PLG-0404

Comments on the Transportation Sections of the U.S. Department of Energy's Draft Environmental Assessments for Potential Nuclear Waste Repository Sites

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Preface

The Electric Utility Companies' Nuclear Transportation Group ("Nuclear Transportation Group")* requested Pickard, Lowe and Garrick, Inc. (PLG) to review the transportation sections of the U.S. Department of Energy's (DOE) Draft Environmental Assessments (EAs) for potential nuclear waste repository sites. This review was limited to the EAs associated with the five sites proposed for nomination for site characterization for selection of the nation's first repository site.

PLG's qualifications to perform this work for the Nuclear Transportation Group are presented in Appendix A of this report. Resumes of PLG personnel who contributed to this report are presented in Appendix B.

* The Nuclear Transportation Group currently consists of 37 investor-owned and publicly-owned electric utilities responsible for the construction or operation of 99 power reactors. The members are Alabama Power Company, Arizona Public Service Company, Baltimore Gas & Electric Company, Boston Edison Company, Carolina Power & Light Company, Commonwealth Edison Company, Consolidated Edison Company of New York, Inc., Duke Power Company, Duquesne Light Company, Florida Power & Light Company, Georgia Power & Light Company, Gulf States Utilities Company, Houston Lighting & Power Company, Indiana & Michigan Electric Company, Kansas City Power & Light Company, Kansas Gas & Electric Company, Middle South Services, Inc., Nebraska Public Power District, New York Power Authority, Niagara Mohawk Power Corporation, Northeast Utilities, Northern States Power Company, Pacific Gas & Electric Company, Pennsylvania Power & Light Company, Philadelphia Electric Company, Public Service Company of Colorado, Public Service Electric & Gas Company, Rochester Gas & Electric Corporation, Sacramento Municipal Utility District, South Carolina Electric & Gas Company, Southern California Edison Company, Texas Utilities Generating Company, Union Electric Company, Virginia Electric & Power Company, Wisconsin Electric Power Company, Wisconsin Public Service Corporation and Yankee Atomic Electric Company. The Edison Electric Institute supports the Group financially and participates in its activities.

Project Scope

The Nuclear Transportation Group requested PLG to perform the following tasks:

1. Provide engineering consulting services to the Nuclear Transportation Group and perform an independent technical evaluation of DOE's analyses of transportation costs and risks.

2. Review computer codes and documentation for those codes that are used to predict costs and risks of transportation to the potential repository sites. These computer codes are RADTRAN II (risk analysis) and WASTES (cost analysis). These codes were reviewed to check the accuracy of input data and the validity of assumptions made in the models. The reviews were performed to determine the degree of confidence that should be placed in the results obtained from these models.

3. Determine if the cost and risk models comport with sound and acceptable methods of environmental analysis; i.e., are these types of models used by DOE and other organizations for similar purposes?

4. Determine if the cost and risk models (and their input data) are appropriate to support valid conclusions, e.g., if these models should have been further refined so that they would be less "generic." Also, determine the degree to which the cost and risk models produce conservative or nonconservative results.*

5. Determine if the results obtained from the cost and risk models (a) adequately evaluate the local and national transportation impacts so that a high degree of confidence should be placed in the results, and (b) enable DOE to rank accurately the sites in terms of transportation costs and risks.

* The term "conservative" is used here to describe calculations and assumptions that result in bounding estimates of risk. Actual risks would be much lower.

Completed Tasks

PLG performed the following tasks to accomplish the goals established by the Nuclear Transportation Group:

1. Obtained copies of all studies and reports cited by DOE in their generic transportation appendix, and reviewed all those reports.

2. Reviewed the Nuclear Waste Policy Act (NWPA) and the Repository Siting Guidelines to evaluate the goals of the NWPA and the corresponding DOE responsibilities.

3. Reviewed cost and risk computer codes and the documentation for these codes. Performed sensitivity analyses for the risk analysis computer code, RADTRAN II.

4. Examined information presented in the EAs and compared this information to the requirements contained in the Repository Siting Guidelines.

5. Reviewed Chapter 7 ("Comparative Evaluation of Sites Proposed for Nomination") of the EAs to examine DOE's method of ranking the sites in terms of local and national transportation costs and risks.

6. Reviewed the EAs to determine, based on PLG's previous experience in transportation cost and risk analyses, (1) if there are important transportation issues not adequately addressed by DOE, and (2) if there are other transportation strategies for improved safety and efficiency that were not sufficiently considered by DOE.

