UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
CONSOLIDATED EDISON COMPANY OF NEW YORK (Indian Point Unit 2)	)	Docket Nos. 50-247 SP 50-286 SP
	)	
POWER AUTHORITY OF THE STATE OF NEW YORK (Indian Point Unit 3)	)	January 31, 1983

DIRECT TESTIMONY

Of

CHARLES PERROW, Ph. D.

On Behalf Of

FRIENDS OF THE EARTH, INC.

And

THE NEW YORK CITY AUDUBON SOCIETY

ON COMMISSION QUESTION 1

DS03

Testimony of Charles Perrow

In the matter of the Indian Point, N.Y. Nuclear Power Stations

I am a tenured professor of sociology at Yale University. I received my Ph.D. in 1960 from the University of California at Berkeley. My field is organizational theory and analysis. I am the author of four books and about 30 chapters or articles in professional journals. I first studied nuclear plants when the Social Science Research Council commissioned a paper on the organizational aspects of the Three Mile Island accident, as a part of their contract with the President's Commission on the Accident at Three Mile Island; the paper was made available to the Commissioners. Subsequently I have studied nuclear power plants more extensively as a member of the National Research Council's Committee on Human Factors; as a member of the Nuclear Regulatory Commission's Reactor Safety Goals panel; as a consultant under contract to the Battelle Memorial Institute in connection with their contract with the Nuclear Regulatory Commission regarding organizational forms that best promote safety (NUREG 0731); as a result of a two year grant from the National Science Foundation; as a result of a grant from the Office of Naval Research to study the organizational context of human factors; and in connection with a book I am preparing under contract with Basic Books, Inc., on accidents in high risk systems.

Nuclear power plants are one of a handful of systems that have low probability accidents with high catastrophic potential. Some others are chemical plants, recombinant DNA engineering and

research, and nuclear weapons systems. In common with these other systems, nuclear power plants have a production system which is both highly interactive and tightly coupled. I argue that these characteristics, defined below, make it inevitable that serious accidents will occur which design engineers could not anticipate, and which operators cannot avoid. Accidents in systems where the linkages between the parts are complex rather than linear, and where the coupling is tight rather than loose, are inevitable, and no amouunt of engineered safety devices nor operator training can prevent them. The reason for this is as follows:

Most industrial and other systems are primarily limited to linear interactions--those that occur in expected production sequence. Complex interactions are those of unfamiliar sequences, or unplanned and unexpected sequences, and are either not visible to designers or operators or not immediately comprehensible. Systems which transform things abound in complex interactions; those that maunufacture, fabricate or assemble things can be limited to linear interactions, i.e. those that are visible, expected and planned.

Linear systems are safer because they can easily separate subsystems, install buffers between them, isolate failed parts, substitute materials or personnel, and have direct, on-line control and information sources. This means that when something fails, diagnosis is easy, natural buffers exist, and recovery is easily made. Component failures are inevitable because nothing is perfect, neither designs, equipment, procedures, operators, supplies and materials, or environment, (called the DEPOSE components of any

system)

However, in systems with complex interactions, even though safety devices and buffers are intentionally designed in, there will occasionally be multiple failures in independent units or subsystems which can interact in unforeseen and unexpected ways. There are connections which are unplanned, unexpected and probably invisible. The designer cannot anticipate all the interconnections of possible failure sources, and the operators cannot comprehend them when they occur.

If, in addition, such a system is also tightly coupled--that is, its functioning is highly dependent upon precise timing, its sequences are invariant, there is no slack in resources, and there is only one way to make the thing--then the operator cannot intervene to prevent an incident from propagating into a serious accident. In linear systems, loose coupling means that delays are possible, alternative sequences are available, various methods can be used to achieve the goal, there is slack in supplies, equipment, personnel, quality standards etc., and there are fortuitous recovery aids available. Thus, even if a system has complex interactions, if it is loosely coupled the consequences of the interaction of multiple, independent failures are not severe. Recovery is possible. When complex interactions exist with tight coupling, the possibility of "system accidents" is greatly increased.

