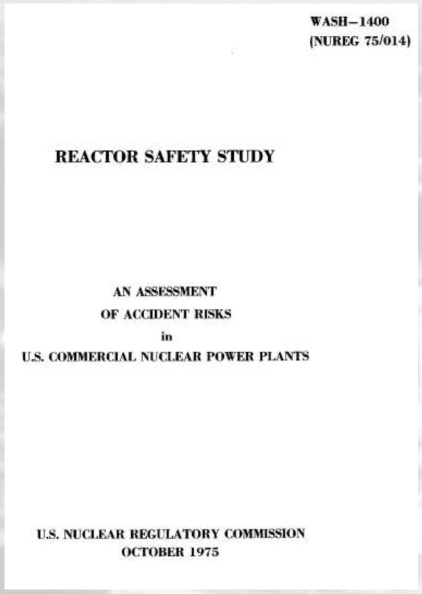
U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Seminar: WASH-1400 and the Origins of Probabilistic Risk Assessment (PRA) in the Nuclear Industry


WASH–1400
(NUREG 75/014)

REACTOR SAFETY STUDY

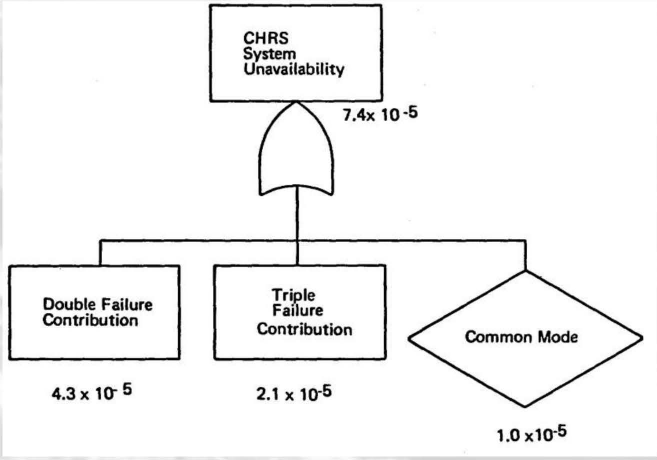
AN ASSESSMENT
OF ACCIDENT RISKS
in
U.S. COMMERCIAL NUCLEAR POWER PLANTS

U.S. NUCLEAR REGULATORY COMMISSION
OCTOBER 1975

Saul Levine

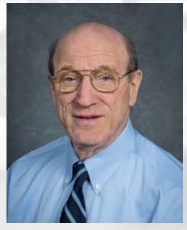
WASH-1400 Study Directors

Norman Rasmussen



Dr. Thomas Wellock

Tom Wellock is the historian for the U.S. NRC. Trained as both an engineer and a historian, he writes scholarly histories of the regulation of commercial nuclear energy. Until 2010 he was a Professor in the Department of History at Central Washington University in Ellensburg, Washington. He is the author of two books, Critical Masses: Opposition to Nuclear Power in California, 1958-1978 and Preserving the Nation: The Conservation and Environmental Movements, 1870-2000, and has authored numerous articles on the history of nuclear power. As an engineer, he worked for General Dynamics Corporation as a reactor test engineer in the construction of Los Angeles and Trident class submarines.



Dr. Robert J. Budnitz

Dr. Budnitz has been involved with nuclear-reactor safety and radioactive waste for many years. He is on the scientific staff at the University of California Lawrence Berkeley National Laboratory (LBNL), where he works on nuclear power safety security and radioactive-waste management. From 2002 to 2007 he was at UC's Lawrence Livermore National Laboratory (LLNL), during which period he worked on a two year special assignment in Washington to assist the Director of Office of Civilian Radioactive Waste Management to develop a new Science & Technology Program. Prior to joining LLNL in 2002, he ran a one-person consulting practice in California for over two decades. In 1978-1980 he was a senior official on the staff of the U.S. NRC, serving as Deputy Director and then Director of the Office of Nuclear Regulatory Research. In this two-year period, Dr. Budnitz was responsible for formulating and guiding the large NRC research program. From 1967-1978 he was at LBNL, including three years (1975-1978) as Associate Director of LBNL and Head of LBNL's Energy & Environmental Division.

U.S. Nuclear Regulatory Commission
Two White Flint North Auditorium
November 9, 2015, 10:00am to 12:00pm

Office of Nuclear Regulatory Research

KNOWvember
NRC'S KNOWLEDGE MANAGEMENT PROGRAM

A Figure of Merit:
The Search for the "P" in PRA

Tom Wellock

November 9, 2015

- Determinism—The preferred approach to safety.
- Fault-tree methodology borrowed from aerospace.
- WASH-1400 started at request of Congress

- Determinism—The preferred approach to safety.
  - Probabilism sought since early 1950s.
- Fault-tree methodology borrowed from aerospace.
  - Much work done in nuclear field.
- WASH-1400 started at request of Congress
  - AEC had already initiated study on its own for political and technical reasons.

- **Hanford Reactors**
  - **Safety through isolation**
  - **Reactor Safeguard Committee (ACRS)**
  - **Little inherent safety**
  - **Defense-in-Depth (1948)**

Hanford B Reactor

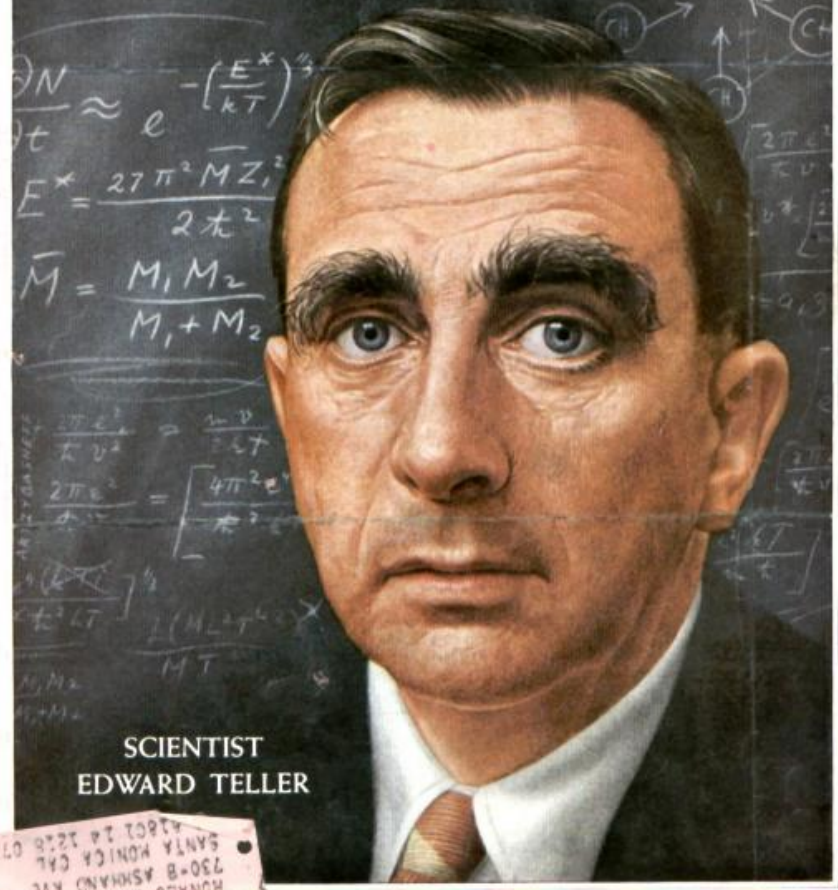
TWENTY-FIVE CENTS ★ NOVEMBER 18, 1957

Edward Teller

U.S. SCIENCE
Where It Stands Today

TIME

THE WEEKLY NEWSMAGAZINE



SCIENTIST
EDWARD TELLER

YEAR
REG. U.S. PAT. OFF.
VOL. LXX NO. 21

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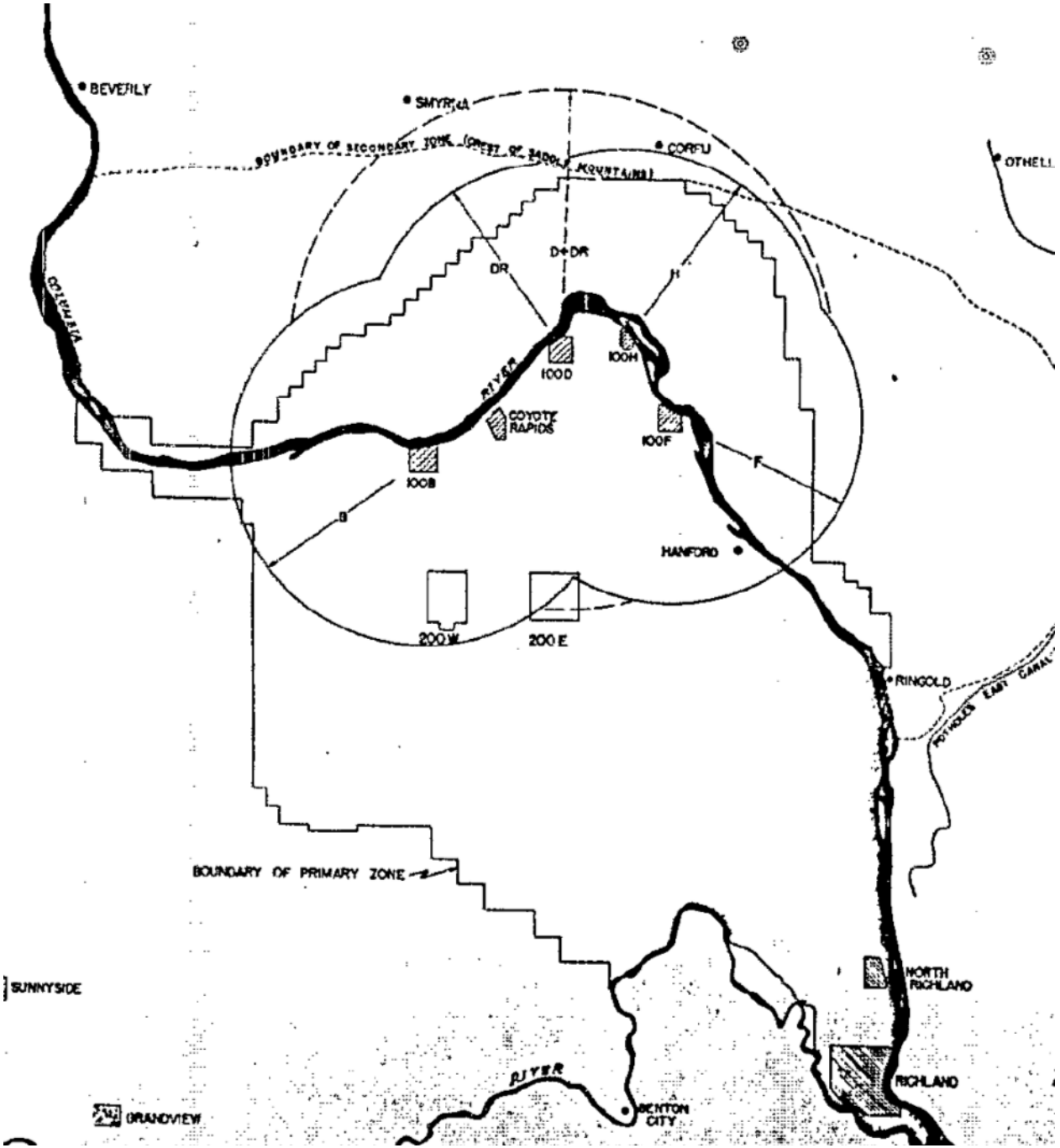
WASH-3: The First Safety Standard