Discussion and Comments

PLG's comments on the costs and risks of transporting spent nuclear fuel are presented below.

1. Transportation of spent nuclear fuel is not a "new" activity, and it is certainly not a "high tech" activity. Transportation of this commodity relies on the engineering design, construction, maintenance, and operation of such routine items as cranes, trucks, rail cars, and shipping casks. The extent to which engineers and technicians have mastered these subjects is clearly evidenced by the lack of serious transportation accidents involving spent nuclear fuel. Further, transportation of spent nuclear fuel is much less hazardous than transportation of other materials such as toxic chemicals and explosives, since it is not easily dispersed after an accident. Significant quantities of spent nuclear fuel have been successfully shipped over several decades and many routes, both in the U.S. and abroad.

2. Arguments have been raised that the DOE transportation analyses in the EAs might be "too generic", and that the analyses presented in the generic transportation appendix are not sufficiently refined to choose among the potential repository sites. This argument presumes that the risks of transporting spent nuclear fuel may be significant (i.e., large when compared to other risks that are encountered routinely in society) and, therefore, may be crucial in ranking the potential repository sites. On the basis of PLG's experience in transportation risk analysis, these concerns are unfounded. The DOE analyses are sufficient to demonstrate that these risks are very small. In fact, these risks are so small that they are not useful in attempting to differentiate among the proposed sites. Table I presents results for the statistically estimated number of fatalities that DOE estimates could be expected to occur because of spent nuclear fuel shipments. These results include both radiological and nonradiological fatalities over an assumed 26-year operating period for the repository. These results are very conservative because they are based on conservative input assumptions (for example, current cask designs are used; see comment 7). They also include a statistical estimate of expected "latent cancer fatalities", also a conservative estimate, since these fatalities may not occur because of other causes of death during the long (10- to 20-year) latency period.

Table I

Total Transportation-Expected Fatalities (Reference 1)

(26-Year Operating Period)

Mode/Category	Richton	Deaf Smith	Davis Canyon	Yucca Mt.	Hanford
Truck (100%)					
Radiological	1.3	2.1	2.7	3.1	3.6
Nonradiological	29	43	59	72	78
Total	30.3	45.1	61.7	75.2	81.6
Rail (100%)					
Radiological	8	10	13	17	18
Nonradiological	1.7	2.3	2.9	3.6	3.8
Total	9.7	12.3	15.9	20.6	21.8

Note: Both costs and risks of spent fuel transportation are generally directly proportional to the distance traveled. Since most reactor plants are located in the eastern U.S., both costs and risks are estimated to be higher for sites in the western U.S.

Data gathered by the U.S. National Safety Council for fatalities that occurred in the U.S. in 1980 show that 416,509 cancer fatalities and 105,718 accident-related fatalities occurred that year (reference 2). Also, as stated in reference 1, natural background radiation (from cosmic rays and from natural radioactivity) will statistically result in 117,000 latent cancer fatalities over a 26-year period; about 65,000 people will die from truck accidents, and about 32,000 people will die from rail accidents over a 26-year period. Thus, even the highest estimate of fatalities that statistically might result from spent fuel transportation over a 26-year period (81.6 for truck transportation to Hanford) is many orders of magnitude less than the estimated number of fatalities from other causes. Based on Table I, it is also worth noting that for truck transportation, nonradiological fatalities (e.g., resulting from collisions) would be at least 20 times greater than radiological fatalities. Thus, the DOE evaluation was correct in assigning a relatively low weight to both local and national transportation risks.

3. The "generic" (non-route specific) analyses performed by DOE are adequate for the purpose of estimating the radiological and nonradiological risks associated with spent fuel transportation on a national and local basis. Obviously, every mile of the U.S. highway system differs in risk from every other mile, just as every mile of railroad track differs in risk from every other mile. The key concepts in the "generic" approach used by DOE in the EAs are (a) that the existing accident data base can be used to predict future accident rates and (b) that the accident risks can be averaged and, therefore, that the "standard deviation of risk" is not large. These concepts are the foundation of all accident rate predictions, not just hazardous material accident analyses. In fact, PLG and other engineering consulting firms routinely employ similar analyses using the existing accident data base.

