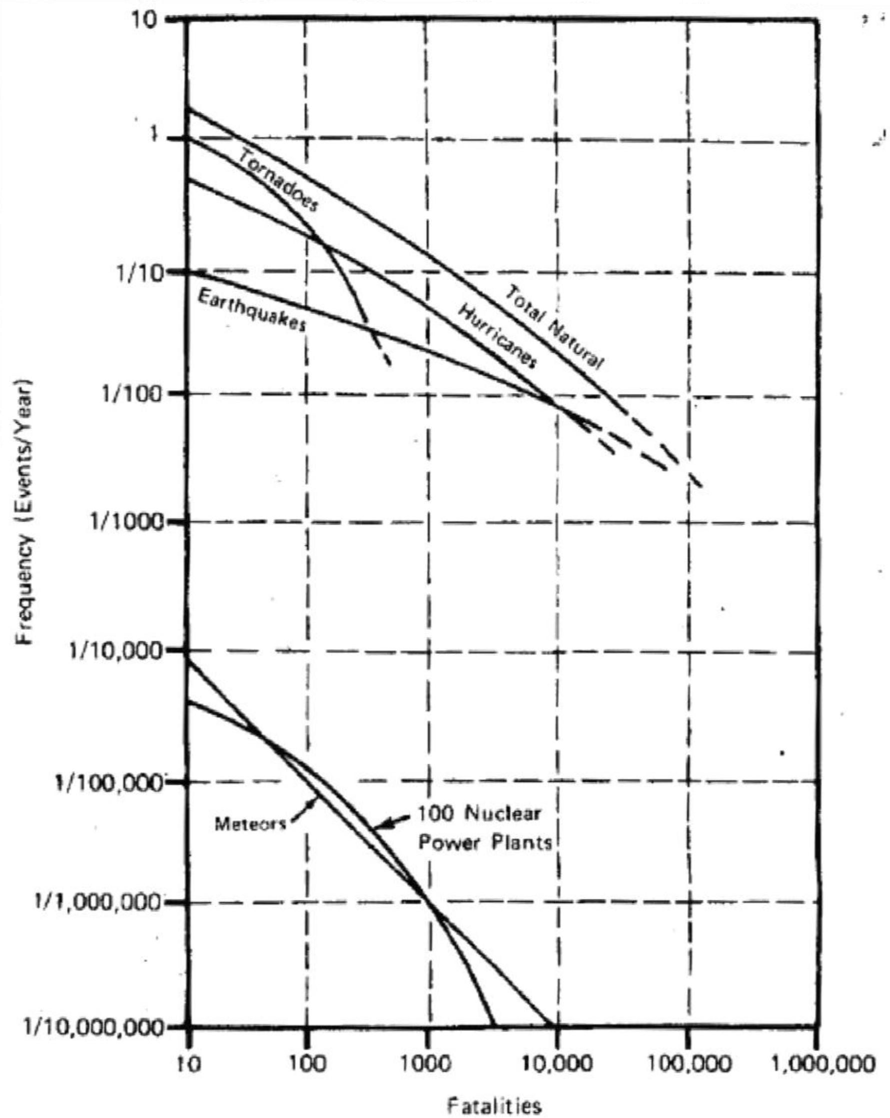


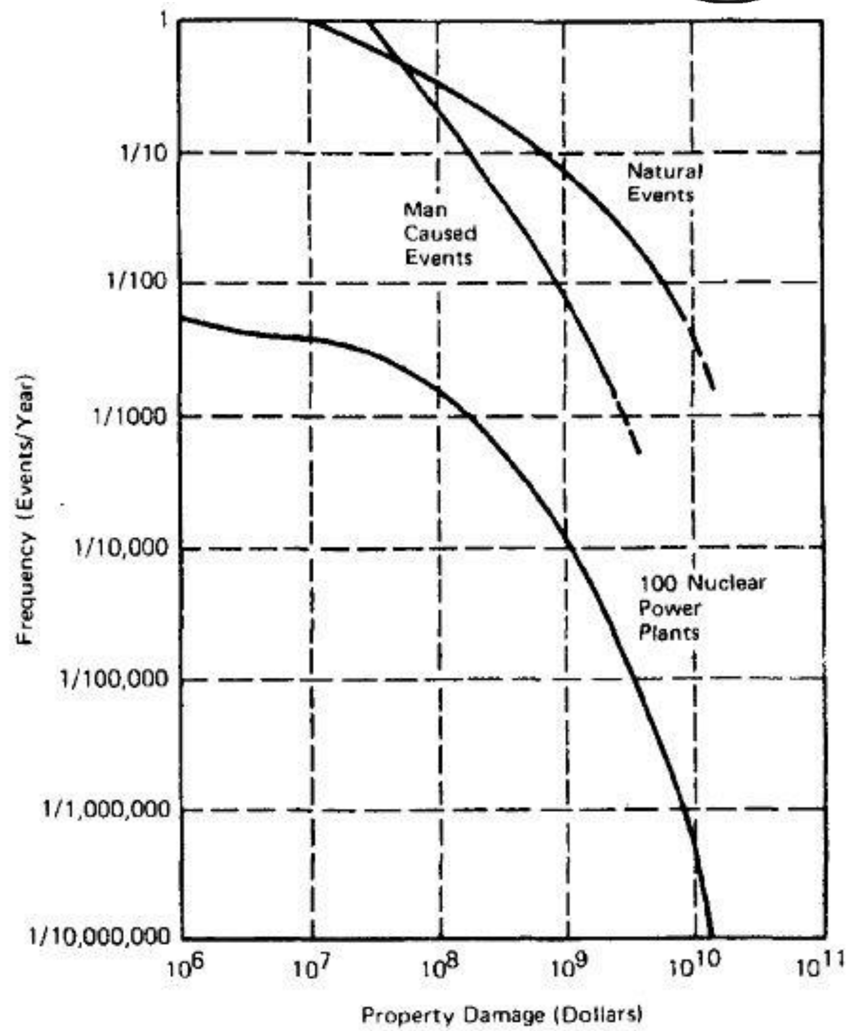
FIGURE 1-2 Frequency of Fatalities due to Natural Events

WASH 1400

FIGURE 1-3 Frequency of Property Damage due to Natural and Man-Caused Events

Notes:

1. Property damage due to auto accidents is not included because data are not available for low probability events. Auto accidents cause about $15 billion damage each year.
2. Approximate uncertainties for nuclear events are estimated to be represented by factors of 1/5 and 2 on consequence magnitudes and by factors of 1/5 and 5 on probabilities.
3. For natural and man caused occurrences the uncertainty in probability of largest recorded consequence magnitude is estimated to be represented by factors of 1/20 and 5. Smaller magnitudes have less uncertainty.



