UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	Docket Nos. 50-247-SP
CONSOLIDATED EDISON	)	50-286-SP
OF NEW YORK (Indian Point, Unit 2)	)	
	)	
POWER AUTHORITY OF THE STATE	)	
OF NEW YORK (Indian Point, Unit 3)	)	

DIRECT TESTIMONY OF FRANK ROWSOME AND ROGER BLOND
CONCERNING COMMISSION QUESTION 1

Q.1 State your name and position with the NRC.

A.1 My name is Frank H.Rowsome. I am Deputy Director of the Division of Risk Analysis in the Office of Nuclear Regulatory Research.

Q.2 What are your responsibilities in that position?

A.2 I assist the Director in planning and managing the research program in risk assessment, probabilistic safety analysis, operations research, reliability engineering, and related regulatory standards development.

Q.3 Have you prepared a statement of your professional qualifications?

A.3 Yes, the statement of my professional qualifications is attached to this testimony.

Q.4 State your name and position with the NRC.

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A.4 My name is Roger M. Blond. I am the Section Leader for the Accident Risk Section of the Reactor Risk Branch of the Division of Risk Analysis of the Office of Research.

Q.5 What are your responsibilities in that position?

A.5 I am responsible for providing technical and managerial direction in developing methods and research in accident risk analysis and in performing applications in risk assessment.

Q.6 What is the purpose of this testimony?

A.6 Commission Question 1 calls for an assessment of the risk pending and after any improvements in emergency preparedness identified in the response to Commission Question 4. The bulk of the risk testimony by the staff describes the risk pending these improvements. The purpose of this testimony subsection is to identify the risk reduction potential of improvements in emergency preparedness.

Q.7 Please summarize your findings.

A.7 The risk reduction attributable to improvements in emergency preparedness is not known, but is not expected to be large.

Q.8 What improvements in emergency preparedness are considered?

A.8 The staff has not attempted to model specific improvements in emergency preparedness. Rather, we will display and discuss sensitivity studies to show the influence of various emergency response strategies on risk.

Q.9 Why has the staff not attempted to calculate the risk reduction afforded by specific improvements in emergency preparedness?

A.9 We can and have calculated the effects of emergency response upon risk. However, we do not have an objective and useful way to translate the state of emergency planning and preparedness into a model of emergency response effectiveness. In developing PRA models we prefer to use objective, historical data for the reliability of safety functions. Thus, we are led to look at the difference between historical examples of planned vs. unplanned evacuations to model the effect of emergency preparedness upon emergency response. The historical data suggest that there is no statistically significant difference between planned and unplanned evacuations. See, e.g., J. M. Hans, Jr., and T. C. Sell, "Evacuation Risks - An Evaluation," U.S. Environmental Protection Agency, EPA-520/6-74-002 (1974). Were we to employ this data, it would show no effect of emergency preparedness upon emergency response, and therefore no effect upon risk. This is not to say that there is really no effect, only that we cannot objectively predict it with available data. However, we can have some confidence that evacuations with or without planning will generally take place expeditiously.

Q.10 What emergency response scenarios have been employed in the risk calculations for Indian Point?

A.10 The emergency response scenarios are defined in Sarbeswar Acharya's testimony in Section III.C.A above. Three emergency response scenarios, each with and without supportive medical treatment, have been analyzed, giving six distinct cases. They are defined in Table III.C.2. Briefly, the three emergency response scenarios are these:

1) Evacuation-relocation model

The model is taken to be representative of emergency response if no external event, such as an earthquake or hurricane, compromises evacuation or shelter feasibility, and the response of choice is evacuation. Evacuation of the 10 mile radius EPZ begins two hours after warning and the effective radial evacuation speed is taken to be an average of 1 1/2 miles per hour. Shielding factors typical of everyday life are applied before evacuation and beyond 10 miles. Beyond 10 miles people remaining in areas of severe fallout contamination (projected seven-day dose greater then 200 rem) are assumed to be relocated 12 hours after plume passage. People in areas of less severe but still significant fallout contamination are assumed to be relocated 7 days after plume passage.