A system accident is one that is, in effect, caused by the system itself, in contrast to a component failure accident which is simply caused by the component failure. DEPOSE components are bound

to fail at some time, and one may trigger another in a domino fashion (expected production sequence). We guard against component failures with redundant components, buffers, circuit breakers, shutdowns, isolation etc. This limits the number of accidents resulting from component failures; the failure remains an incident. In complex systems, the interaction of failures can defeat these safety devices. One important safety device is operator intervention, but if the interaction of failures is incomprehensible to the operator (and unanticipated by the designer), he or she cannot intervene successfully. If the system is also tightly coupled, the time frame makes comprehension and then intervention even more difficult.

For these reasons the usual calculations of expected failure, or risk assessments, are inappropriate for systems that are complexly interactive and tightly coupled. These risk analyses emphasize single failures, or common mode failures that are anticipated and understandable, and virtually ignore the interaction of small failures in independent subsystems that can mysteriously or unexpectedly become linked together. Thus, many of the accidents that have occurred in nuclear plants are truely "incredible" in the sense of having fantastically low probabilities according to conventional calculations of failure, yet may have occurred several times.

Three Mile Island was such an accident. Four independent failures occurred, and the operators could not be expected to be aware of any of these. Most other serious accidents, such as the fire at Browns Ferry, the Fermi accident near Detroit, and the

Dresden 2 accidents, as well as some at government reactors, have been system accidents. I have identified several others in the literature, drawn from the NRC-sponsored journal, Nuclear Safety. One study found that most accidents that led to scram (dropping the control rods in the reactor and ending the fissioning) have multiple causes that involve separate subsystems. Nuclear plants, I conclude, are prone to system accidents, even if they are quite infrequent. Most failures do not cause accidents; most accidents are simple component failure accidents; but there appear to be at least a few every year that are system accidents.

Indian Point Unit 2 and 3 nuclear plants are no different from other nuclear plants in this respect. Indeed, if these plants should have a history of above average Licensee Event Reports or outages, or particularly poor management, the opportunities for component failures would be higher, and thus the opportunities for unanticipated interactions or failed attempts at recovery (that is, for system accidents) would be even higher. The evaluation of Unit 2 by the Systematic Assessment of Licensee Performance Review Group of the NRC is not encouraging in this respect. It found "evidence of weaknesses in five functional areas. These areas were plant operations, maintenance, reporting, committee activities, and management control." It "received a relatively large number of items of noncompliance, including escalated enforcement action, when compared with other facilities." It was ranked in the lowest group.

Fortunately, no system accidents have led to significant emissions of harmful materials as yet, but this is because we have

had only a few hundred years experience with each of our various types of reactors. There are roughly three size categories, two major types (PWR and BWR), and three different manufacturers. This means that our experience with, say, a 1000 mw range PWR built by Westinghouse, is very limited. Given the size and complexity of these installations, we would need perhaps 1000 plant/years experience with each type and manufacturer to be able to say that all the unexpected things that could happen have happened, and that in view of the changes we have made, that we can say the system is mature. Even then, system accidents will still appear. Ammonia production, for example, is a very mature system in the chemical industry, yet ammonia plants experience one serious fire every 11 months, some of which are quite baffling and of unknown origin. These plants are also tightly coupled and complexly interactive.

Nor are we likely to learn enough from experience to prevent system accidents. Experience teaches us that one type of unexpected interaction may occur, and we can guard against that one, but with millions of parts there are millons of others we have not experienced. Indeed, as the result of the "experience" at TMI, the operating regulations on similar plants were changed. Yet within a few months at least two plants had accidents that were more serious than they needed to be because the operators were required to follow the new regulations (regarding High Pressure Injection), despite their better judgement. The new rule was then greatly relaxed, and we are not much better off, in terms of one particular failure, than we were before this "experience" that one might think we could have learned from. System accidents are, in a

sense, the result of unique combinations of factors; changes made on the basis of one of these unique combinations may not affect another one.