WASH 1400

TABLE 1-1 AVERAGE RISK OF FATALITY BY VARIOUS CAUSES

Accident Type	Total Number	Individual Chance per Year
Motor Vehicle	55,791	1 in 4,000
Falls	17,827	1 in 10,000
Fires and Hot Substances	7,451	1 in 25,000
Drowning	6,181	1 in 30,000
Firearms	2,309	1 in 100,000
Air Travel	1,778	1 in 100,000
Falling Objects	1,271	1 in 160,000
Electrocution	1,148	1 in 160,000
Lightning	160	1 in 2,000,000
Tornadoes	91	1 in 2,500,000
Hurricanes	93	1 in 2,500,000
All Accidents	111,992	1 in 1,600
Nuclear Reactor Accidents (100 plants)	-	1 in 5,000,000,000

Probability Distribution for Early Fatalities per Reactor Year

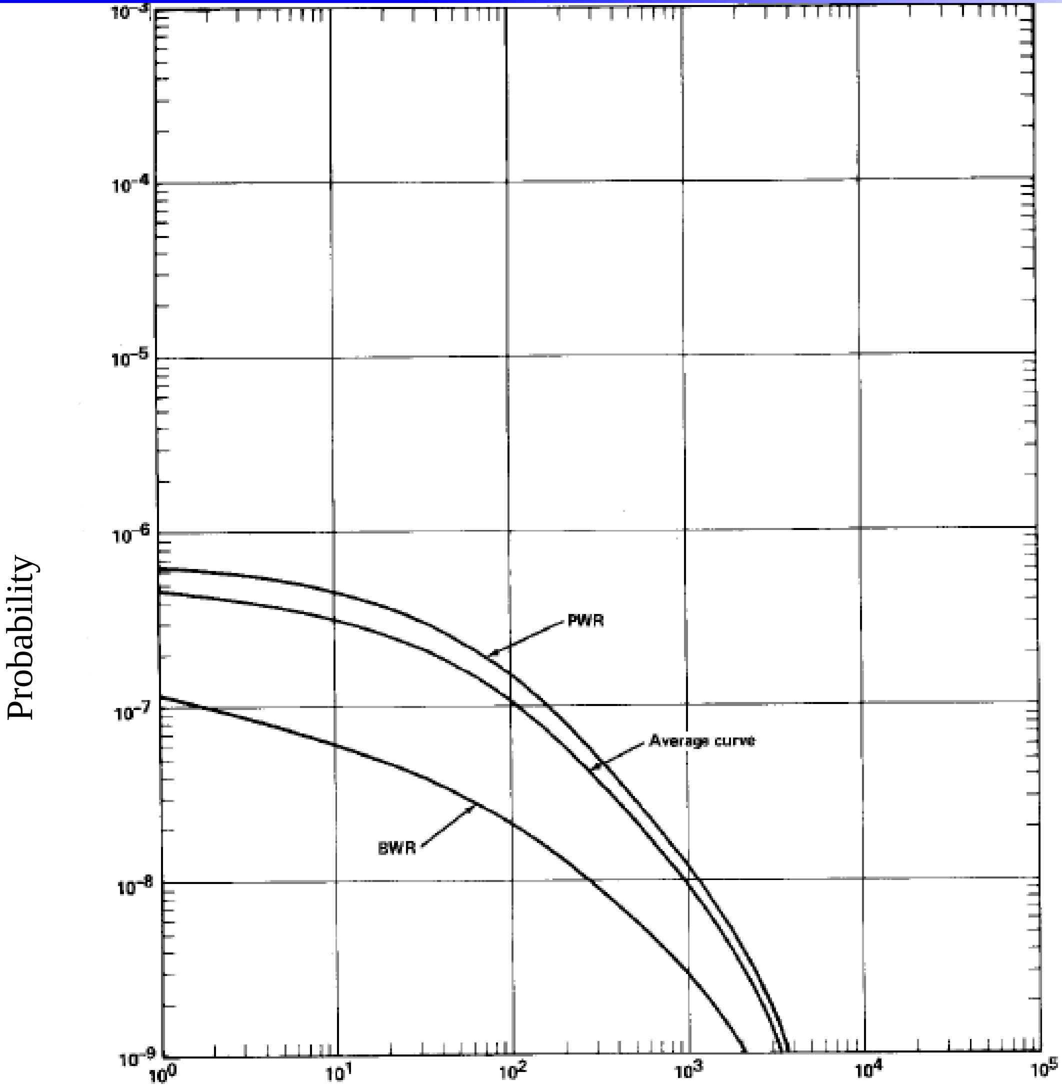


FIGURE 5-3 Probability Distribution for Early Fatalities per Reactor Year

Fatalities

WASH 1400

1. Who did this study and how much effort was involved?
2. What kind of nuclear power plants are covered by the study?
3. Can a nuclear power plant explode like an atom bomb?
4. How is risk defined?
5. What causes the risks associated with nuclear power plant accidents?
6. How can radioactivity be released?
7. How might a core melt accident occur?
8. What features are provided in reactors to cope with a core melt accident?
9. How might the Loss-of-Coolant Accident lead to a core melt?
10. How might a reactor transient lead to a core melt?
11. How likely is a core melt accident?
12. What is the nature of the health effects that a core melt accident might produce?
13. What are the most likely consequences of a core melt accident?
14. How does average annual risk from nuclear accidents compare to other common risks?
15. What is the number of fatalities and injuries expected as a result of a core melt accident?
16. What is the magnitude of the latent, or long-term, health effects?
17. What type of property damage might a core melt accident produce?
18. What would be the cost of the consequences of a core melt accident?
19. What is the chance of a reactor meltdown in year 2000 if 1000 reactors are operating?
20. How do we know that the study has included all accidents in the analysis?
21. What techniques were used in performing the study?