2) Early relocation model

The early relocation model of emergency response portrays a case in which the public takes no evasive action prior to plume passage. Shielding factors typical of everyday life are employed in the dose calculation. Eight hours after plume passage, people in the footprint of the plume within the plume exposure EPZ are assumed to be relocated to uncontaminated ground, so that they cease to accumulate a dose from fallout eight hours after plume passage. Beyond 10 miles, people in areas of severe fallout contamination (projected seven day dose greater than 200 rem) are assumed to be relocated 12 hours after plume paggage, just as in the "evac-reloc" model. Likewise, people beyond the EPZ in areas of less severe but still significant fallout contamination are assumed to be relocated 7 days after plume passage.

3) Late relocation model

This model is taken to be representative of the case in which a severe earthquake or hurricane precludes evacuation, damages buildings so that no sheltering shielding factors are applied - as though everyone were outdoors - and relocation from areas of severe fallout contamination is delayed for 24 hours after plume passage.

Q.11 How do the projected risks differ for these three emergency response scenarios?

A.11 The comparison for Unit 2, as it is currently designed and operated is shown in Table IV.B.1 below. This table summarizes results from Dr. Acharya's tables III.C.6, 13 and 20.

TABLE IV.B.1
Expected Risks for Indian Point Unit 2
vs. Emergency Response Model

Risk type	evac-reloc(1)	early reloc(1)(3)	late reloc
Early fatalities w (2)	0.0148	0.0149	0.0252
Early fatalities wo (2)	0.0360	0.0361	0.0634
Early injuries	0. 115	0. 115	0. 166
Total cancer fatalities	0. 209	0. 210	0. 228
Person rem	2610.	2610.	2810.
Property damage ($)	281,000	263,000	262,000
Source table	III.C.6	III.C.13	III.C.20

(1) late relocation is applied to accidents caused by earthquakes and hurricanes in each case.
(2) w = with supportive medical treatment, wo = without.
(3) Release Category C is modeled with evacuation for those occurrences not caused by earthquakes or hurricanes.

The corresponding results for Unit 3 are shown in Table IV.B.2, which summarizes Dr. Achary's tables III.C.7,14,and 20.

TABLE IV.B.2
Expected Risks for Indian Point Unit 3
vs. Emergency Response Model

Risk type	Expected (average) casualities per unit year		
	evac-reloc (1)	early reloc(1)(3)	late reloc
Early fatalities w (2)	.00375	.00390	.0125
Early fatalities wo (2)	.0111	. 0113	.0353
Early injuries	.0409	. 0412	.0762
Total cancer fatalities	.1138	. 1144	.1292
Person rem	1430	1440	1600
Property damage ($)	165,000	145,000	144,000
Source table	III.C.7	III.C.14	III.C.20

(1) Late relocation is applied to accidents caused by earthquakes and hurricanes in each case.
(2) w= with supportive medical treatment, wo= without.
(3) Release category C is modeled with evacuation for those occurences not caused by earthquakes or hurricanes.

Q.12 What inferences do you draw from Tables IV.B.1 and 2?

A.12 First note that the annual average health risks are quite small (well below one casualty per unit year) in all the risk categories. Next, note that "early relocation" is very nearly as effective as "evacuation/relocation" in limiting expected health risks. The two cases differ by 4% or less in each risk category in Tables IV.B.1 and 2, though not all accidents are modeled as having a different emergency response in the two cases. Third, note that either early relocation or evacuation yields lower expected risks than late relocation. Fourth, note that supportive medical treatment, if available to those receiving high doses, can substantially reduce early fatalities.

Q.13 Why is the property damage estimate higher with evacuation than without?

A.13 The property damage estimate includes the cost of evacuation as well as the costs associated with interdiction, cleanup, etc. The latter costs are the same in each case. The difference arises from the costs of the evacuation when it is assured to take place.