$$D=0.01\sqrt{P}$$


BEVERLY
SMYRNA
CORFU
OTHELL
DR
D+DR
100D
100H
COYOTE RAPIDS
100F
100B
HANFORD
200W
200E
RINGOLD
POTHOLES EAST CANAL
BOUNDARY OF PRIMARY ZONE
SUNNYSIDE
NORTH RICHLAND
RICHLAND
BENTON CITY
GRANDVIEW

BY JWJordan DATE 6/8/81
BY AE Bartley DATE 6/10/81
LQ Orgill 5/11/99
PDQman 6-7-99

A. B. Greninger, Manager
Engineering Department
703 Building, 700 Area

July 20, 1953

This document consists of 4 pages, [redacted]

EVALUATION OF PROBABILITY OF DISASTER

- Failure to develop “top event” leads to focus on component and system reliability instead.

- Hanford’s experience unique. Risk quantification not pursued at Savannah River—more inherent safety.

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Seeing the Forest with Trees

Decision and Fault Trees in the 1960s

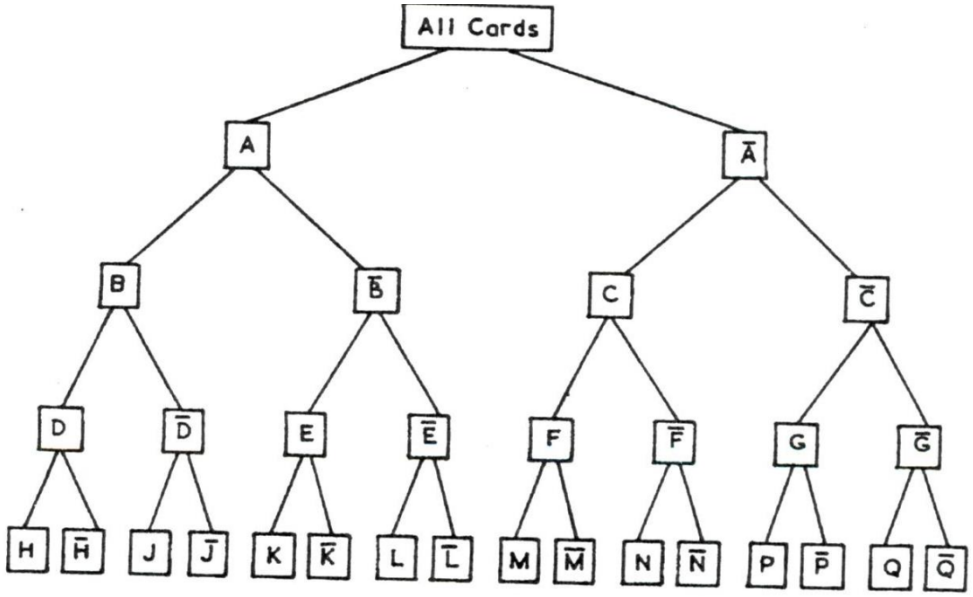
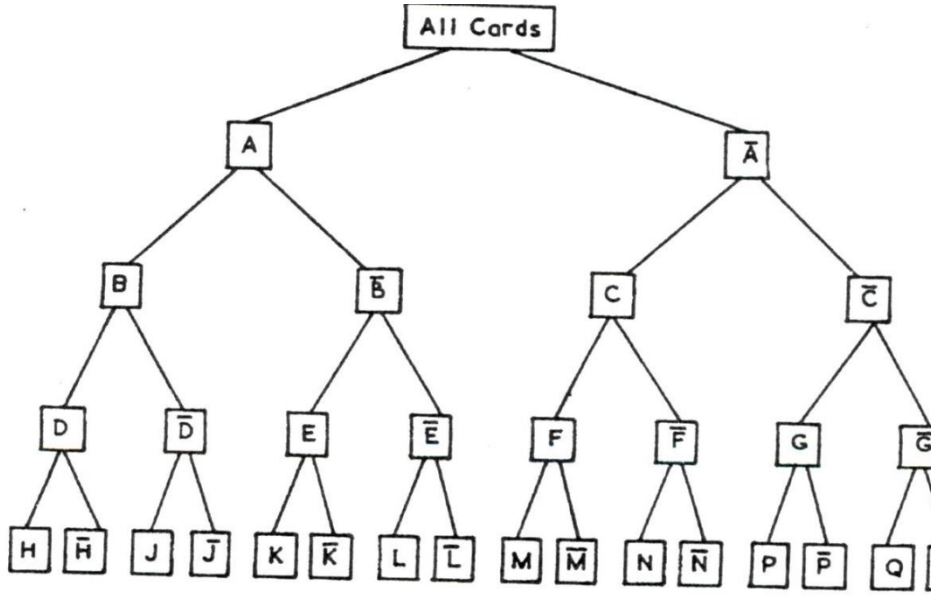


FIG. 1. Progressive splitting on the biological pattern. (It does not follow that every split will be in terms of a new variable; in practice it is quite feasible for group G to be split on variable D, or for group C to be split on variable B.



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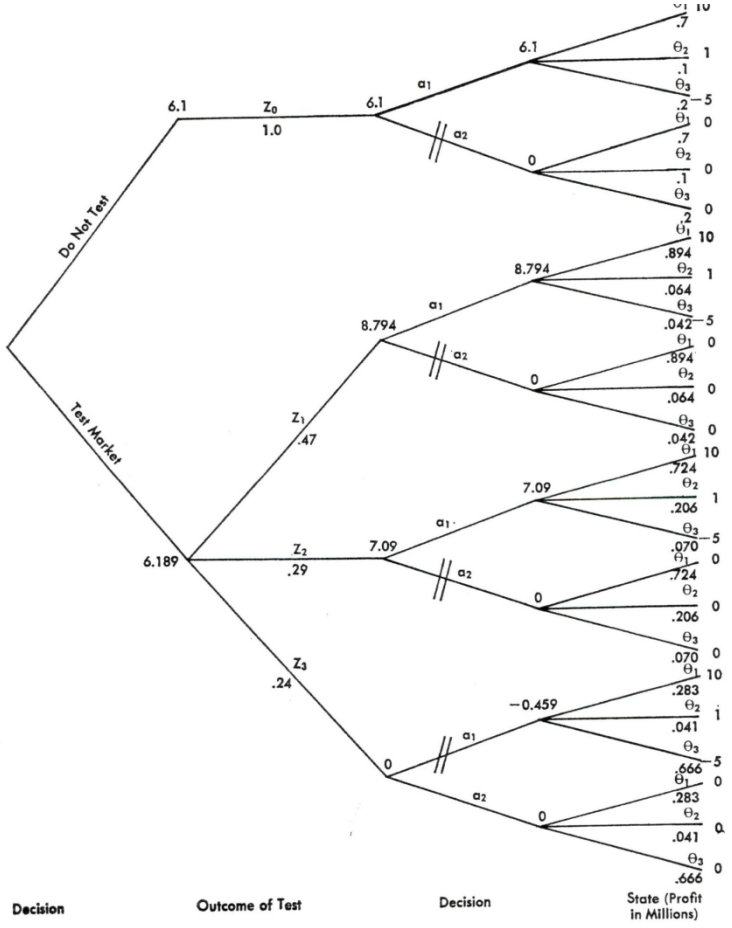