4. Arguments have been raised that human error in packaging spent nuclear fuel should be specifically considered in transportation risk analyses. Whether an accident is caused by human error or mechanical failure, it is still included in the transportation accident data base. Thus, these factors are already implicitly included in the DOE analyses. Further, human error rates for spent fuel shipments would be lower than those for other types of shipments because operating procedures require checks and verifications of cask contents, radiation levels, integrity, etc.

5. Arguments have been raised that the "generic" analyses do not account for large changes in the population density of an area, such as those occurring during rush hours in cities, nights/weekends in cities, etc. Again, these changes are accounted for as part of the overall "averaging" process, so that large increases in population density are balanced by large decreases in population density at other times.

6. The DOE method of ranking the potential repository sites complies with the DOE siting guidelines (49FR47769). As demonstrated in Appendix A of the EAs, transportation risks (radiological and nonradiological) are so small (see comment 2 above) that they are not a significant factor in evaluating the proposed repository sites. However, the national transportation costs are significant and differ significantly among the potential sites, depending primarily on the relative distance from the nuclear power plants.* The costs associated with transportation in the vicinity of potential sites, e.g., the costs of repository access roads, are small for all the proposed sites when compared to national transportation costs.

* Cost estimates range from 1.5 to 3.5 billion dollars. National costs are indeterminate, however, at this time because many unknown factors (e.g., the decision to construct a monitored retrievable storage (MRS) facility and the determination of specific routes and modes) may affect the ultimate transportation costs.

7. The risk analysis philosophy presented in the DOE generic transportation appendix (p. A-15) is clearly conservative in that conservative values are used in many steps in the analysis. The following are two of the more conservative assumptions used by DOE:
   (a) Existing casks designs were used in the analysis. It is expected that future cask designs will result in fewer required shipments.
   (b) The estimated number of spent fuel assemblies requiring shipment is conservative by perhaps as much as a factor of two.

   A much better understanding of the overall conservatism could be conveyed if a "best estimate" approach were used and an overall factor of conservatism applied to the best estimate results. Also, relative risk comparisons, for example, comparison of spent fuel transportation risks to other everyday transportation risks, would be helpful in putting spent fuel transportation risks in perspective. Such comparisons would emphasize that while there may be a calculated difference in risk among the sites, such differences are not statistically significant and the levels of risk are so low that they do not serve as a valid basis for making comparisons between sites (see comment 2 above).

8. The RADTRAN II transportation risk model and DOE's use of it are adequate for performing the analyses outlined in the EAs. Checks of both the input data and results have been made and verify the adequacy and use of the model. Results of sensitivity analyses performed by PLG show that for each population zone (a) radiological transportation risks for accident-free transportation are directly proportional to shipping cask radiation levels, and (b) for each accident severity class, radiological transportation risks for transportation accidents are directly proportional to assumed accident rates. Thus, radiological transportation risks would still be low and nondeterminative in site selection even if DOE's assumed values for accident rates or for cask radiation levels were significantly increased.

9. Unit risk factors are defined as the increments of risk associated with a unit of distance traveled, e.g., the number of latent cancer fatalities per kilometer. The DOE spent fuel transportation analyses compute "unit risk factors" for truck and rail shipments in rural, suburban and urban environments. This approach is valid on a national scale, but is at least an order of magnitude too conservative on a local scale because of conservative population density assumptions. Also, the national transportation risk analyses (based on RADTRAN II) are overly conservative since these analyses are based on national transportation accident statistics. It would be expected that special driver/crewman training and procedures, and customized and well-maintained equipment will reduce the accident rate for spent fuel shipments below national average accident rates.

10. The DOE analyses define "reactor centroids" (points equidistant from several nuclear power plant locations) as points of origin for the spent fuel shipments, and then assume that spent fuel shipments are made on existing rail lines or on the interstate highway system. Census data for 1980 were used to estimate population densities. This approach is a reasonable means of estimating overall transportation risk. There could be several different acceptable routes from a reactor to a repository site and there is no need to identify and evaluate specific routes to verify the validity of the DOE analyses.

11. The DOE analyses consider two "bounding cases" for the transportation modal mix, i.e., 100% truck and 100% rail. Analysis of these two cases is sufficient to estimate the risk of any other modal mix, such as 50% rail and 50% truck. The exact modal mix cannot be specified at this time, because road and railroad track conditions, tariffs, and other factors may change during the next 10 to 15 years (spent fuel shipments will begin in 1998).