Q.14 Is it suprising that the latent cancer fatality and person rem risks for the evacuation/relocation model is very close to the value for the early relocation model?

A.14 No. Person-rem, and the latent casualty risks that are thought to be very roughly proportioned to person-rem, are only modestly influenced by what happens in the plume exposure EPZ. These are long-range effects. The two emergency response models evac/reloc and early reloc are identical in their portrayal of emergency response beyond ten miles.

In Dr. Acharya's Table III.C.12, where the contributions to the societal latent cancer fatality risk are displayed as a function of 'istance from the reactor to the site of exposure, one sees that most of the latent cancer committments originate from exposures at distances greater than 10 miles.

Q.15 Why is evacuation/relocation only slightly more effective than early relocation in limiting the average values of early fatalities?

A.15 An important clue to the cause of this surprising result can be found in Tables III.C.6,7,13 and 14. Most of the early casualities originate in accidents triggered by earthquakes or hurricanes.

We have assumed that any earthquakes or hurricanes severe enough to trigger an accident at either unit would also render the roads impassable and threaten to deprive the population of the benefits of shielding factors typical of everyday life (most people in-doors). We have not done a non-nuclear risk assessment to evaluate the direct effects of such earthquakes or hurricanes. Instead, our model is conservative. For reactor accidents triggered by earthquakes and hurricanes everyone is modeled as being outdoors, no anticipatory evacuation takes place, and relocation from ground severly contaminated by fallout does not occur until 24 hours after plume passage.

One can trace the origin of the expected risks to release categories (using tables III.C.4 and 5). These can further be traced to damage states using Dr. Meyer's containment event trees in section III.B of the testimony. The testimony in III.A can then be used to trace contributors to their origins in accident sequences. When this is done for early fatalities, the following picture emerges.

Table IV.B.3 makes it clear that 90% of the expected early fatality risk posed by severe reactor accidents at the site can be traced to earthquakes and hurricanes. Since we have assumed at the outset that evacuation (as opposed to late relocation) cannot be applied to these accidents, it is clear that anticipatory evacuation is only being considered as potentially applicable for 10% of the early fatality risk.

Q.16 Can other clues to relative effectiveness of anticipatory evacuation vs early relocation be found in the risk analysis?

A.16 Yes. See, for example, table III.C.5, it describes the average consequences to be expected for each release category for each emergency response model at each plant.

TABLE IV.B.3
Origins of early fatality expected risks posed by accidents at Indian Point Units 2 and 3*

Accident sequence	expected risk early fatalities per year	percent of early fatality percent of site total early fatality projections
Seismic: Direct Containment (Backfill) Failure at Unit 2	6×10^{-3}	31%
Seismic: Loss of control or power at Unit 2	4.9×10^{-3}	25%
Hurricane: Loss of all AC power due to high winds (Unit 2)	3.6×10^{-3}	18%
Seismic: Loss of control or power at Unit 3	2.8×10^{-3}	14%
Interfacing system LOCA, Unit 3 RHR suction line	7.3×10^{-4}	3.7%
Interfacing system LOCA, Unit 2 RHR suction line	6.7×10^{-4}	3.4%
Seismic: Direct Containment (backfill) failure at Unit 3	3.3×10^{-4}	1.7%
Fire: resulting in loss of all cooling, Unit 2	2.7×10^{-4}	1.4%
Fire: resulting in loss of all cooling, Unit 3	2.2×10^{-4}	1.1%
All other sequences combined		0.7%
Site total	$1.9b \times 10^{-2}$	100%

*Evaluated for the "after fix" design and "early reloc"/later reloc" emergency response. For no case is evacuation credited. Supportive medical treatment is assumed.

Anticipatory evacuation (if feasible) is an effective early fatality risk reduction strategy for Release Category C,D,E,F and G. By that I mean that large percentage reductions in average early fatalities can be had by replacing the early relocation model with the evacuation/relocation model. However, note that the expected number of early fatalities are not very large for any of these release categories.