NUREG-1150, published 1990

NUREG–1150
Vol. 1

Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants

Final Summary Report

U.S. Nuclear Regulatory Commission

Office of Nuclear Regulatory Research

Five U.S. Nuclear Power Plants Evaluted in NUREG-1150

Table 1: Five U.S. Nuclear Power Plants Evaluated in NUREG-1150

Name	Type	Containment	Vendor	Constructor	Operation
Surry (2 Units)	PWR (3 loops) 788MWe	Dry-sub atmospheric	Westinghouse	Stone & Webster	1972-present
Peach Bottom	BWR-4 1065MWe	Mark I	GE	Bechtel	1974-present
Sequoyah (2 units)	PWR (4 loops) 1148 MWe	Ice condenser containment	Westinghouse	TVA	1981-present
Grand Gulf	BWR-6 1,250MWe	Mark III	GE	Bechtel	1985-present
Zion (2 units)	PWR (4 loops) 1,100MWe	Prestressed concrete, steel lined dry containment	Westinghouse	Sargent & Lundy	1973-1998

NRC Objectives for NUREG-1150

- Assess Possible BWR & PWR Severe Accidents
- Assess Public Risks
- Update 1975 WASH-1400 Risk Assessment Process
- Identify Plant-Specific Risks
- Summarize the Risk Analyses

NUREG-1150

Table 2: NUREG-1150 Key Plant Attributes

Attribute	Surry (Ch3)	Peach Bottom (Ch4)	Sequoyah (Ch5)	Grand Gulf (Ch6)	Zion (Ch7)
Plant type	PWR (3 loop)	BWR 4	PWR (4 loop)	BWR-6	PWR (4 loop)
Battery time	2 hrs	10 – 12 hrs	2 hrs	12 hrs	(not given)
Mean core damage frequency per reactor year	3 E-5	3 E-6	4 E-5	3 E-6	2 E-4
Range of time to core damage	5 min to 8 hours	15 min to 13 hours	Not provided	20 min to 12 hours	Not provided
Maximum early fatalities	1,000	3	3,000	30	10,000

NRC Guidance For Use of NUREG-1150

- Examination of Accidents
- Accident Management Strategies
- Improving Containment
- Evaluating Plant Operational Features
- Strategies for Implementing Safety Goals
- Emergency Planning
- Prioritizing Research Projects
- Prioritizing Generic Issues
- Applying PRA to Routine Inspections