12. Some distances from reactor centroids to the repository sites that are listed in DOE's Appendix A (Tables A-1 and A-2) differ from those listed in the referenced Sandia report (SAND84-1795). These differences should be eliminated or explained. However, the resolution of this matter will not have a significant impact on the cost or risk results.

Appendix A
Previous PLG Transportation Studies

For nearly 30 years, Pickard, Lowe and Garrick, Inc. (PLG) has been involved in the technical and economic aspects of the back end of the nuclear fuel cycle. After the demise of commercial reprocessing of spent nuclear fuel in the mid-1970's, PLG became more intimately involved in the following activities:

1. Design and analysis of high-density spent fuel storage racks (including potential benefits and difficulties associated with storage of consolidated fuel rods and credit for fuel depletion in criticality safety analyses).

2. Evaluation of spent fuel storage and disposal options including essentially all concepts proposed for both onsite and offsite storage.

3. Costs and risks associated with the transportation of spent nuclear fuel.

4. Evaluation of proposed concepts for a Monitored Retrievable Storage (MRS) facility and management of a conceptual design and evaluation study for an MRS.

5. Evaluation of implications of the Nuclear Waste Policy Act of 1982 (NWPA).

    a. contractual considerations
    b. schedule, program costs and utility fees
    c. establishment of criteria and objectives for system integration studies including transportation
    d. establishment of criteria for DOE's acceptance rate and priority system

PLG's participation in the activities described above has been sponsored by many of our utility clients as well as the Edison Electric Institute and the Utility Nuclear Waste Management Group.

The evaluation of the risks associated with nuclear transportation involves consideration and knowledge of essentially all aspects associated with the transportation of the materials of interest. The following is a list of specific transportation risk evaluations by PLG which demonstrates our knowledge and experience with issues involved in the transportation of nuclear materials:

1. Spent Fuel Transportation Criteria (Electric Power Research Institute). Assessment (with Transnuclear, Inc.) of the margins and public risk inherent in using the mode-independent transport cask design criteria as defined by Federal regulations. Objectives of the project included evaluation of the equivalence between current regulatory test conditions and real/credible accidents, and identification of major contributors to high-risk scenarios that may be associated with extreme accident environments.

2. Risk Model for Transport of Hazardous Materials (U.S. Army). Developed a computerized risk model with users manual to enable client evaluation of the change in risk resulting from changes in materials, routing, or container design for hazardous biological and chemical materials. Risk was evaluated in terms of selected health effects on a per trip basis. Initial data bases were established for accident rates by carrier type, population density, atmospheric dispersion, and container system equipment failures.

3. Proposed Regulations for Specification of Highway Routes for Transportation of Fissile Class III and Large Quantities of Radioactive Material (Southern California Edison Company). Performed an analysis of the risk to the public from shipment of spent nuclear fuel over proposed routes from the three nuclear plant sites in California. Results of this analysis were presented as testimony to the California Highway Patrol.

4. Transportation of Spent Nuclear Fuel from Oconee Nuclear Station for Storage at McGuire Nuclear Station (Duke Power Company). Analyzed the risk to the public from transporting spent nuclear fuel between the Oconee and the McGuire plants. Results of this analysis were presented as testimony before the Atomic Safety and Licensing Board.

5. Proposed Rulemaking on Transportation of Radioactive Materials and Spent Fuel (16 Utility Companies). Performed a cost/risk/benefit tradeoff analysis to determine whether special trains should be required for shipment of spent fuel from nuclear power plants. Results were presented as testimony before the Interstate Commerce Commission.

Appendix B
Resumes of PLG Personnel

Recommendations

1. DOE should better explain the RADTRAN II model and the results obtained from this model in their generic transportation appendix. These explanations should also discuss the degree of confidence that can be placed in the risk calculation results, and should state that the risk results are conservative (establish upper bounds of risk) and discuss the assumptions that make the results conservative.

2. DOE should carefully consider national transportation costs in ranking the potential repository sites. Because the radiological and nonradiological risks of transporting spent nuclear fuel by truck and rail are very small, there is no meaningful difference in risk among the sites. Therefore, differences in risk are not significant in ranking sites. However, a cost comparison is a significant contributor to ranking the sites. In applying the guidelines and ranking the sites, DOE should consider the relative costs of national transportation, as well as the overall costs of constructing, operating and maintaining the proposed repository sites.