Average early fatalities in the thousands are expected only for Release Category A or B events. The percentage change in early fatalities associated with the replacement of early relocation with evacuation is small for these release categories. Thus table III.C.5 seems to suggest that evacuation tends not to be an effective strategy for the high-consequence release categories, but is effective for the lower-consequence release categories. One of the principal reasons for this can be found in the characteristic times of the accidents. The high consequence release category A and B events proceed very quickly. The warning time for these accidents is modeled to be one hour, whereas the delay time between notification and the start of evacuation is modeled to be two hours. Thus the plume will emerge from the plant one hour ahead of the start of evacuation, as we have modeled it. This may or may not be realistic, but it is clear that we cannot count on evaucation to reliably preclude plume arrival for these quickly developing releases.

In addition, under rare weather conditions, the release category A and B events can yield early fatalities beyond 10 miles. Our model does not credit evacuation beyond ten miles. This, too, helps to account for the similarity in early fatality projections for evacuation as early relocation in release category A or B accidents.

Q.17 Would anticipatory evacuation appear to offer much greater risk reductions if it were modeled to take less time to evacuate the plume exposure EPZ?

A.17 No, not unless anticipatory evacuation were assumed to be feasible for earthquake and hurricane-induced accidents as well as accidents of on-site origin, and be rapid for both classes of accidents.

Q.18 Could a change in the accident likelihood portion of the PRA for Indian Point show anticipatory evacuation to be substantially more effective in limiting early fatalities?

A.18 No, except for cases of very low risk, because there are no release categories for which the early fatality consequence is large and anticipatory evacuation is highly effective, there can be no mix of these release categories, weighted by likelihood, that would show evacuation to have substantial leverage on a high risk of early fatalities.

Q.19 What are the key assumptions to which the finding is sensitive that early relocation is nearly as effective as anticipatory evacuation?

A.19 The heart of the finding lies in the consequence analysis. However, since there are diverse and redundant reasons for believing that the risk with an anticipatory evacuation emergency response is not, on the average, appreciably lower than the risk with early relocation, we infer that the finding is one of the more reliable insights into risk to be drawn from the PRA.

Q.20 What are the key differences between anticipatory evacuation and relocation?

A.20 As modeled in the PRA, evacuation starts after the warning is given, and results in an initial delay period followed by people moving radially outward from the plume exposure EPZ, without regard to actual plume direction. Relocation, on the other hand, is modeled as the end time after which people cease to accumulate ground exposure due to fallout contamination.

In practice, we interpret evacuation as an anticipatory action to avoid plume and/or ground exposure. Relocation, on the other hand, is based upon measured levels of ground contamination and can be much more discriminating.

Evacuation does not require mapping of ground contamination, but it does entail moving large populations substantial distances. Relocation presumes that ground contamination has been mapped, but it need entail no more than moving people from comparatively small area of highly contaminated ground short distances to the nearest area where the contamination is low. Thus the resource requirements and practical problems in the way of effective relocation are quite different from those of evacuation.

Q.21 What is the difference between the "early reloc" and "late reloc" models?

A.21 The two relocation models differ in relocation time, in relocation criterion, and in shielding factors applied.

In the early relocation model, everyone within the plume exposure EPZ ceases to accumulate doses from ground contamination eight hours after plume passage, without regard to levels of ground contamination. Beyond ten miles, people in highly contaminated areas (projected seven-day dose to the bone marrow over 200 rem) are relocated 12 hours after plume passage. People beyond ten miles in areas of lesser fallout contamination cease to accumulate early exposure doses from fallout seven days after the accident in the late relocation model, at all distances from the site, people in highly contaminated areas are relocated 24 hours after plume passage, and people in areas of lesser contamination are taken out of the early exposure calculation at 7 days of ground exposure.

The early relocation model entails sheltering shielding factors typical of everyday life, whereas in the late relocation model, everyone is presumed to be out-doors.

Q.22 What interpretation can be given to the differences in risk between the "early reloc/late reloc" risk estimates and the pure "late reloc" risk estimates?