Comparison of Early Fatality Risks

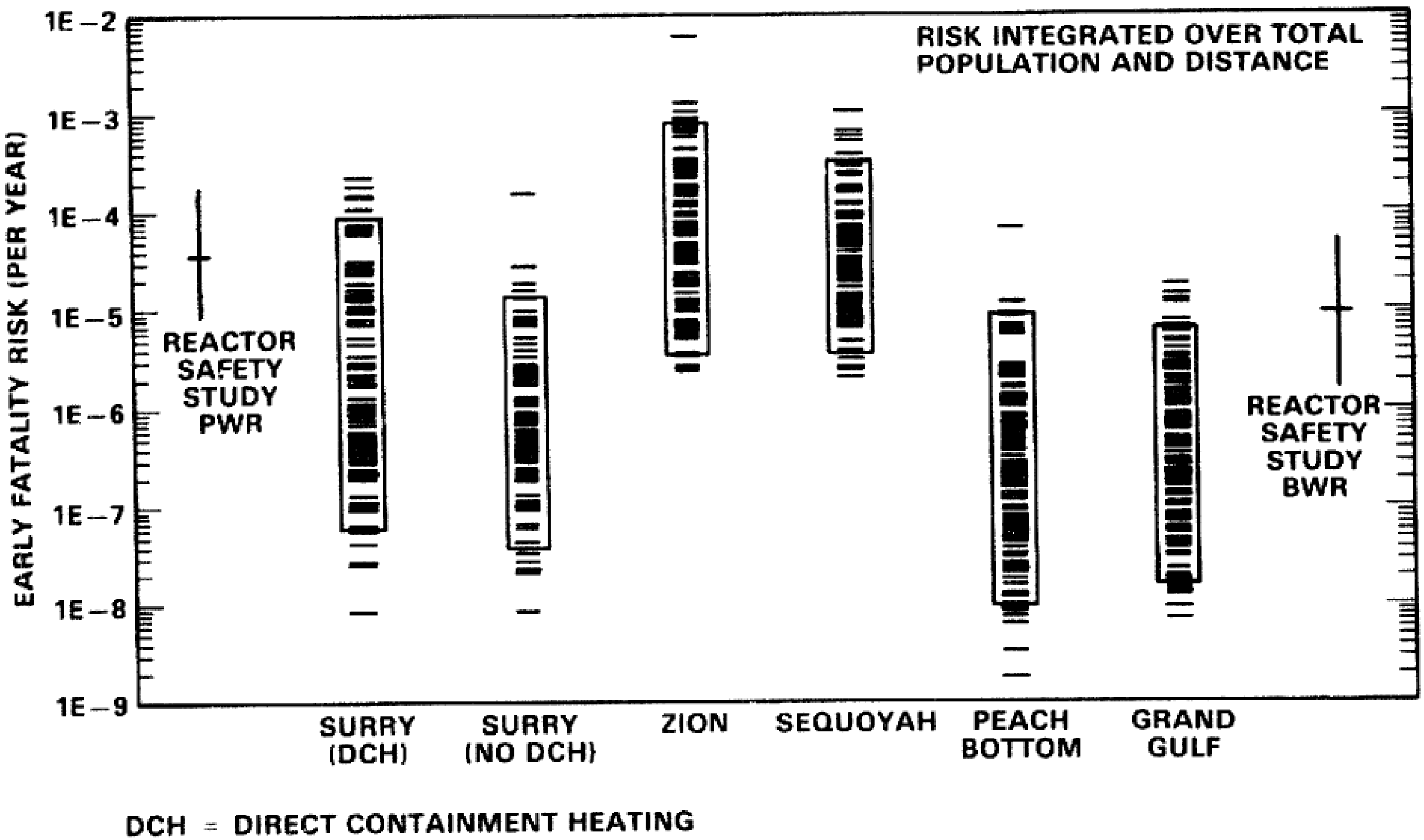


Figure ES.3 Comparison of early fatality risks

Probability of One or More Early Fatalities

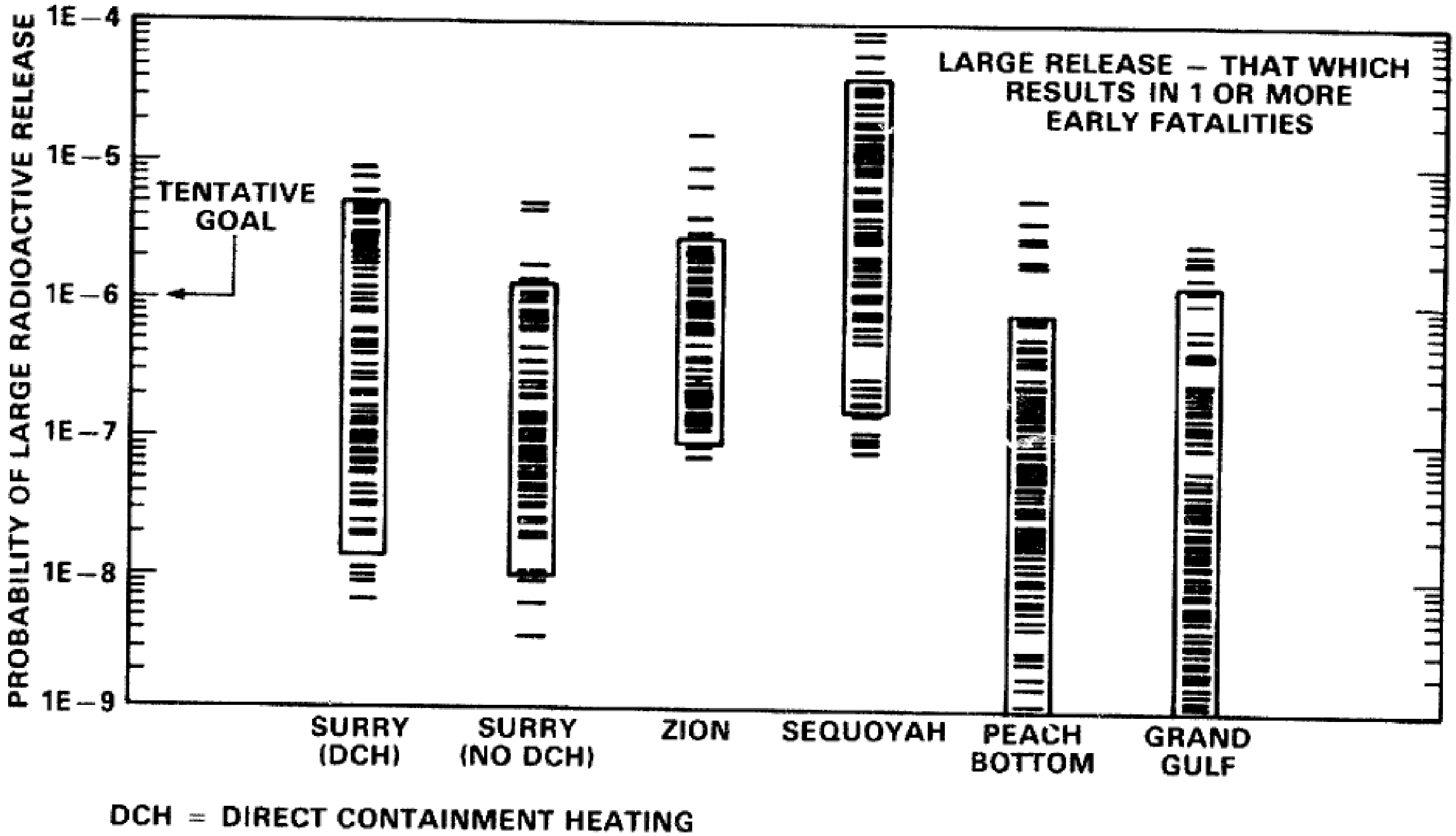


Figure ES.7 Probability of one or more early fatalities

Identification and Evaluation Of PWR In-Vessel Severe Accident Management Strategies (NUREG-5856)