3. DOE has correctly decided that selection and analyses of proposed routes for spent fuel transportation and the precise mix of transportation modes are not appropriate at this stage in the site evaluation process because specific routing and modal mixture information is not yet available and because the results could be changed significantly by, for example, the decision to build a monitored retrievable storage (MRS) facility. DOE should revise its generic transportation appendix to explain that overall risk will not be significantly affected by the selection and use of specific routes or a precise modal mixture. Accordingly, the selection and use of specific routes or a precise modal mixture is not an important factor in ranking the sites.

4. DOE should discuss spent fuel characteristics in their generic transportation appendix. This discussion should include or reference descriptions of typical boiling water reactor (BWR) and pressurized water reactor (PWR) fuel assemblies and should list quantities of radioactivity by isotope in 5-year old and 10-year old assemblies. Finally, the generic transportation appendix should be revised to include a glossary of terms to explain such expressions as "unit risk factors" and "risk."

References

1. K.S. Neuhauser, J.W. Cashwell, P.C. Reardon and G.W. McNair, "A Preliminary Cost and Risk Analysis for Transporting Spent Nuclear Fuel and High-Level Wastes to Candidate Repository Sites," SAND84-1795, October, 1984.

2. National Safety Council, "Accident Facts, 1984 Edition," 1984.

JAMES K. PICKARD

Educational Background:

B.S., M.S., Electrical Engineering, Massachusetts Institute of Technology.

Employers and Experience:

1954-Present	Pickard, Lowe and Garrick, Inc. Served in a consulting capacity to electric utility companies on nuclear matters. Organized the predecessor firm to PLG in 1954 and has since served as a principal in the firm. During this period, PLG has worked with and continues to work with many utilities on many power reactor projects. Led a survey study by PLG for Edison Electric Institute regarding the alternate methods of handling and disposing of spent nuclear fuel and high-level radioactive waste and subsequently served as advisor to Edison Electric Institute's study, "Conceptual Design and Evaluation Study for an Interim Off-site Spent Fuel Storage Installation." Serves on the Atomic Industrial Forum's Industry Oversight Committee on Nuclear Waste Management.
1948-1954	Atomic Energy Commission, Washington, D.C. Served in various technical and managerial roles including work on international control of nuclear fuels, operations analyses of weapons material production, and development of electric utility power reactor programs and systems.
1946-1948	Johns Hopkins Applied Physics Laboratory. Studied nuclear-powered missiles.
1941-1946	General Electric Company; Kellex Corporation. Worked as an engineer in the development and design of the Oak Ridge uranium gaseous diffusion plants.

Memberships, Licenses, and Honors:

Registered Nuclear Engineer, District of Columbia
Member of American Nuclear Society, and American Institute of Electrical Engineers
Former Organizer, Major Owner, Officer and Director of NUS
Former Director of Atomic Industrial Forum

B. JOHN GARRICK

Educational Background:

Ph.D., Engineering, University of California, Los Angeles, 1968.
M.S., Engineering, University of California, Los Angeles, 1962.
B.S., Physics, Brigham Young University, 1952.
U.S. Atomic Energy Commission Grant-in-Aid, Oak Ridge School of Reactor Technology, 1954-1955.

Employers and Experience:

1975-Present Pickard, Lowe and Garrick, Inc. President and Chief Executive Officer of Pickard, Lowe and Garrick, Inc., an engineering consulting firm of approximately 100 employees. Consultant in reliability and availability, risk analysis, licensing and safety, management systems, and engineering. Pioneered early use of reliability and risk analysis technology in nuclear and fossil power plants. Served on several design review and safety committees and other task forces related to power plant design and operations. Study director of numerous major risk studies of nuclear power plants including Oyster Creek, Zion, Indian Point, LaSalle, Pilgrim 1, Midland, Seabrook, Three Mile Island Unit 1, Beznau, and Browns Ferry. Extensive experience with hearings and the general nuclear licensing process. Coordinator and principal lecturer for the annual UCLA short course on power plant risk and reliability. Presented numerous seminars on risk, reliability, and safety analysis at such institutions as the Massachusetts Institute of Technology, the University of California, and the United Kingdom's National Centre of Systems Reliability. Served on several accreditation teams evaluating engineering curriculum at different universities. Organized and conducted numerous workshops and training programs on maintenance, reliability, and availability for the Electric Power Research Insitute, the Department of Energy, and many utilities. Published over 100 papers and reports on nuclear power plant risk, reliability, siting, and energy technology.