A.22 The differences in expected risks are summarized in Table IV.B.1 and 2, drawn from Dr. Acharya's Tables III.C.13, 14, and 20. In both cases the accidents attributed to earthquakes and hurricanes, the regional non-nuclear disasters, are modeled with late relocation. Therefore the difference originates in the treatment of accidents not triggered by earthquakes and hurricanes.

Early fatalities and early injuries are appreciably lower with early relocation rather than late relocation. There is a slight difference in cancer fatalities and person rem in the two models. It is not surprising that there is little difference for person rem. Much of the expected person rem originates in the large number of people who receive small individual doses of radiation at considerable distances.

Clues to the origin of the more substantial influence on early health effects can be seen in Dr. Acharya's Tables III.C.17 and 18. Those accidents originating in earthquakes and hurricanes cause early fatalities at greater distances than do accidents of on-site origin. Part of this difference originates in the difference in the mix of release categories for these two groups of accidents, but part is also due to the difference in emergency response assumed. This can be seen in Table III.C.5. A level of exposure too small to cause early fatalities with the better shielding and quicker relocation associated with "early reloc" may rise to a level of exposure above the threshold for early fatalities with the lesser shielding and more prolonged exposure of the late relocation model. Therefore one would expect a greater range and larger area within which people might incur early health effects if the late relocation model is applicable than would be the case if early relocation or evacuation applies.

Q.23 What inferences do you draw from the foregoing analysis on the effectiveness of emergency response strategies at risk reduction?

A.23 Several inferences seem to follow:

1) The provision of supportive medical treatment can lower early fatality risks. See, eg., Tables III.C.6,7 etc., and compare, eg., Figure III.C.1 and 2.

2) The time within which people are relocated from areas highly contaminated by fallout can influence the dose committment. Early relocation can shrink the area within which people could incur doses approaching the threshold for early injuries or early fatalities.

3) Sheltering can influence the dose committment. This sheltering can also shrink the area within which people could incur doses approaching the threshold for early injuries or fatalities.

4) Anticipatory evacuation-as a general strategy-appears to offer very little risk reduction at Indian Point compared with early relocation. There are two principal reasons for this:

   a) Earthquakes and-to a lesser extent-hurricanes play a large role in the risk profile of the Indian Point Units. The feasibility of evacuation is in doubt for these events. We have pessimistically assumed that neither anticipatory evacuation nor early relocation is feasible for such accident scenarios.

   b) We do not feel justified in assuming that evacuation can reliably clear the ten mile EPZ ahead of plume arrival for the more rapidly evolving accidents. The more slowly evolving accidents-for which evacuation is highly effective-have less severe consequences with or without evacuation than do some of the rapidly evolving accidents.

Q.24 What inferences can be drawn on the effectiveness of emergency preparedness as a risk limitation strategy?

A.24 Since we have identified no objective means to map the state of emergency preparedness into a prediction of the speed or reliability of emergency response, we cannot draw any quantitative conclusion. However, evacuation planning, as distinct from other elements of emergency preparedness, does not appear to be a fruitful risk limitation tactic.

Q.25 Does this conclude your testimony on Commission Question 1?

A.25 Yes.

PROFESSIONAL QUALIFICATIONS
FRANK H. ROWSOME, 3rd
U.S. NUCLEAR REGULATORY COMMISSION

I am Frank H. Rowsome, 3rd, Deputy Director of the Division of Risk Analysis in the Office of Nuclear Regulatory Research. I have served in that capacity since joining the NRC in July 1979. The work entails planning, budgeting, managing and staffing the Division. Much of the work of the Division is devoted to research in reactor accident risk assessment. The remainder entails risk assessment applied to non-reactor aspects of the nuclear fuel cycle and to standards development related to system reliability or risk.

I received a bachelor's degree in physics from Harvard in 1962. I studied theoretical physics at Cornell, completing all requirements for a Ph.D except for the dissertation in 1965. From 1965 to 1973, I taught and engaged in research in theoretical physics at several colleges and universities.