FIG. 1.—Analysis of proposal to test-market new product

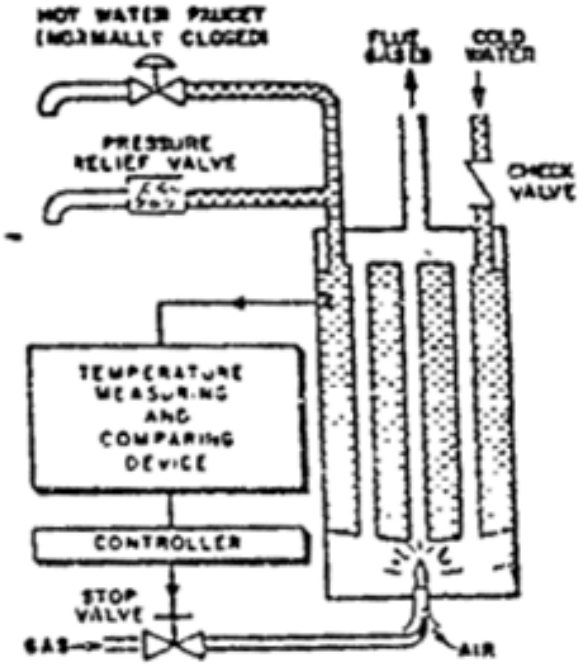


Figure 7-1a. Domestic Hot-Water System

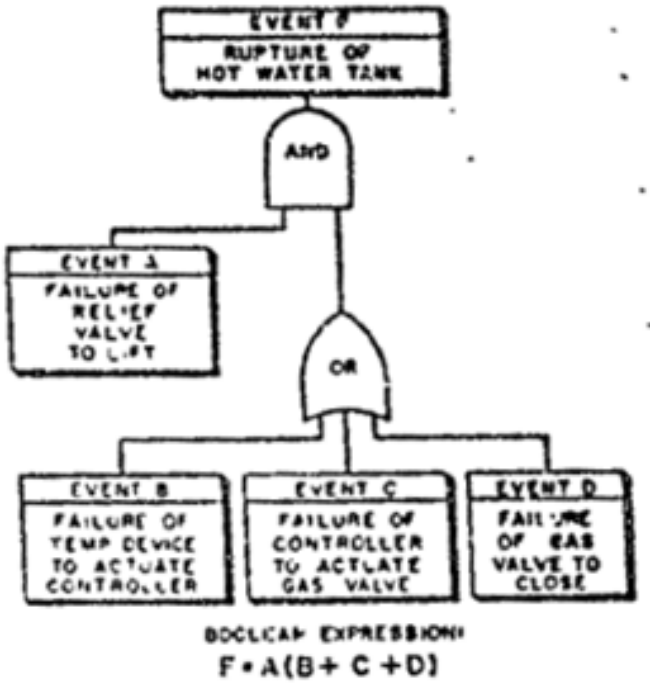


Figure 7-1b. Fault Tree and Boolean Expression for Hot-Water System

Bell Labs Fault Tree for a Hot Water Heater (1962)

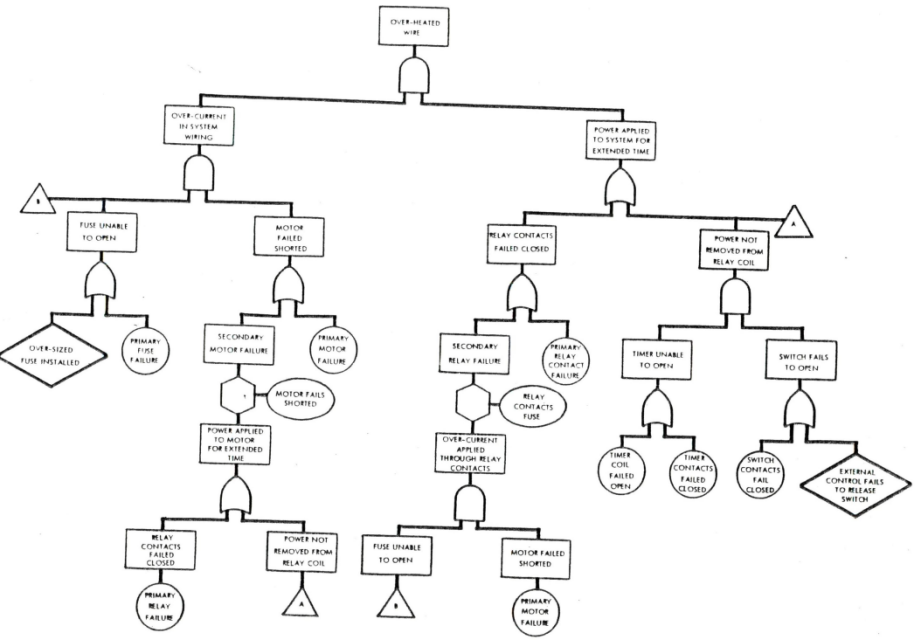


FIGURE 8 : FAULT TREE WITH SECONDARY FAILURE TECHNIQUE
(The triangles indicate a transfer to another portion of the tree)

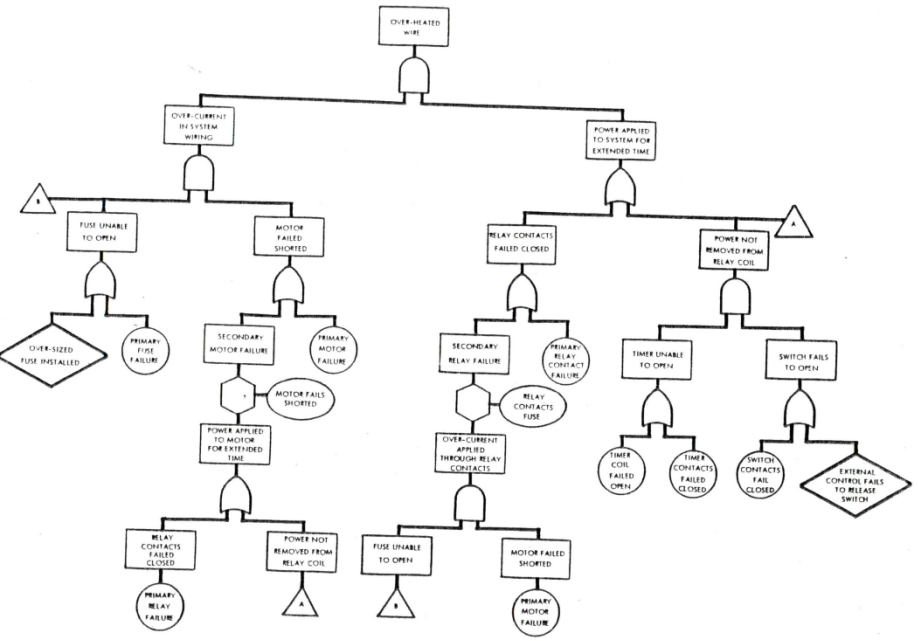
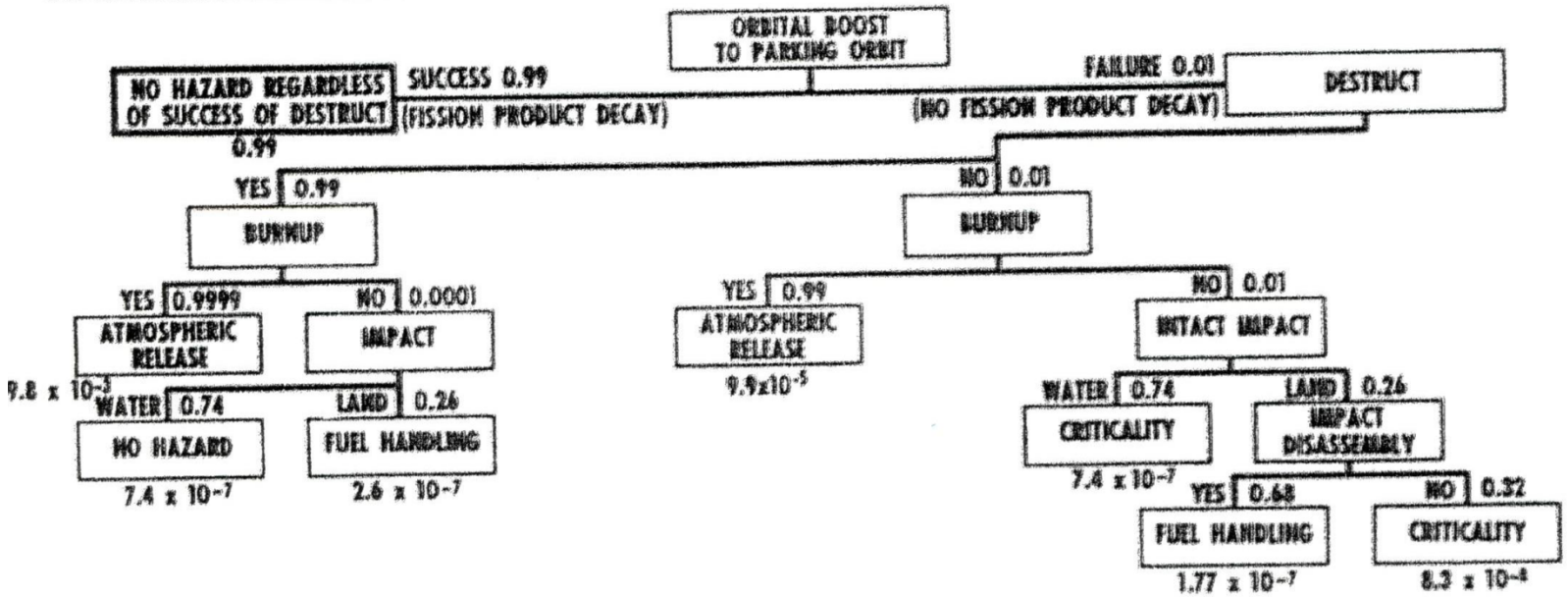
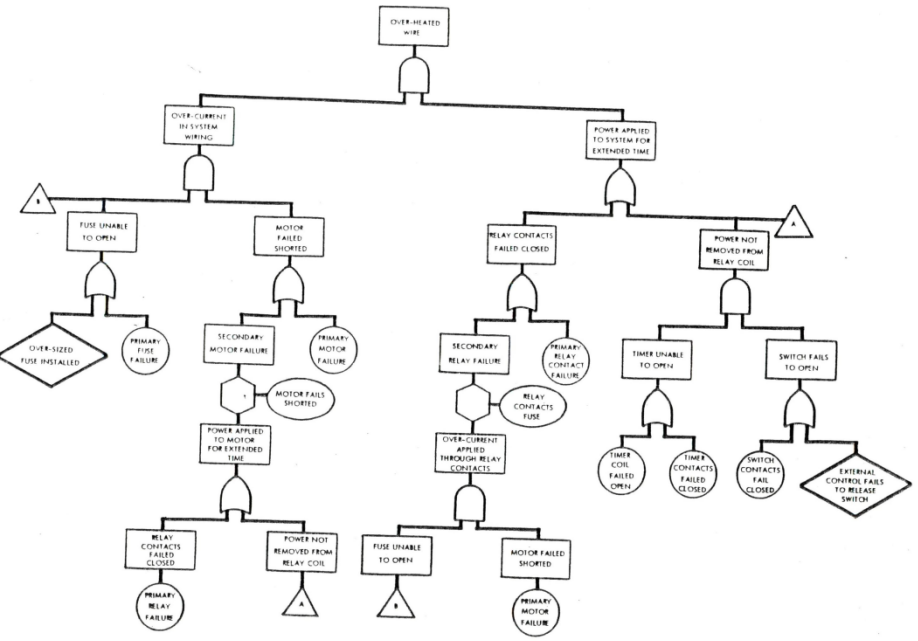