Adjunct Professor, University of California, Los Angeles; member of several institutional committees including the UCLA Radiation Committee, the Select Review Committee for the Clinch River Breeder Reactor, Design Review Board for the Midland Nuclear Power Plant, Direction and Control System Advisory Committee of the Governor's Emergency Task Force on Earthquake Preparedness, and Boston Edison's Audit and Nuclear Review Committee.

1957-1975	Holmes & Narver, Inc. Key Positions: Member of Board of Directors President, Nuclear & System Sciences Group Senior Vice President; Science & Technology, The Resource Sciences Corporation, Tulsa, Oklahoma (parent company).
1955-1957	U.S. Atomic Energy Commission, Washington, D.C., Physicist, Hazards Evaluation Branch.
1952-1954	Phillips Petroleum Company, USAEC Contractor, National Reactor Testing Station, Idaho, Physicist.

Memberships, Licenses, and Honors:

American Nuclear Society
Fellow, Institute for the Advancement of Engineering
New York Academy of Sciences
Atomic Industrial Forum
Pacific Coast Electrical Association
American Association for the Advancement of Science
American Institute of Management, Presidents Council
Who's Who in the West (ninth edition)
Who's Who in Atoms (fifth edition)
Who's Who in American Science
Leaders in American Science (eighth edition)
Who's Who in Frontier Science and Technology (first edition)
Registered Professional Engineer, State of California

THOMAS R. ROBBINS

Educational Background:

Graduate Courses in Physics, University of Pittsburgh, 1957-1959
B.S., Physics, Pennsylvania State University, 1957

Employers and Experience:

1969-Present — Pickard, Lowe and Garrick, Inc. Senior Consultant. Nuclear Design and Fuel Management. Responsibilities include technical and economic evaluations of initial core and reload fuel designs for boiling water reactors and pressurized water reactors; analysis and negotiation of contracts for nuclear fuel and associated engineering services; core and fuel optimization to improve uranium utilization and power costs; design and criticality analysis of spent fuel and new fuel storage racks; technical and economic evaluation of spent fuel storage alternatives; evaluation of nuclear waste disposal alternatives and costs; development and application of both detailed core analysis and scoping analytical models for boiling water reactors and pressurized water reactors; analysis, support and evaluation of core-related startup test procedures and physics test results.

Nuclear Plant Safety and Safety-Related Activities. Member and consultant to Senior Safety Audit and Review Committees. Responsibilities include evaluation of management controls and organization of utility nuclear power activities; review and evaluation of reactor safety, licensing, and setpoint analysis including neutronic, thermal-hydraulic, transient and accident analyses; audits of nuclear power plant operations and engineering for compliance with license and regulations; design reviews and design control audits for initial and reload core designs including neutronic, thermal hydraulic, and mechanical designs and transient and accident analyses. Certified Lead Auditor. Performed development and application of analytical models for the quantitative assessment of risks to nuclear power plants from ships and aircraft.

1964-1969 — NUS Corporation. Manager, Reactor Physics. Responsibilities included nuclear design and analysis and operational analysis and support of central power station, military and maritime reactors; reactor design and safety analysis and onsite assistance for refuelings and physics tests; criticality safety analysis for spent fuel racks and proposed reprocessing plants; computer code application and development for core neutronics analysis and fuel management; preparation and evaluation of technical and bid specifications, and safety analysis reports; and core neutronics analysis to support radioactive isotope (Co-60 and Pu-238) production in power reactors.

1963-1964 Babcock & Wilcox Company. Lead Engineer Nuclear Design and Analysis. Performed nuclear design calculations of the spectral shift controlled reactor prototype and for all soluble poison controlled reactors then offered by Babcock & Wilcox for central power stations. Consulted on applications of naval reactor-developed computer codes for core analysis of central power station, maritime and test reactors.

1957-1963 Bettis Atomic Power Laboratory. Senior Scientist, Large Power Reactor Project, Destroyer Project, Advanced Reactor Development and Analysis Project. Developed analysis models for core design based on analysis of critical experiments, including burnable poisons. Performed design and analysis of moving fuel control method utilized for the light water breeder reactors. Performed nuclear design and analysis of advanced water reactor concepts for utilization in nuclear powered submarines and destroyers.