In 1973 I joined the Bechtel Power Corporation as a nuclear engineer. My initial assignment was to perform accident analyses for nuclear plant license applications. After six months in that job, I was transferred to a newly formed group of systems engineers charged with developing for Bechtel a capability to perform risk assessments and system reliability analyses of the kind the NRC was then developing for the Reactor Safety Study. In that capacity I performed reliability analyses of nuclear plant safety systems, developed computer programs for system reliability analyses, performed analyses of component reliability data, human reliability analyses, and event tree analyses of accident sequences. I progressed from nuclear engineer, to senior engineer, to group leader, to Reliability Group Supervisor before leaving Bechtel to join the NRC in 1979. In this last position at Bechtel, I supervised the application of engineering economics, reliability engineering, and analysis techniques to power plant availability optimization as well as nuclear safety analysis.

While serving as Deputy Director of the Division of Risk Analysis (and its anticedent, the Probabilistic Analysis Staff), I also served as Acting Director (7 months), acting chief of the Reactor Risk Branch (9 months) and acting chief of the Risk Methodology and Data Branch (4 months).

This experience has given me the practitioner's view as well as the manager's view of those facits of reactor risk assessment entailing the classification of reactor accident sequences, system reliability analysis, human reliability analysis, and the estimation of the likelihood of severe reactor accidents. I have the manager's perspective but not the practitioner's experience with those facits entailing containment challenge analysis, consequence analysis, and risk assessment applied to other parts of the nuclear fuel cycle.

My role in the development of testimony for this hearing has been as coordinator of the preparation of testimony on risk and one of the coordinators of the technical critique of the licensee's "Indian Point Probabilistic Safety Study." I am not an expert on the design or operation of the Indian Point plants.

List of Publications

1. "The Role of System Reliability Prediction in Power Plant Design," F.H. Rowsome, III, Power Engineering, February 1977.

2. "How Finely Should Faults be Resolved in Fault Tree Analysis?" by F.H. Rowsome, III, presented at the American Nuclear Society/Canadian Nuclear Association Joint Meeting in Toronto, Canada, June 18, 1976.

3. "The Role of IREP in NRC Programs" F.H. Rowsome, III, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

4. "Fault Tree Analysis of an Auxiliary Feedwater System," F.H. Rowsome, III, Bechtel Power Corp., Gaithersburg Power Division, F 77 805-5.

PROFESSIONAL QUALIFICATIONS
ROGER M. BLOND
U.S. Nuclear Regulatory Commission

I am Roger M. Blond, Section Leader of the Accident Risk Section, Reactor Risk Branch, Division of Risk Analysis, Office of Research. I have been with the NRC since August 1974. In my present position, I am responsible for providing technical and managerial direction in developing methods and research in accident risk analysis and in performing applications in probabilistic risk assessment. This work includes: (1) developing risk models for calculating the physical processes and consequences of reactor accidents; (2) rebaselining accident consequences and reactor risk; and (3) developing value/impact analysis methods for reactor design improvements.

In addition to the Section Leader position, I have the following responsibilities:

- I am the Chairman of the International Benchmark Exercise on Consequence Modeling, sponsored by the Committee on the Safety of Nuclear Installations, of the Nuclear Energy Agency, Organization of Economic Cooperation and Development. As Chairman, I am responsible for organizing and directing the comparison study which includes the participation of 30 organizations representing 16 countries. The study was chartered to compare the large number of computer models that had been developed to calculate the offsite consequences of potential accidents at nuclear power facilities.

- I am responsible for developing the technical rationale for the development of improved siting criteria. This work includes the development of a set of representative potential reactor accident source terms. and a full parametric study of all the factors important to siting considerations from the risk perspective:

- I am a member of the Technical Writing Group of the IEEE/ANS PRA Procedures Guide - NUREG/CR-2300. This effort is developing a source document on PRA techniques. I am a co-author of the consequence modeling sections of the report.