FIGURE 8 : FAULT TREE WITH SECONDARY FAILURE TECHNIQUE
(The triangles indicate a transfer to another portion of the tree)





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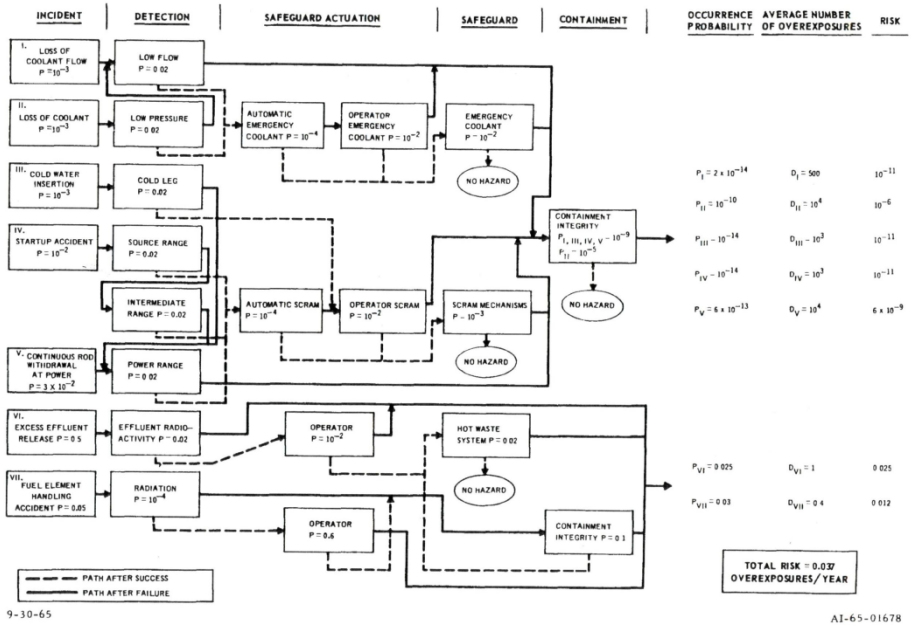
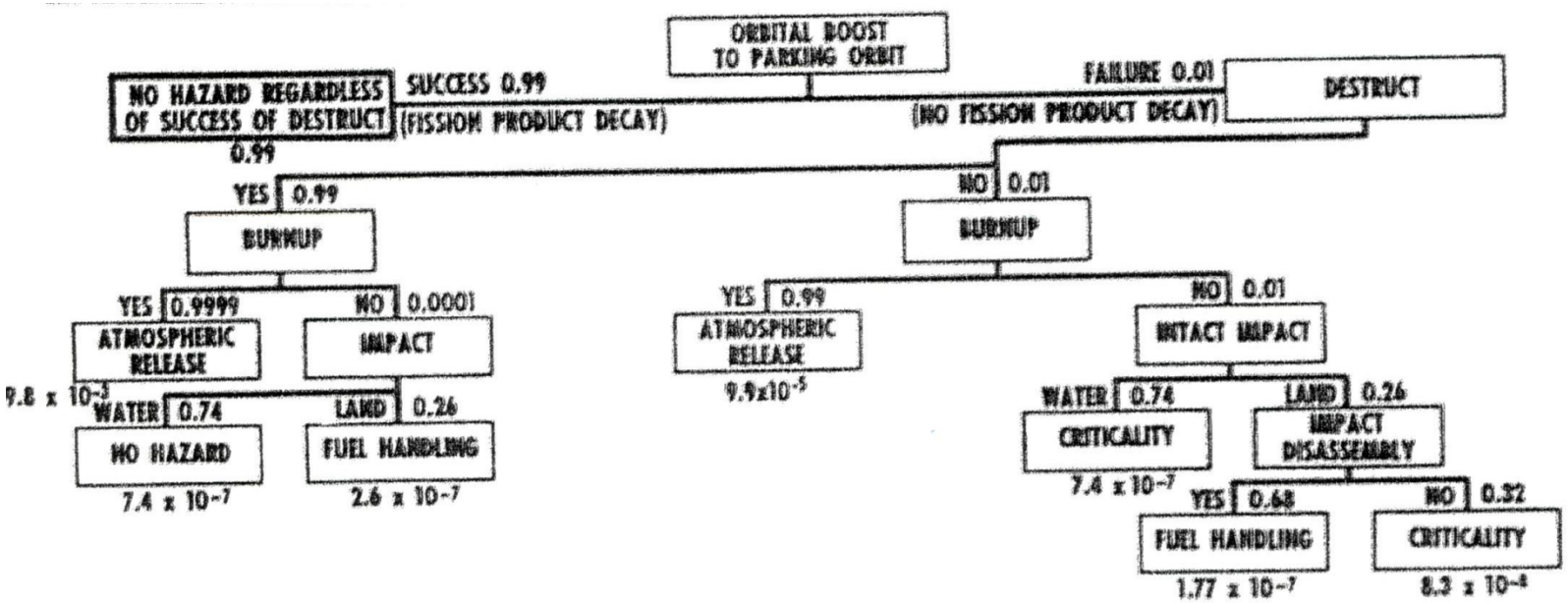


Figure 1. Hazard Evaluation Diagram



FAULT TREE FOR TOTAL LOSS OF POWER

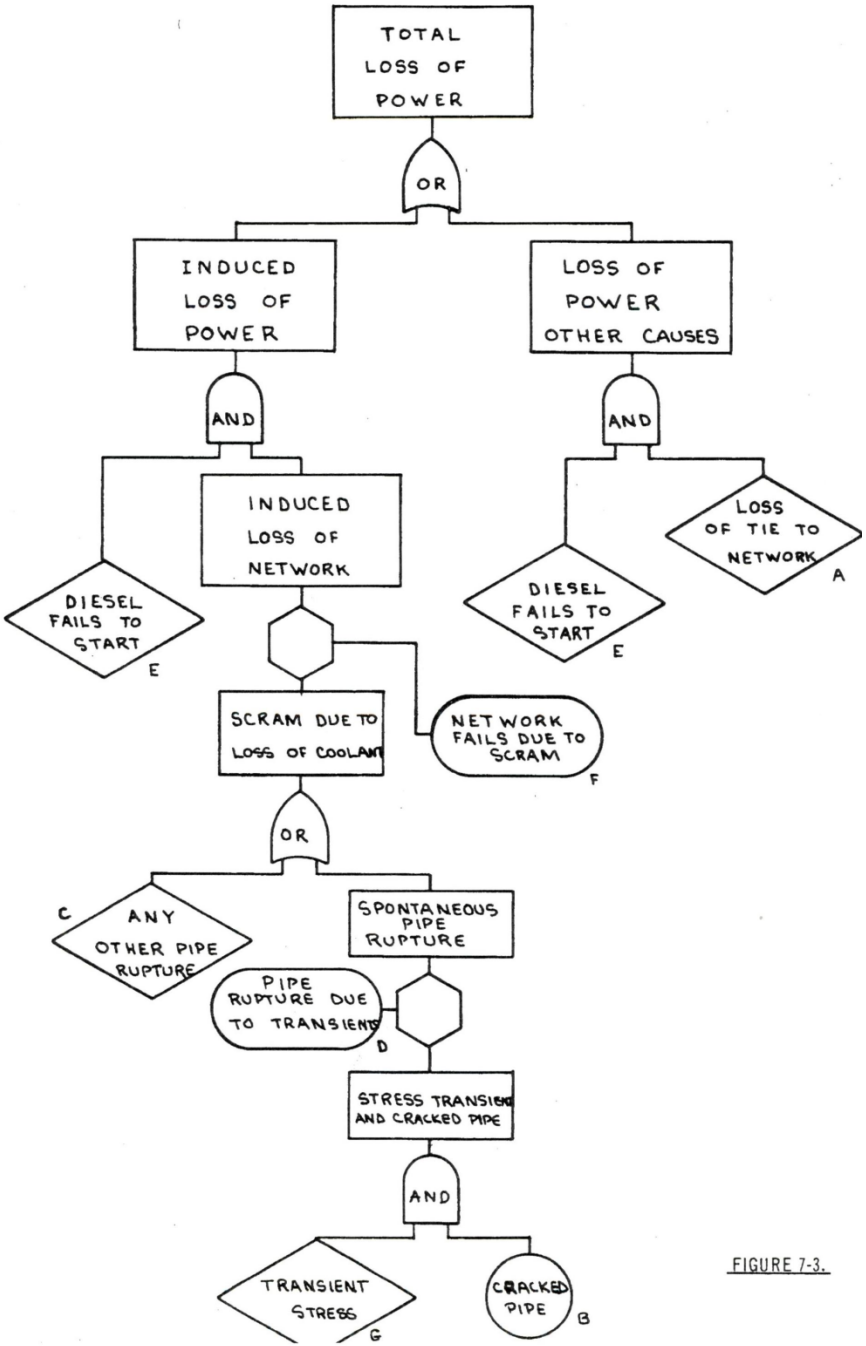


FIGURE 7-3.