Reactor Safety Top Level Logic Tree

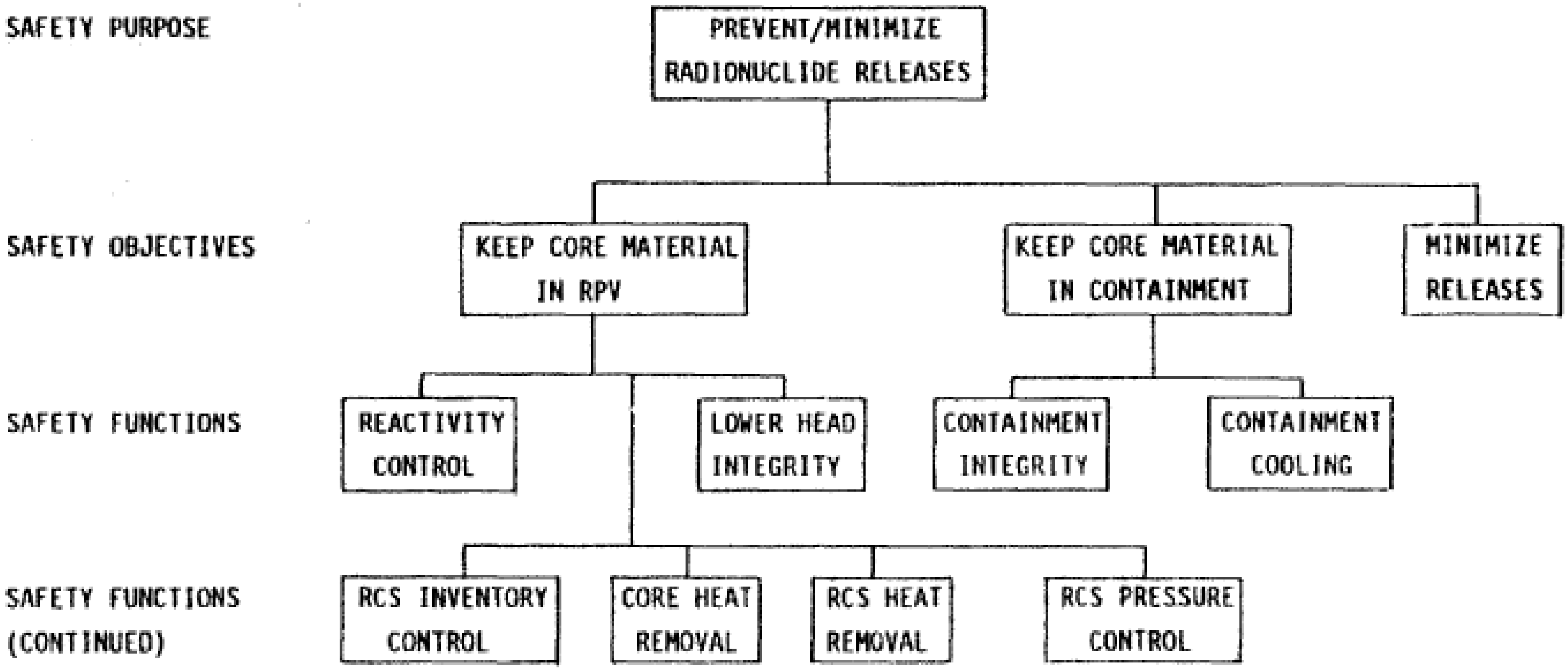


FIGURE 1.1. Reactor Safety Top Level Logic Tree

Classification of Proposed Strategies

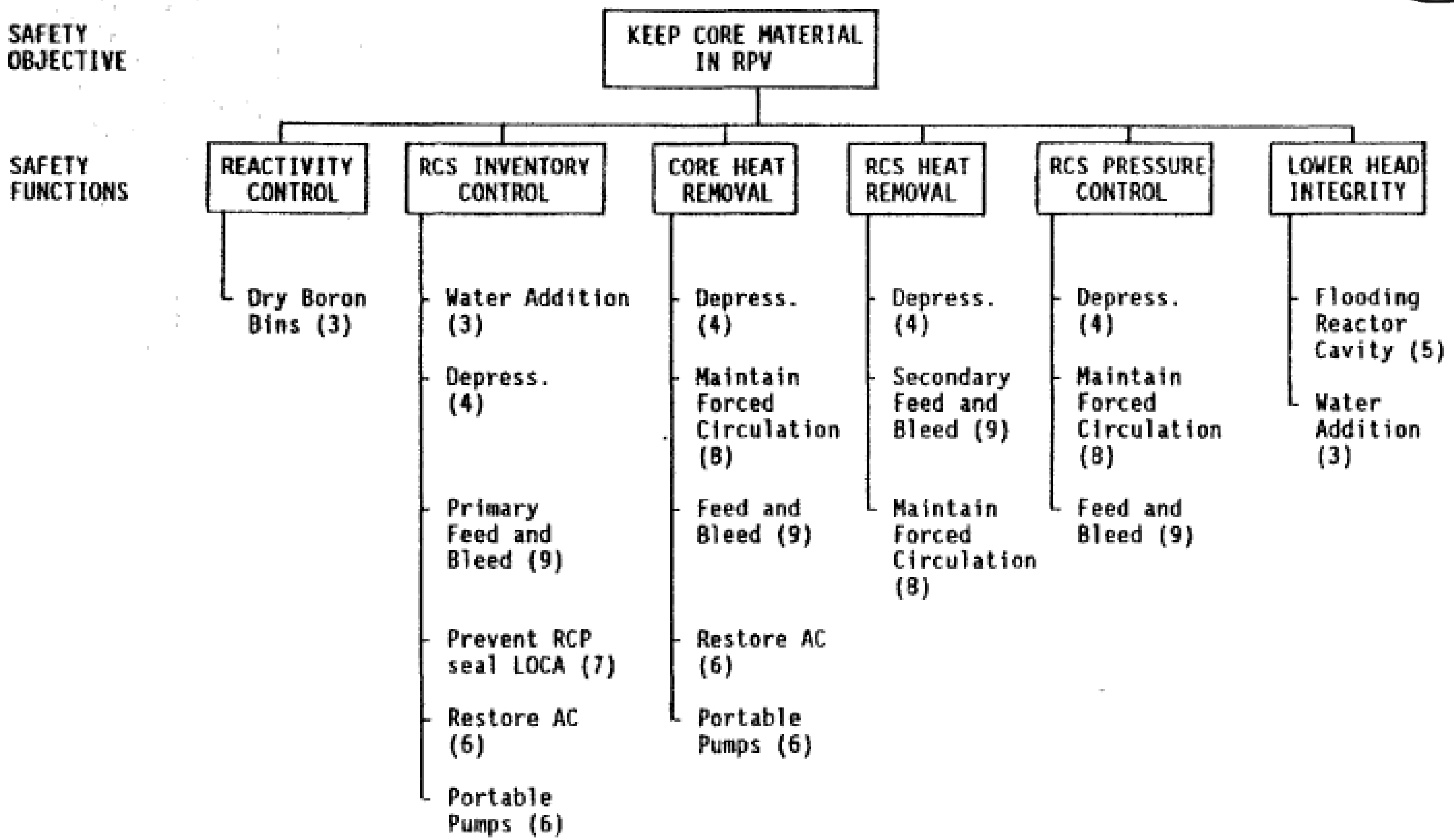


FIGURE 1.2. Classification of Proposed Strategies

Identification and Assessment of BWR In-Vessel Severe Accident Mitigation Strategies (NUREG-5869)