Memberships, Licenses and Honors:

American Nuclear Society
Guest Lecturer, Massachusetts Institute of Technology, Nuclear Fuel Management Summer Program, 1972-1976

STANLEY KAPLAN

Educational Background:

Senior Postdoctoral Fellowship, University of Southern California, 1967-1969
Ph.D., Mechanical Engineering and Applied Matehmatics, University of Pittsburgh, 1960. Postdoctoral courses in mathematics at the University of Pittsburgh and Carnegie Institute of Technology, 1960-1965.
M.S., Mechanical Engineering, University of Pittsburgh, 1958.
Graduate of the Oak Ridge School of Reactor Technology, 1955.
B.S., Civil Engineering, City College of New York, 1954

Employers and Experience:

1977-Present — Kaplan & Associates, Inc., a consulting firm specializing in risk analysis and applied decision theory.

Concurrently Adjunct Professor, Department of Chemical, Nuclear and Thermal Engineering, University of California, Los Angeles, and Associate Consultant, Pickard, Lowe and Garrick, Inc.

Mathematician and engineer well known for contributions to risk analysis and reliability theory, reactor physics, kinetics, and computational technique. Specialist in probabilistic methodology; decision theory; risk analysis; and, particularly, applications of Beyes' theorem. In this connection, has worked specifically and recently on developing probabilistic and decision theoretic treatments of various phases of the energy business. Included here are probabilistic risk assessment analyses of several existing nuclear plants, hazardous material transportation and storage, spent fuel pools, aircraft impact, offshore oil storage, pipelines, and tarsands projects (business and construction risk). Developer of the discrete probability distribution method for probabilistic calculations, the two-stage Beyesian technique for data analysis, the "set of triplets," probability of frequency," "cause table," and "environmental table" concepts in risk analysis. Originator of the matrix theory of event trees and discrete probability distribution approach to seismic risk analysis.

1975-1977 — Private consultant specializing in risk analysis and decision theory.

1972-1975 — Holmes & Narver, Inc., Anaheim, California.
Director, Advanced Technology Division;
Director, Systems Sciences Division;
Technical Director, Nuclear & Systems Sciences Group.

1971-1972	Director of Software Development, COMARC Design Systems, Inc., San Francisco, California.
1969-1971	Product Manager and Senior Staff Member, Computer Sciences Corporation, Los Angeles, California.
1967-1969	Special Research Fellow, U.S. Public Health Service at University of Southern Califronia, Los Angeles.
1955-1967	Westinghouse Bettis Atomic Power Laboratory, West Mifflin, Pennsylvania. Experimentalist, Experimentalist in Charge, Scientist, Senior Scientist, Advisory Scientist.
1962-1967	Concurrently Adjunct Professor of Mechanical Engineering, University of Pittsburgh; Lecturer, Department of Mathematics, Carnegie Institute of Technology.
1954	Lecturer, Department of Civil Engineering, City College of New York.

Memberships, Licenses and Honors:

American Society of Civil Engineers
American Nuclear Society
Society of Industrial and Applied Mathematics
New York Academy of Sciences

WILLARD C. GEKLER

Educational Background:

Short Course, Radioactive Waste Management for Nuclear Power Reactors, University of California, Los Angeles, 1975.
Reactor Safety Course, United Kingdom Atomic Energy Authority, 1967.
Systems Safety Analysis Course, University of Washington, 1965.
Graduate Work, Nuclear Engineering, University of California, Los Angeles, 1960-1963.
P.R.E. (Petroleum Refining Engineer), Colorado School of Mines, 1954.

Employers and Experience:

1982-Present — Pickard, Lowe and Garrick, Inc. A chemical and nuclear engineer with experience in analysis and design of chemical process, engineering test, nuclear facilities, and waste transport and storage systems. Currently participating in probabilistic risk assessments for nuclear power facilities. Project manager for EPRI study to assess safety margins inherent in current Federal regulations covering mode independent transport cask design criteria. Served as project manager for development of an integrated model for concurrent evaluation of availability, health risk, and utility investment risk at the Sequoyah Nuclear Plant. Other recent work includes coordination and technical review of systems analyses for the Midland Nuclear plant probabilistic risk assessment.

1960-1982 — Holmes & Narver, Inc. Engineer to Technical Director of Process and Energy Systems Division. Performed engineering design and analysis for nuclear and chemical facilities including nuclear reactors, waste transport and storage systems, chemical agent disposal systems, and various test facilities. Responsibilities performed primarily at senior engineer, project engineer, and project manager levels. Also responsible for development of new cogeneration concepts and marketing of concepts.