- I am a member of the Department of Energy Working Group on Probabilistic Risk Assessment.

- I am a member of the NRC Incidence Response Center's Emergency Response Team.

In addition, I am directly involved in the development of a technical rationale for the NRC's Safety Goal, emergency planning and response, and numerous issues and questions which continuously arise in risk assessment.

I am also a lecturer on consequence modeling and accident analysis for the NRC Training Course on Probabilistic Safety and Reliability Analysis Techniques, for the IAEA Training Course on Nuclear Power, and for the George Washington University Seminar on Probabilistic Risk Assessment.

Risk Analyst

Before being selected for the Section Leader position, I was Senior Risk Analyst in the Office of Research. I was responsible for the following areas:

1. Consequence modeling research and development;
2. Performing and reviewing probabilistic risk assessments;
3. Siting and emergency planning and response criteria development; and
4. Integrating probabilistic risk assessment techniques into the regulatory and licensing process.

1. Consequence Modeling Research and Development

   I was responsible for revising the consequence model that was developed for the Draft Reactor Safety Study. During the course of that effort, I developed the following modeling approaches and techniques which were used for the final Reactor Safety Study consequence model (CRAC) and are documented in Appendix VI of WASH-1400 and the CRAC User's Guide:

   1. Meteorological sampling technique;
   2. Diffusion modeling technique;
   3. Time-varying meteorological model;
   4. Depletion approach;
   5. Finite cloud correction model for gamma shine;
   6. Economic model;
   7. Statistical sampling technique;
   8. Emergency response model;
   9. Property damage model; and
   10. Population treatment.

After the completion of the Reactor Safety Study, I developed the following modeling techniques which have been incorporated into the CRAC-2 computer code and documented in the CRAC-2 User's Guide:

1. Revised comprehensive emergency response model;
2. Importance sampling for meteorological data and terrain diffusion model;
3. Revised dosimetry and health effects review; and
4. Comprehensive results display package.

I also performed numerous sensitivity and parametric studies on the models and input used in the consequence model and was responsible for an extensive research program to investigate the significance of various related phenomena to risk. This research involved from five to ten contractor personnel. I also have been responsible for preparing and defending the research program and budget in consequence modeling and emergency planning before the Senior Contract Review Board and the Advisory Committee for Reactor Safeguards.

2. Performing and Reviewing Probabilistic Risk Assessments

I was responsible for all of the risk calculations performed for the final Reactor Safety Study. At the completion of the study, I responded to critiques and questions concerning Probabilistic Risk Assessment from within the NRC, Congress, other Federal agencies, contractors and vendors, intervenors, state and local governments, utilities, and foreign governments. I have also performed risk studies or comparisons for the following analyses:

1. Task Force Report on Interim Operation of Indian Point;
2. Indian Point and Zion Site Risk and Alternative Containment Concepts Study;
3. Hatch consequence study;
4. Three Mile Island Potential Accident Consequence Study and Source Term Study;
5. Generic Environmental Statement on Mixed Oxide consequence study;
6. Anticipated transients without SCRAM consequence study;
7. Diablo Canyon Risk Assessment review; and
8. Clinch River Breeder Reactor consequence analysis review.

I have been responsible for advising and reviewing the following foreign risk assessments:

1. Norwegian Energy Study
2. Swedish Reactor Safety Study
3. German Reactor Safety Study
4. British Windscale and PWR Inquiries

In addition, the Norwegian Government personally invited me to Norway to review the approach and assumptions used in their study.

3. <u>Siting and Emergency Planning and Response Criteria Development</u>

I was the research consultant and member of the NRC/EPA Task Force on Emergency Planning. For the work of the Task Force, I was responsible for formulating the rationale for the emergency planning basis criteria and was the principal author of the Task Force Report on Emergency Planning (NUREG-0396). I also was responsible for developing the Emergency Action Level Guidance (NUREG-0654, Appendix 1) which establishes consistent criteria for declaring emergencies based upon plant parameters.