IDENTIFICATION AND ASSESSMENT OF BWR IN-VESSEL SEVERE ACCIDENT MITIGATION STRATEGIES

Stephen A. Hodge J. C. Cleveland
T. S. Kress M. Petek

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831

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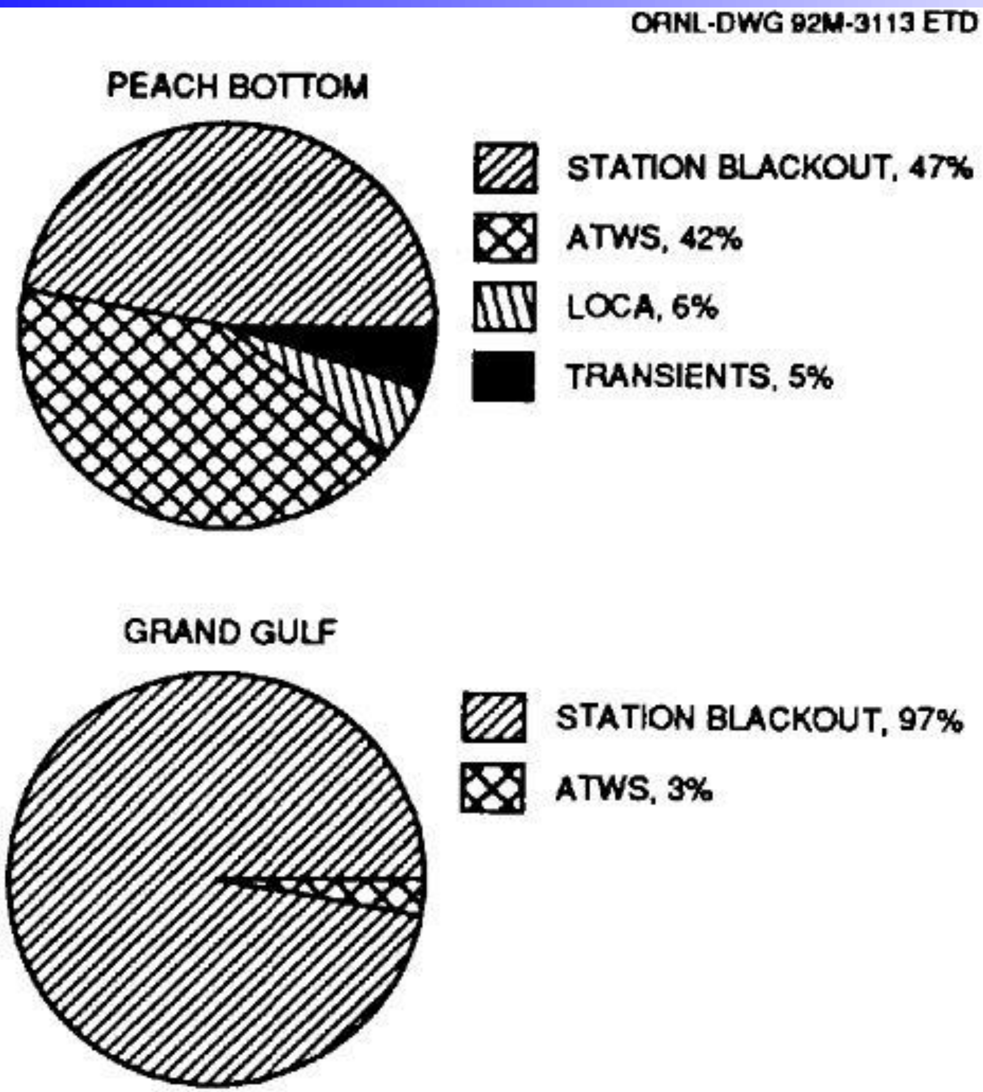