1957-1960 — Mobil Oil Corporation. Process engineer providing research and development and field test direction for new products and product quality improvement at major petroleum refinery.

1955-1957 — U.S. Army. First Lieutenant in Engineer Strategic Intelligence Detachment.

1954-1955 — ESSO Standard Oil Company. Technical assistant to crude distillation section in petroleum refinery. Responsible for process efficiency, evaluation, and improvement.

Memberships, Licenses, and Honors:

The Society for Risk Assessment
Certified Reliability Engineer, American Society for Quality Control, 1976.

FREDERICK J. ZOEPFL

Educational Background:

Ph.D., Nuclear Engineering, University of Maryland, 1983.
Bettis Reactor Engineering School, 1977
M.S., Nuclear Engineering, University of Illinois, 1975.
B.S., Chemical Engineering, University of Pennsylvania, 1974.

Employers and Experience:

1982-Present — Pickard, Lowe and Garrick, Inc. Reviewed technical specification-related procedures for Nine Mile Point, Unit 1 in the following areas: coolant chemistry, coolant activity, radioactive material sources, radiation protection program, respiratory protection program, control of high radiation areas, liquid effluents, gaseous effluents, solid waste, site meteorology and environmental monitoring. Reviewed quality assurance/quality control (QA/QC) programs for San Onofre, Units 2 and 3, and prepared a summary of AEC/NRC QA/QC programs for Southern California Edison. Also involved in development and quality assurance for the Meteorological Information and Dose Assessment System (MIDAS) for commercial nuclear power plants.

1980-1982 — University of Maryland. Graduate Research Assistant. Performed basic and applied research in radiation chemistry of polymers. Experience gained in polymer chemistry, polymer morphology, radiation sources (linear accelerator and cobalt-60), instrumentation (thermoluminescent and dye film dosimetry, differential scanning calorimetry, electron spin resonance spectrometry, carbon-13 NMR spectrometry, IR, UV/VIS, and gel permeation chromatography). Wrote ten published papers and one United States patent application.

1975-1980 — U.S. Navy. Naval Nuclear Propulsion Engineer. Supervised procurement and distribution of radiation detection instruments used in the Naval nuclear propulsion program, including portable survey meters, thermoluminescent dosimetry system, multichannel analyzers and Ge(Li) detectors. Reviewed and approved maintenance and calibration procedures for these instruments. Revised dosimetry recordkeeping requirements for nuclear-powered ships and their support facilities. Reviewed and approved procedures used in the Naval nuclear propulsion program to detect internally deposited radioactivity. Managed external and internal

dosimetry intercomparison programs for approximately 25 facilities involved in maintenance and repair of nuclear-powered ships. Some experience in nuclear reactor emergency planning, environmental monitoring and transportation of radioactive materials. Resigned as Lieutenant, U.S. Navy, in June 1980 to pursue Ph.D. degree.

Memberships, Licenses, and Honors:

American Chemical Society
American Nuclear Society

NATHAN O. SIU

Educational Background:

Candidate for Ph.D., Engineering, University of California, Los Angeles.
M.S., Engineering, University of California, Los Angeles, 1980.
B.S., Engineering, University of California, Los Angeles, 1977.

Employers and Experience:

1982-Present Pickard, Lowe and Garrick, Inc. Associate consultant performing risk assessment modeling and heat transfer analysis. Has specialized in fire risk, trasnportation risk and chemical hazard analysis. Developed probabilistic methods for fire growth and propogation. Has written computer codes COMPBRN and THEAT for fire propagation and heat transfer analysis. Author of fire risk analysis section of Probabilistic Risk Assessment Procedures Guide, NUREG/CR-2300. Has performed analysis of fire propagation in six major probabilistic risk assessment studies. Developed and performed analyses of chemical complexes as potential hazards to nuclear power plants. Performed analysis of the frequency and charactersitics of severe truck and train accidents. Experienced in data analysis. Participated in risk analysis of liquefied natural gas tank ship movements.

Memberships, Licenses, and Honors:

American Nuclear Society
Society of Risk Analysis
Phi Beta Kappa
Graduated Summa Cum Laude
Recipient of Chancellor's Fellowship, 1977
Recipient of Southern California Edison Fellowship, 1982