I performed a study on the cost/benefit of issuing Potassium-Iodide to the general public. Based on this report (NUREG/CR-1433), Potassium-Iodide is not being stockpiled for public distribution. In addition, I have performed numerous studies on emergency protective measures such as sheltering versus evacuation. I also developed the Three Mile Island Emergency Contingency Plan at the time of the accident.

I developed a ranking of high population sites which has been used to designate potentially high risk contributors.

4. <u>Integrating Probabilistic Risk Assessment Into the Regulatory Process</u>

I have provided technical direction on consequence modeling to the regulatory and licensing process for the following areas: Perryman Alternative Site Review; Environmental Impact Statement for Class 9 Accidents; Liquid Pathway Generic Study; in understanding the course and importance of potential accidents; and in source term development. I have on numerous occasions presented the results of my work on consequence modeling and emergency planning and response to other Offices within the agency, other organizations, the Advisory Committee on Reactor Safeguards, and the NRC Commissioners.

Science Applications, Inc. (SAI), April 1973 to April 1975, McLean, Virginia

I was involved with the design and implementation of two major projects.

The first project was the Atomic Energy Commission's Reactor Safety Study. I was a research analyst involved in developing and applying reliability methods in reactor accident sequence quantification and error/uncertainty propagation. I also was given responsibility for the development of an improved consequence model for the final version of the study.

The second project was the Federal Trade Commission's Market Basket Survey. This survey was designed to statistically determine a "typical" market basket of food for the average family and have an accurate comparison of grocery store pricing. I was retained as an expert consultant to the F.T.C. and helped design and implement the survey and analysis techniques.

Computer Sciences Corporation - August 1970 to April 1973, Arlington, Virginia

I was a task leader with Computer Sciences Corporation where I worked on the general support contract for the National Military Command System Support Center (NMCSSC) in the modeling and gaming department. I designed, implemented, and documented the Data Base Preparation Subsystem of the QUICK Reacting General War Gaming model. I was task leader for the QUICK production support task with responsibilities for maintenance and production support of the model and the associated damage assessment models. I was chosen as War Gaming Analysis Section representative to study and evaluate the consolidation and conversion of the Antiballistic Missile System (ABM-I) and QUICK Strategic War Gaming Models.

Imcor-Glenn Engineering, Inc. - June 1968 to April 1970, Rockville, Maryland

Imcor-Glenn Engineering, Inc. Operations Supervisor, Programmer - I was contracted to work for the Naval Ships Research and Development Center on testing and evaluation of the Small Boats Project (PCF) and on the Sonar Dome Project. I was also contracted to the Naval Research Laboratory as site team leader for testing and evaluation of Ultra High Frequency Radio Wave Study. As operations supervisor for the Data Division of Imcor, I was responsible for programming and quality control of processed data.

Awards, Honors, and Publications

I received the NRC Special Achievement Award on October 29, 1976 and a NRC High Quality Award on May 11, 1978. I was a session chairman in Consequence Modeling for the American Nuclear Society/European Nuclear Society Topical Meeting on Probabilistic Risk Assessment, September 20-24, 1981 in Port Chester, New York. I was also a session chairman for the American Nuclear

Society Review Conference on the PRA Procedures Guide, April 1982, in Arlington, Virginia. For this conference, I organized three formal debates on current issues in consequence modeling. I have published numerous papers and reports in probabilistic risk assessment, consequence modeling, siting, emergency planning and response, and on the source term. A list of all publications is attached.

Education

I was awarded a Batchelors of Science in Computer Science in 1970 and a Masters of Science in Operations Research in 1973 from the American University in Washington, DC.

AUTHORED OR CO-AUTHORED THE FOLLOWING PUBLICATIONS

"Relationship of Source Term Issue to Emergency Planning," EPRI/NSA Workshop on Technical Factor Relating Impacts from Reactor Releases to Emergency Planning, Bethesda, MD, January 12-13, 1982.

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