FAULT TREE FOR TOTAL LOSS OF POWER

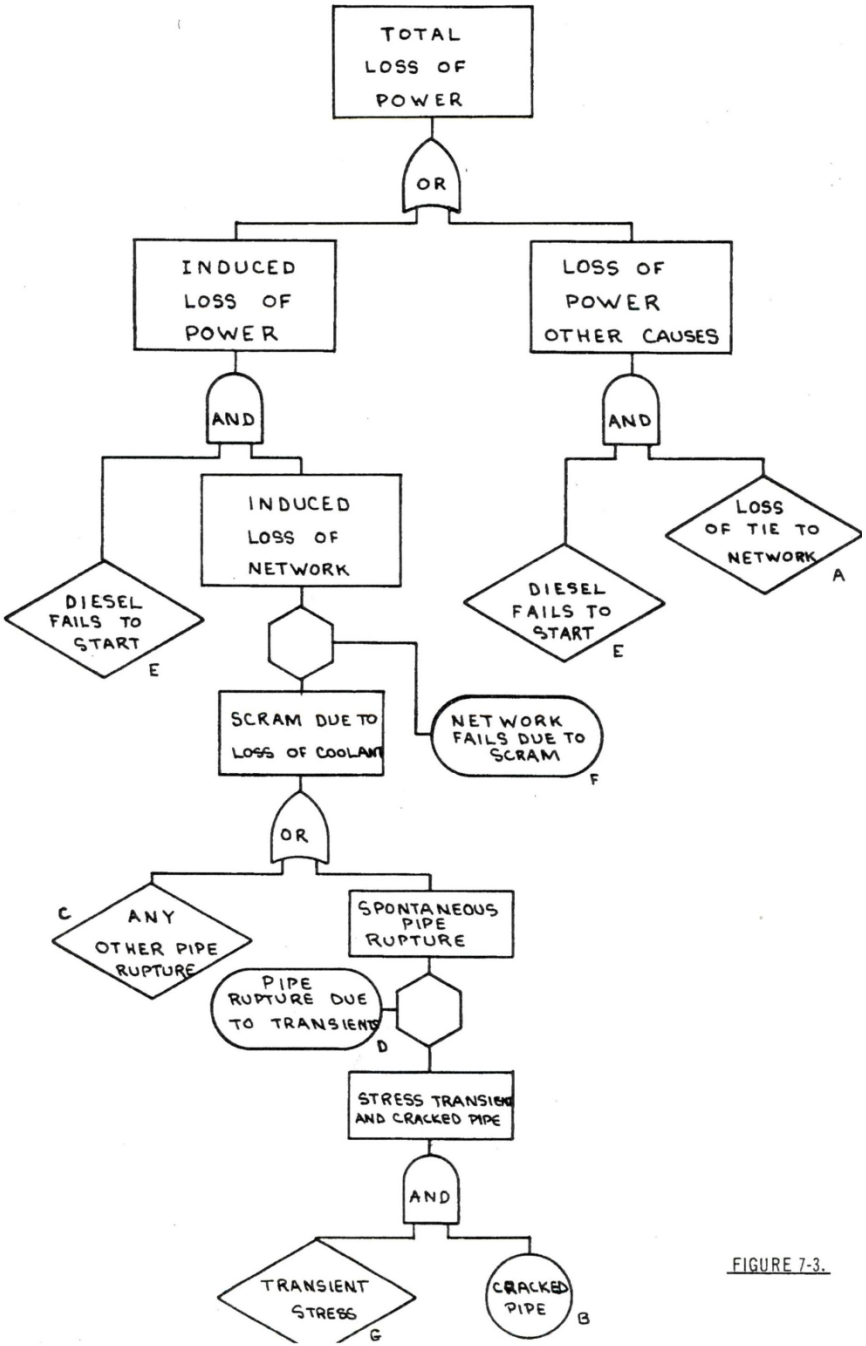


FIGURE 7-3.

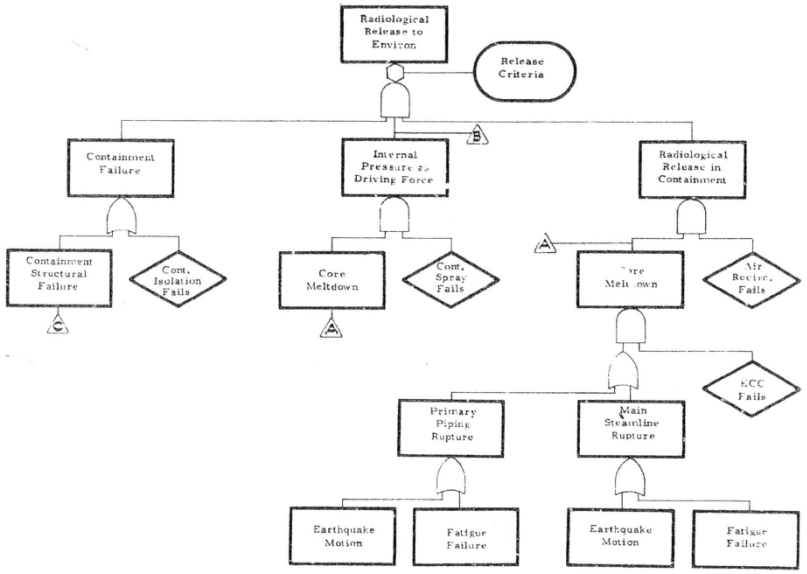


FIGURE 1-1

CONCEPTUAL FAULT LOGIC DIAGRAM

FAULT TREE FOR TOTAL LOSS OF POWER

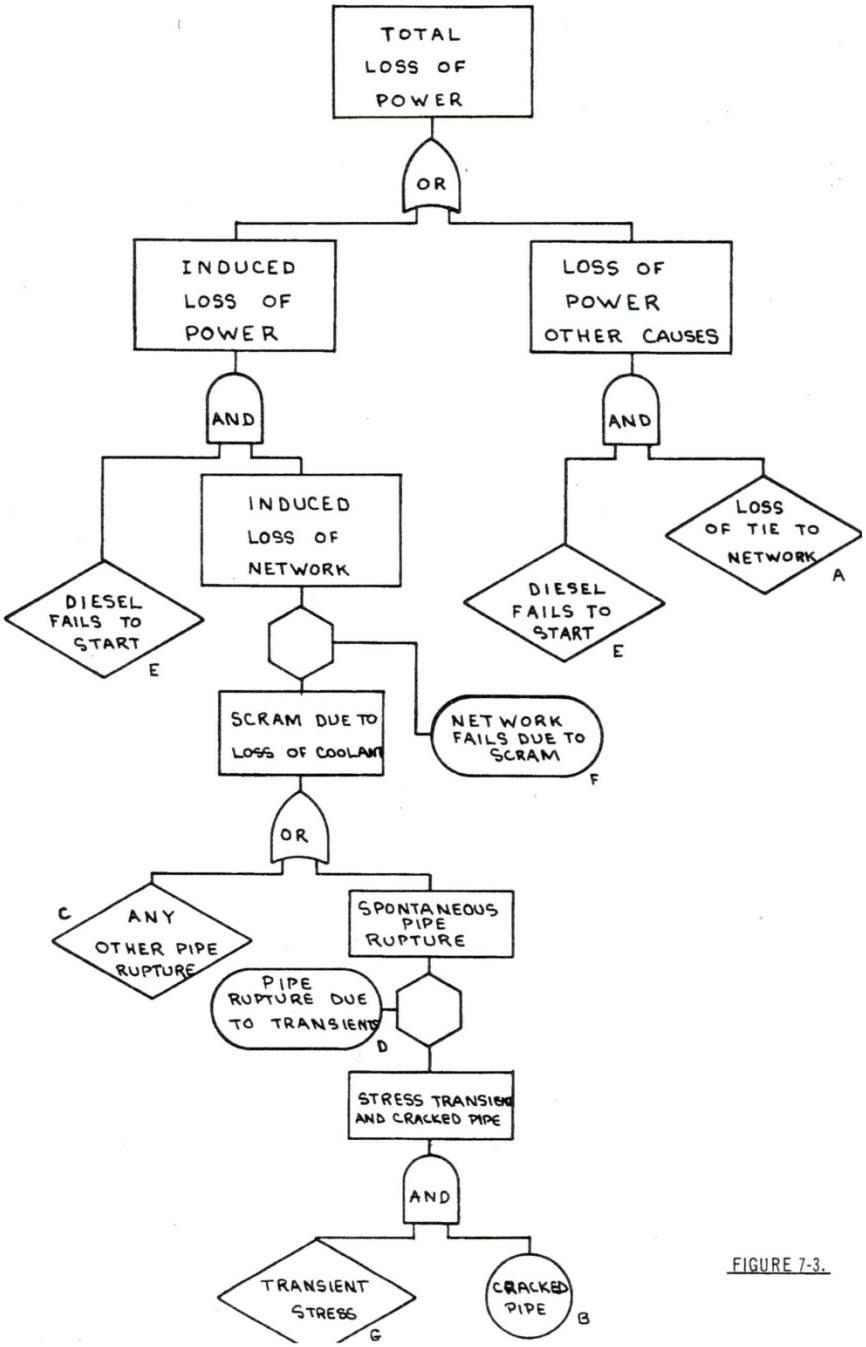


FIGURE 7-3.