Figure 2.1 Dominant accident sequence contributors: station blackout and ATWS

Station Blackout Involving Loss of AC Electrical Power

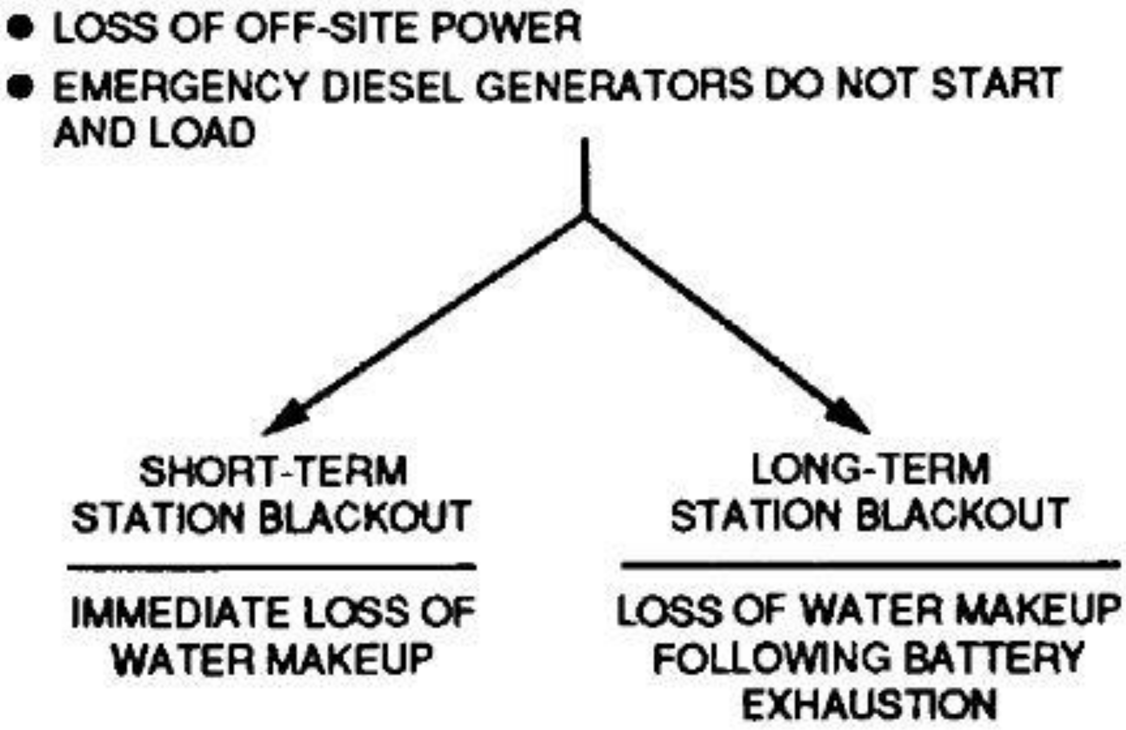


Figure 2.2 **Station blackout involving loss of ac electrical power**

Source-Range Detector Drive Unit And Locations of Detector

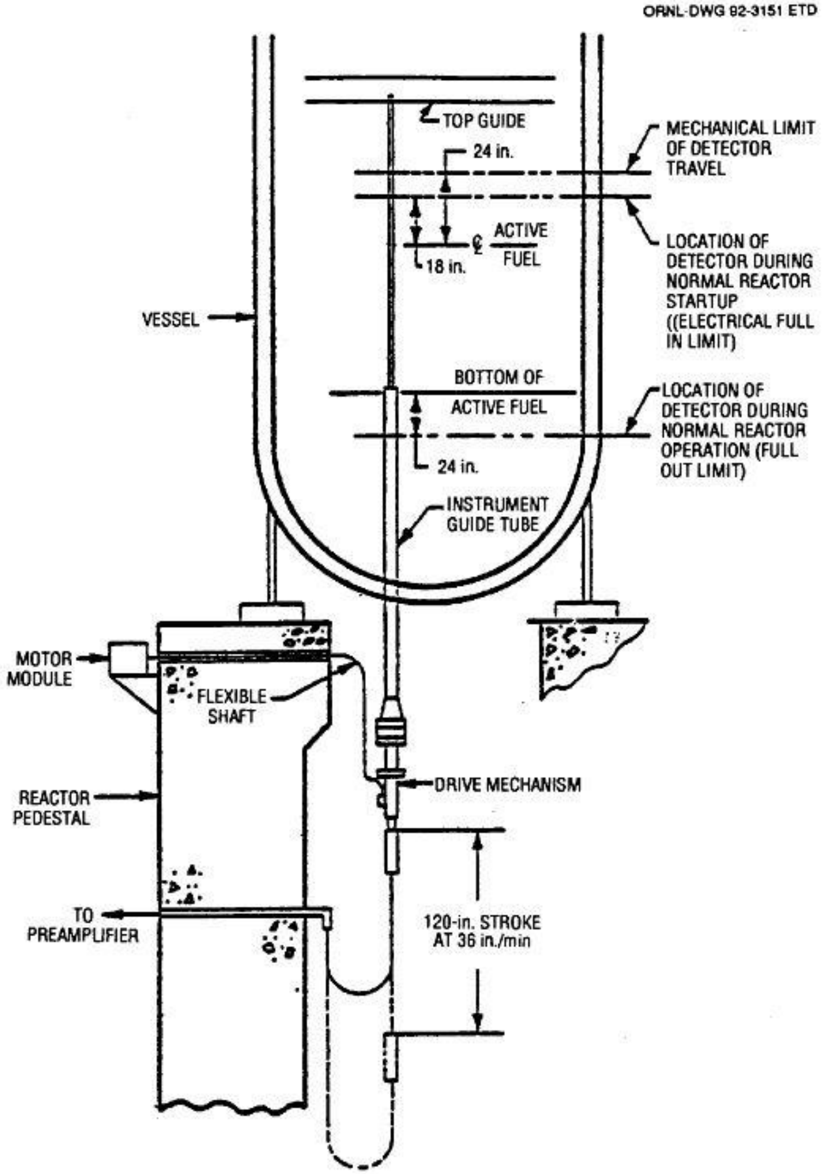


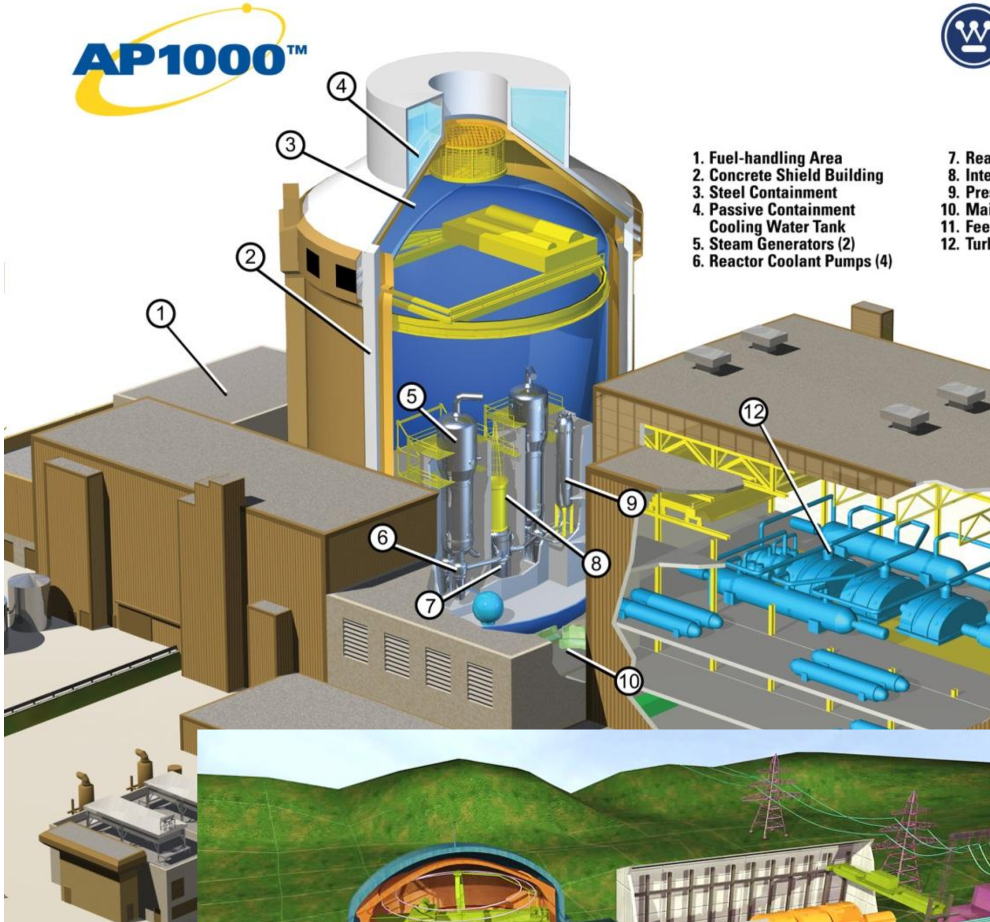
Figure 7.1 Source-range detector drive unit and locations of detector for startup and during power operation (from Browns Ferry Nuclear Plant Hot License Training Program)