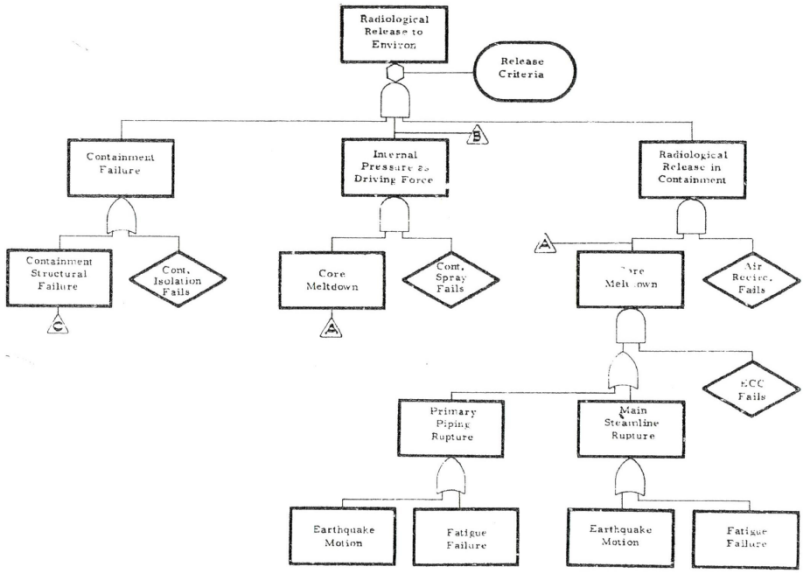


FIGURE 1-1

CONCEPTUAL FAULT LOGIC DIAGRAM

GEAP 13639

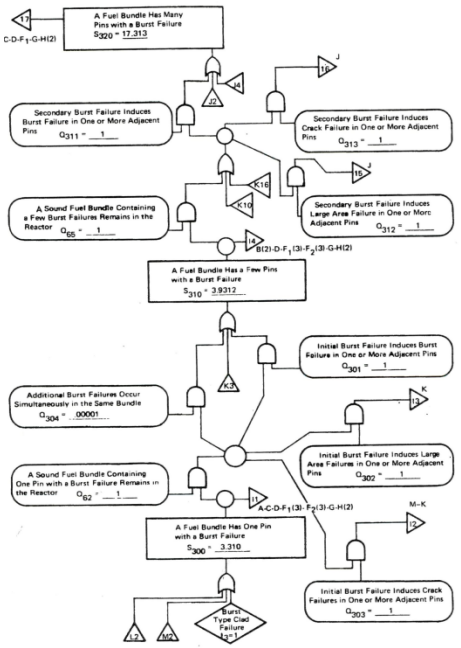
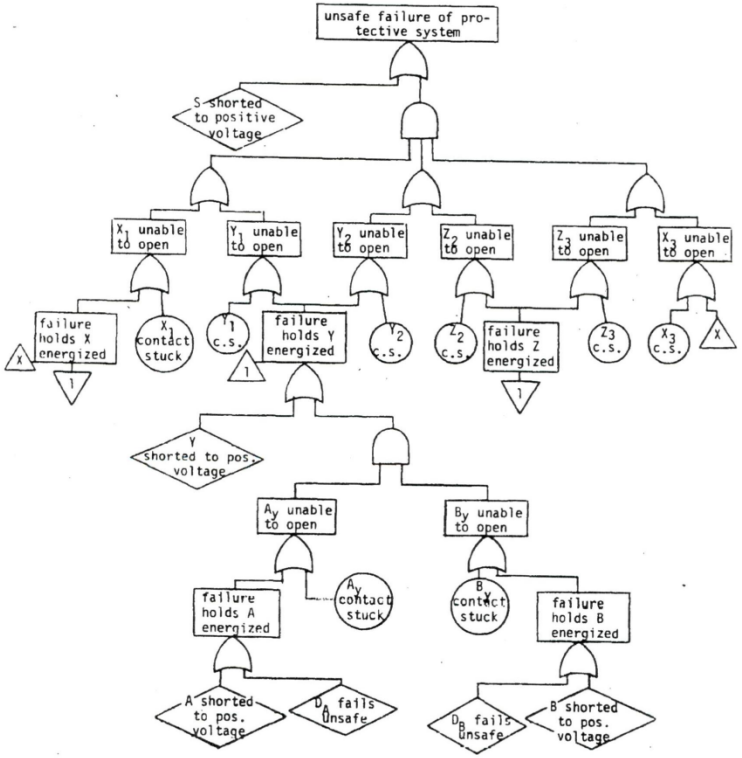


Figure 2-1. Overall Fault Tree Example

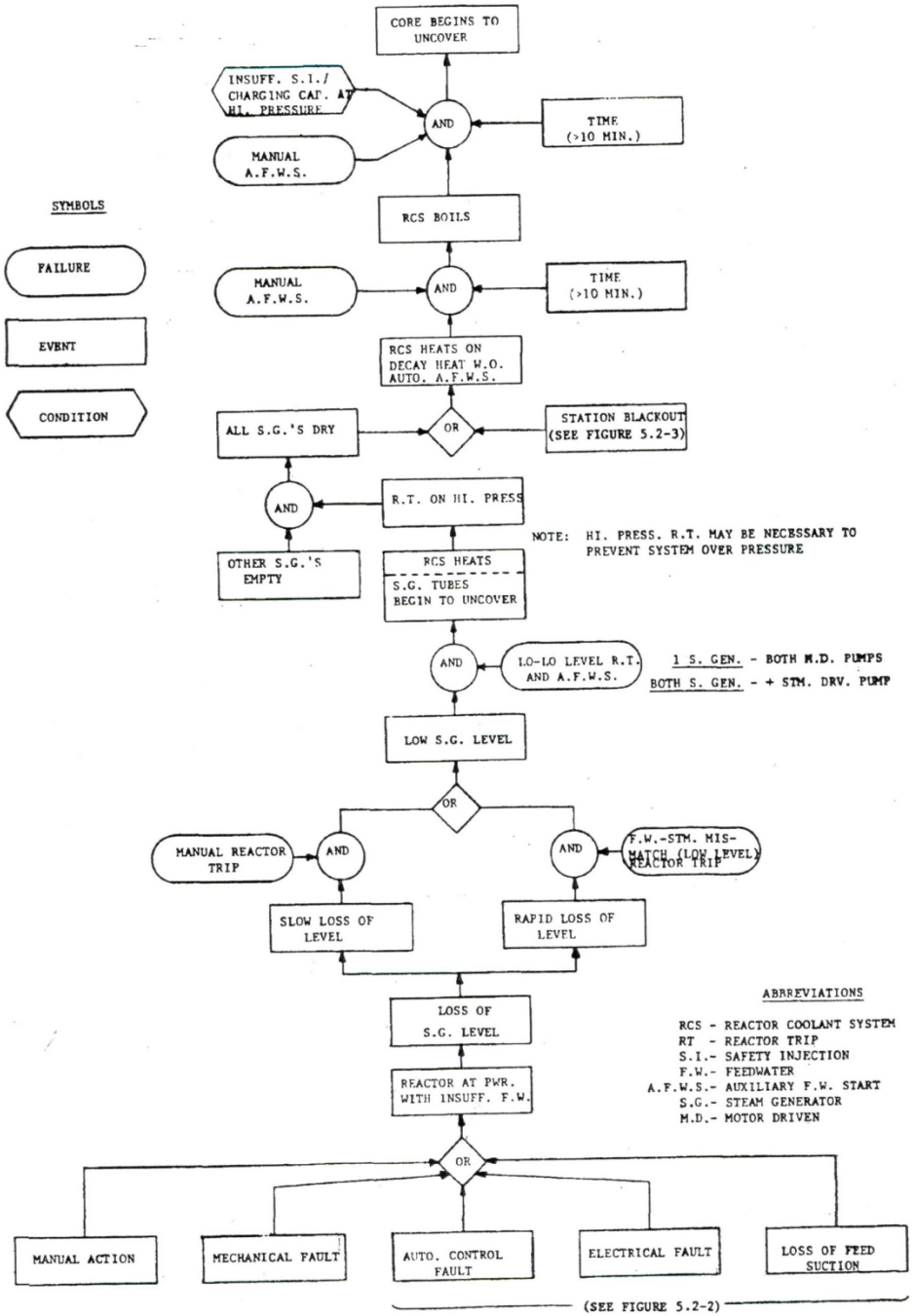


SYMBOLS

FAILURE

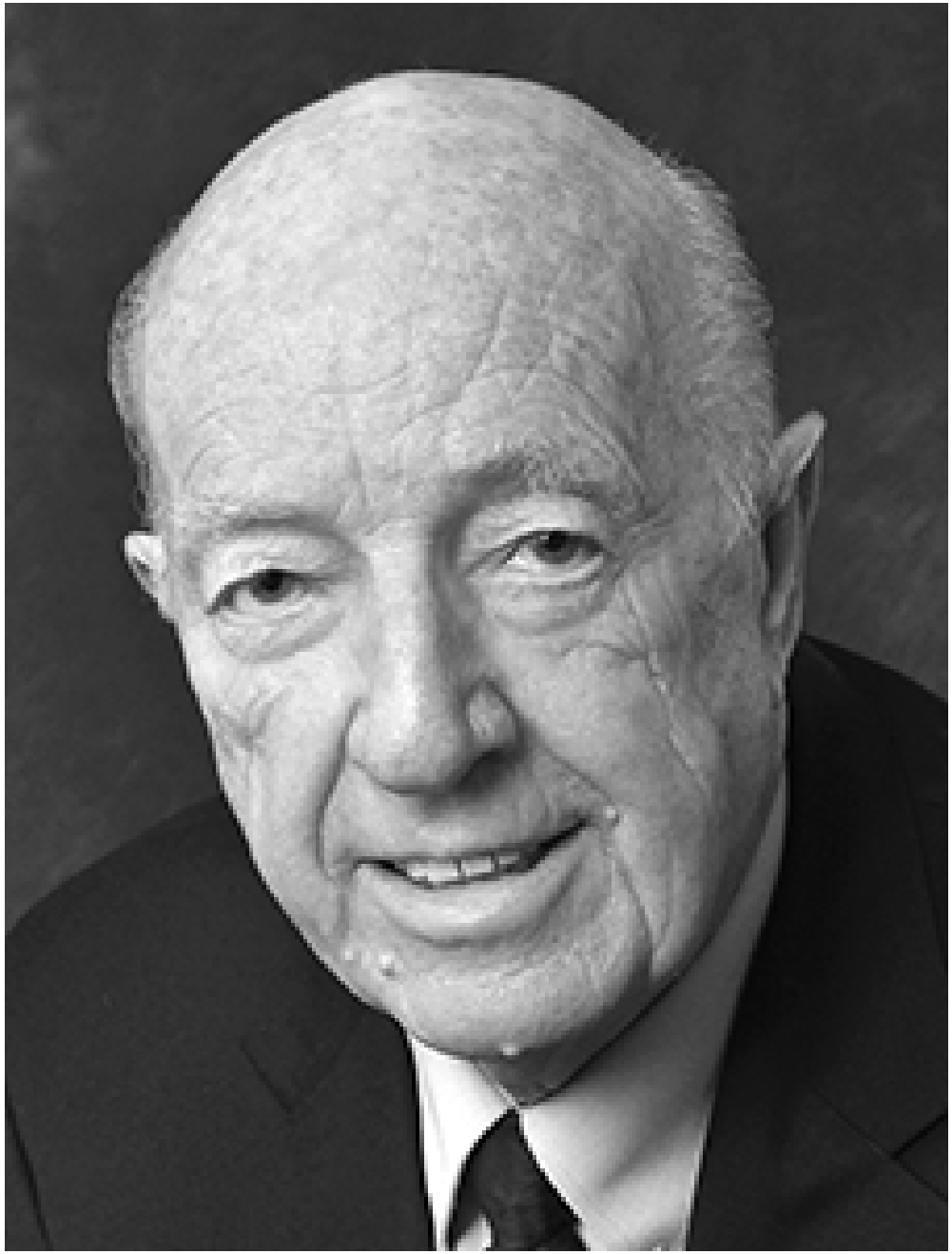
EVENT

CONDITION



ABBREVIATIONS

RCS - REACTOR COOLANT SYSTEM
RT - REACTOR TRIP
S.I.- SAFETY INJECTION
F.W.- FEEDWATER
A.F.W.S.- AUXILIARY F.W. START
S.G.- STEAM GENERATOR
M.D.- MOTOR DRIVEN



John Garrick

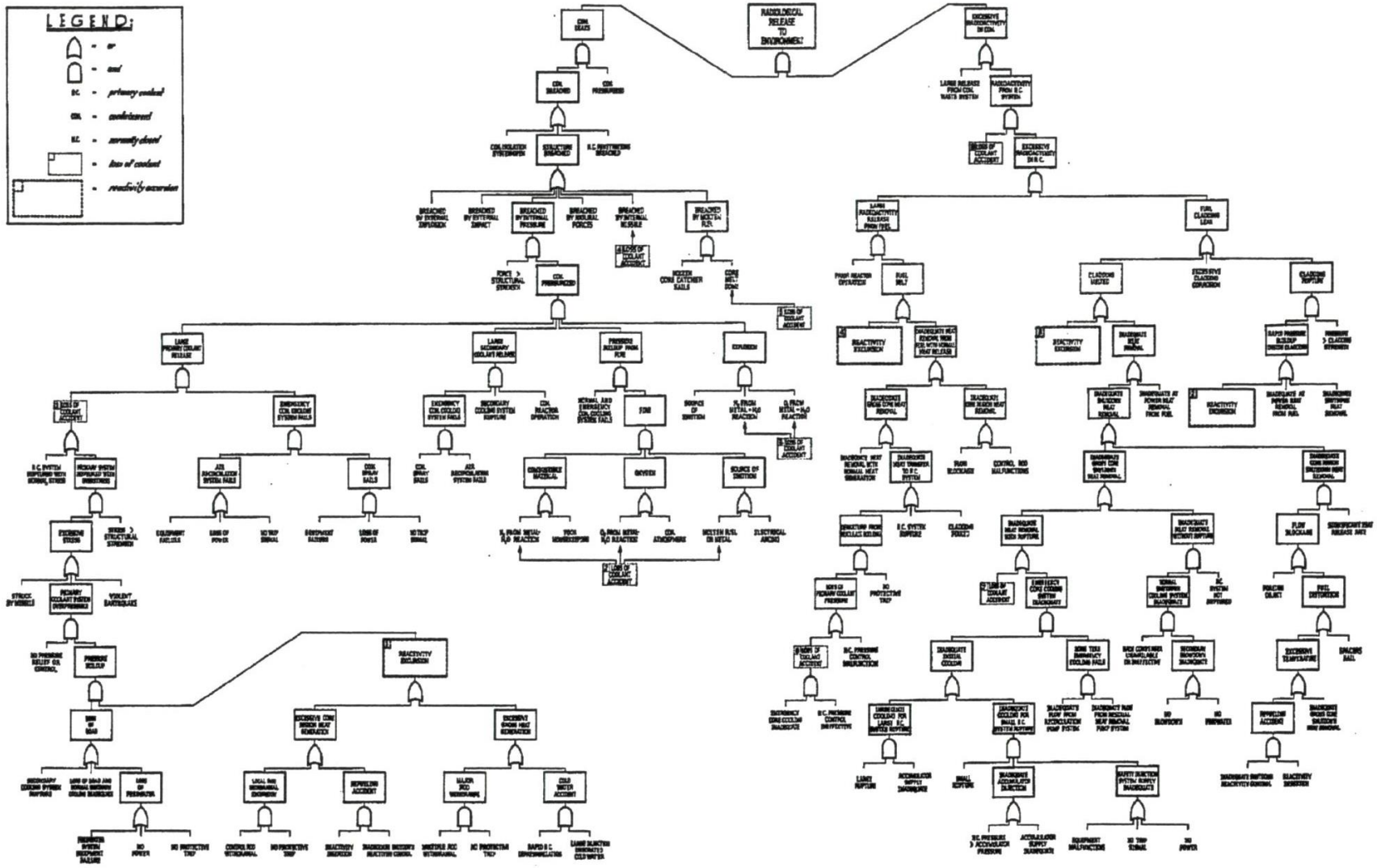


FIGURE 5.7

SUMMARY FAULT TREE

FAULT DIAGRAM FOR INCIDENTS INITIATED BY A REACTOR COOLANT CIRCUIT FAILURE

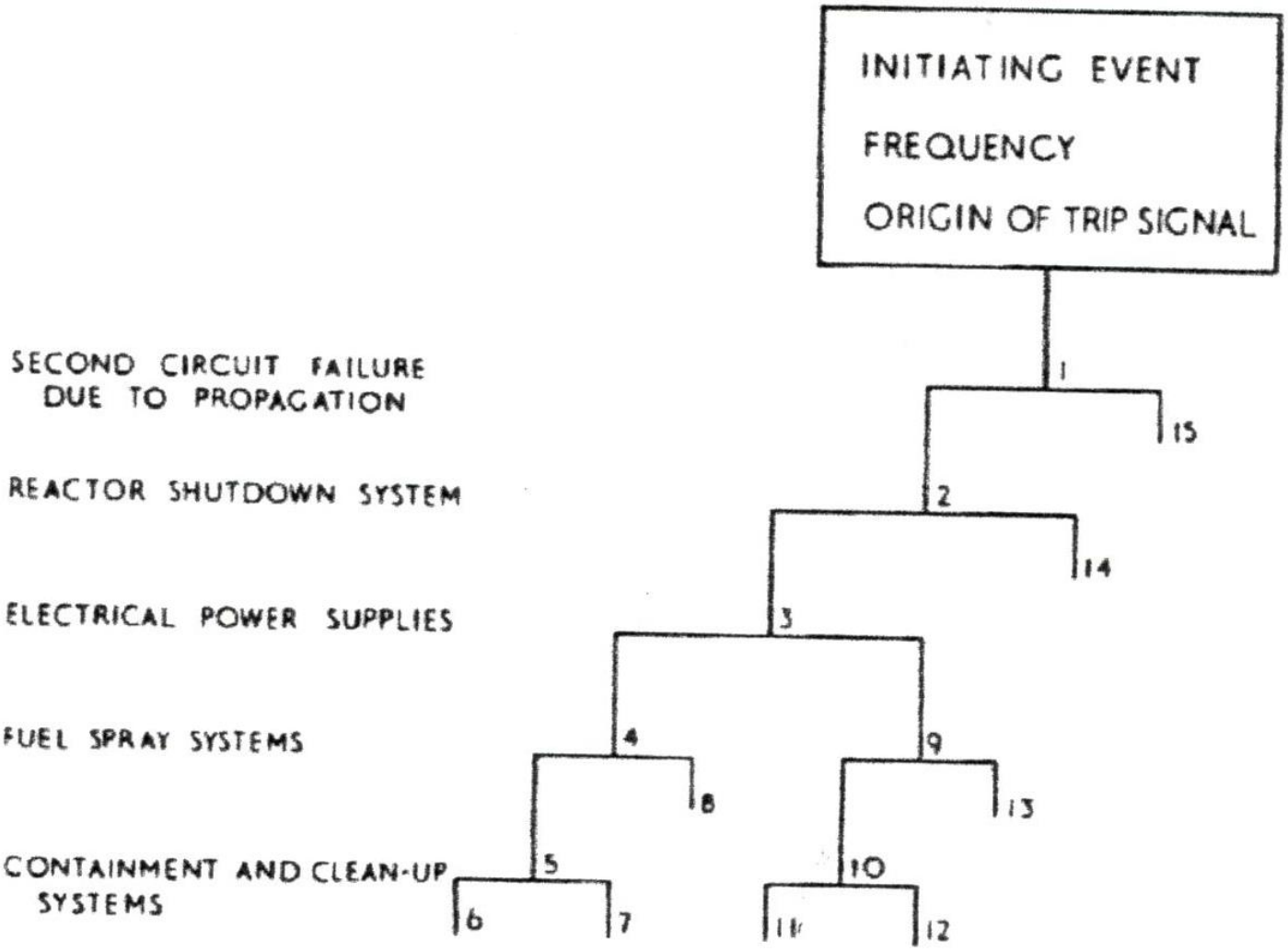


FIGURE 2

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United States Nuclear Regulatory Commission
Protecting People and the Environment