Courage to go forward

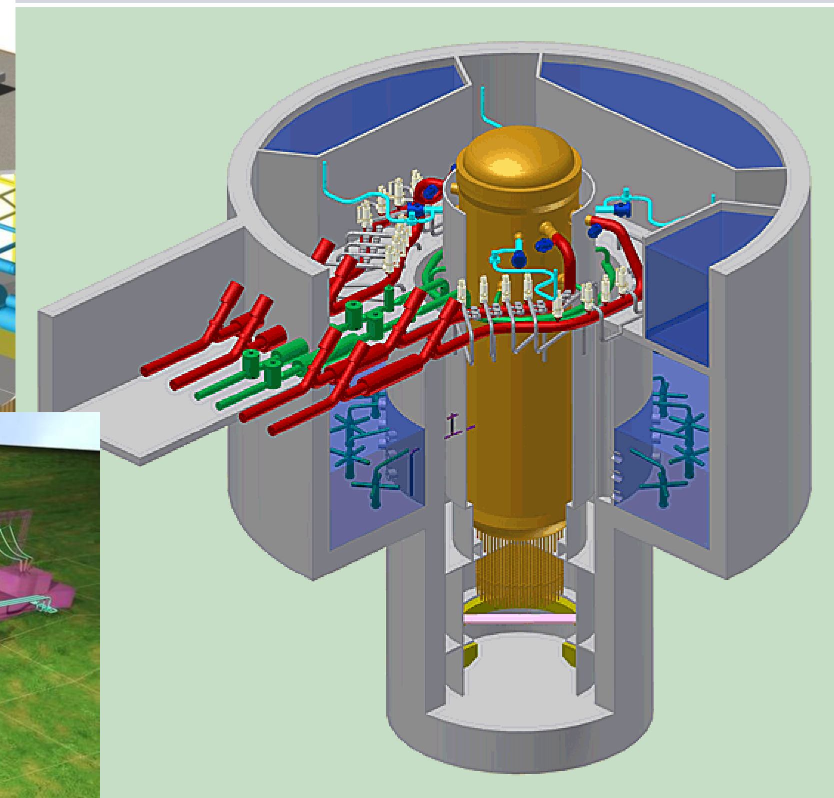
Fukushima Prefecture

Georgia, U.S.A. April 2011

AMERICAN NUCLEAR SOCIETY

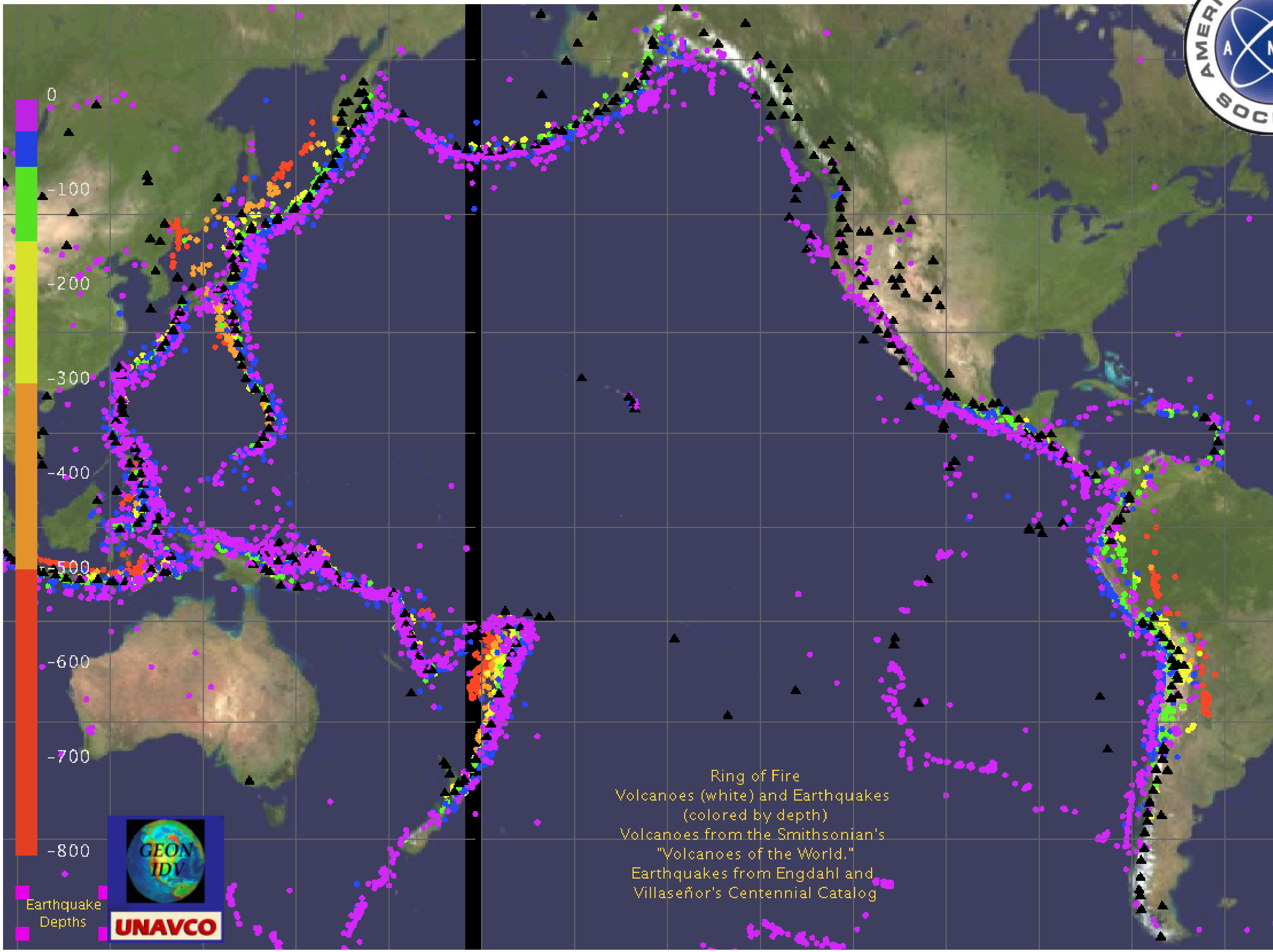


GE's ESBWR Design



Fukushima-Daiichi, April 2011

Pori, Finland 2010
Guardian, UK


0
-100
-200
-300
-400
-500
-600
-700
-800
Earthquake
Depths
GEON
IDV
UNAVCO
Ring of Fire
Volcanoes (white) and Earthquakes
(colored by depth)
Volcanoes from the Smithsonian's
"Volcanoes of the World."
Earthquakes from Engdahl and
Villaseñor's Centennial Catalog

All societies need stable, abundant energy

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ANS