Steve Hanauer

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

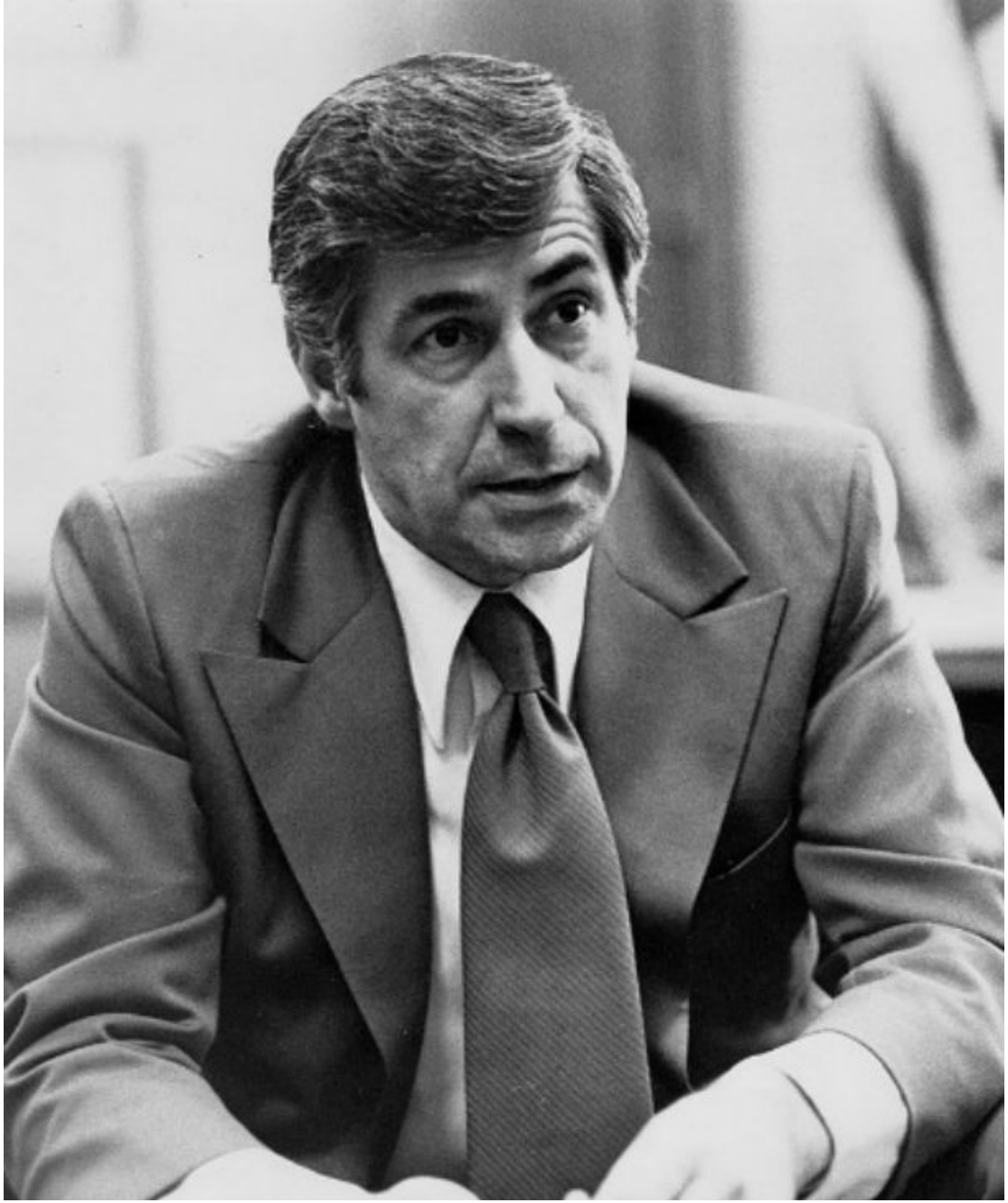
March 1957

- WASH-740 Update (1965)
  - Congressional Request
  - Larger consequences than original study
  - Probability calculations fail
  - AEC refuses to publish
    - Continues funding reliability and risk studies through Holmes and Narver and at Idaho lab.
  - Regulatory skepticism

Under Siege in the 1970s

- Antinuclear Movement
  - Local Opposition
  - Low-level emissions controversy
  - ECCS
- NEPA—Class 9 accidents.
- ATWS

Henry Kendall, Union of Concerned Scientists



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Sen. Mike Gravel

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Saul Levine

U.S.NRC
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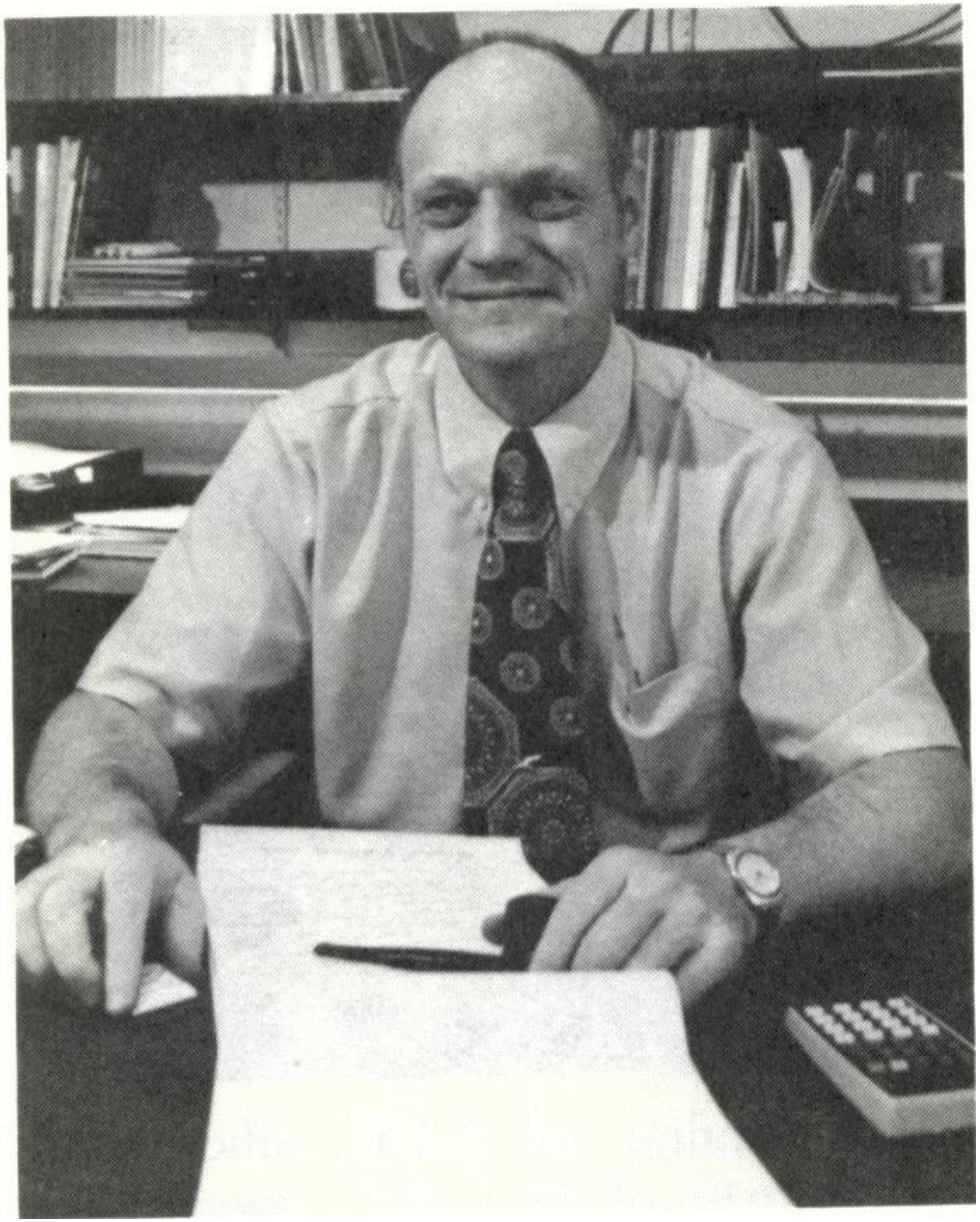

Norm Rasmussen

- WASH-1400

  – Launched in March 1972.
    - Has political goals (Executive Summary) and technical/regulatory.

  – Significant advances in methodology by early 1973. AEC wants PRA analysis group.

  – Early results reported in January 1974 by Dixie Lee Ray. A big hit but trouble ahead.

Ghillie and Jacques (poodle)

WASH-1400: THE FIRST 15 YEARS OF PRA AFTER ITS PUBLICATION (REACTION, PROGRESS, IMPEDIMENTS, AND WHY)

9 November 2015

NRC Seminar on
"WASH-1400 and the Origins of PRA in the Nuclear Industry"

Robert J. Budnitz

Energy Geosciences Division
Lawrence Berkeley National Laboratory
University of California
Berkeley CA 94720 USA
<RJBudnitz @ LBL.gov>

Chronology

1972 - 73	**Early objections (*before the RSS was launched)***
1975	**Publication of WASH-1400 (RSS) – initial reactions**
1975 - 77	**Turmoil -- what do the RSS results mean?**
1977 - 78	**NRC "Lewis Committee", RARG (*"everybody" testified)***
Sept. 1978	**RARG report --- endorsed PRA, criticized aspects of RSS**
Jan. 1979	**NRC Commission "bailed out"–staff and industry reaction**
March 1979	**Three Mile Island !!**
1979 - 80	**Reactions to PRA after TMI (*positive, negative, ambivalent)***
1979 - 83	**First industry PRAs, seismic PRA, fire PRA, PRA Procedures Guide, severe-accident research, AEOD, ASEP, PRA and life extension**
1986	**NRC Safety Goal Policy Statement**
1988 - 91	**IPE, IPEEE**
1990	**NUREG-1150**