Better corporate and better plant management would certainly help reduce the number of component failures in plants; so will better operator training, better equipment, designs and so on. There is a great, great deal that can be done to make nuclear power plants somewhat safer. But there will always be component failures because nothing is perfect--designs, operators, environments or whatever. Thus, in complex systems we can expect a system accident in a reasonable period of time. With tight coupling, there is a high probability that intervention and recovery cannot be quick enough and thorough enough to prevent the propagation of the failures until it results in a catastrophe.

Charles Perrow

Professor of Sociology

Yale University

January 25, 1983

Curriculum Vitae

Charles B. Perrow

Education

University of California, Berkeley
B.A. 1953, M.A. 1955, Ph.D. 1960, all in Sociology

Present Position

Professor, Department of Sociology
Yale University
New Haven, Connecticut 06520

Fellow, Center for Advanced Study in the Behavioral Sciences
Stanford, California 1981-82

Personal

Born 1925, Tacoma, Washington
Married, Two children
Social Security No. 532-18-4107

Teaching Positions

1959-1963 Instructor to Assistant Professor, Department of Sociology, University of Michigan, Ann Arbor.

1963-1966 Assistant to Associate Professor, Department of Sociology, and the School of Public and International Affairs, and the Administrative Science Center, University of Pittsburg.

1966-1970 Associate Professor to Professor, Department of Sociology, University of Wisconsin; Head, Social Organization Center, 1966-1970.

1968-1969 Visiting Professor, Institute of Industrial Relations and School of Business Administration, University of California, Berkeley.

1970-1981 Professor, Department of Sociology, State University of New York at Stony Brook.

1972-1973 Visiting Professor, London Graduate School of Business, London.

1981-1982 Fellow, Center for Advanced Study in the Behavioral Sciences, Palo Alto, California.

Major Research Grants

1957-1958 NIMH Predoctoral Fellowship. Goals and authority in general hospital.

Major Research Grants (continued)

1958-1962	NIMH Grant. Associate Study Director, comparative study of seven juvenile correctional institutions.
1963	NIMH Grant. Panel study of a correctional institution.
1965-1967	NSF Grant. Comparative study of eight industrial corporations.
1967-1968	NSF Grant and Vocational Rehabilitation Grant, Comparative study of fourteen industrial corporations.
1971-1972	NIMH Grant. Insurgency and social change in U.S., 1948-1970.
1973-1976	NIMH Grant. Insurgency and social change in U.S., 1948-1972.
1978	NSF Grant. Origins of industrial bureaucracy in the U.S.
1980-1982	NSF Grant. Accidents in High Risk Systems.

Consultancies and Minor Grants

1956-1958	Evaluation study for OVR of Home Care Program, Mount Zion Hospital; Evaluation study of alcoholic rehabilitation program, California State Alcoholism Commission.
1963-1964	Evaluation study of half-way home program for Federal Bureau of Prisons (with other co-investigators); Consultant and research role for City Youth Commission.
1974-1975	Consultant to Philips Industries, Eindhoven, Holland, on work structuring program.
1972-1973	Consultant on various projects in public sector for Imperial College of Science and Technology, London.
1972-1975	Workshop leader, for Dale-Loveluck Associates, running two-day workshops for executives in London.
1973-1974	Evaluation study of administrative practices in student services at Stony Brook.

Consultancies and Minor Grants (continued)

1975 Consultant on evaluation strategies for AID rural health programs; Consultant, Office of Telecommunications Policy, electronic funds transfer.

1979 Background paper for President's Commission on the Three Mile Island Accident, "TMI--A Normal Accident."

1981-1982 Dioxin in the Office Building: the Generation of Risk Assessment in Terms of Personal Tragedy and Organizational Dilemmas. Russell Sage Foundation, small grant.

Teaching Interests

Complex Organizations, Industrial Society, Technology and Social Change, Social Movements, Research Design, Sociological Theory.

Current Research and Writing

My long term project is a volume titled "A Society of Organizations" which considers the development of the industrial bureaucratic form in the U.S. from about 1820 to the present. The first part, which is fairly well researched to date and partly drafted, deals with the origins of factory bureaucracy from 1820 to 1890, with attention to the creation of a wage dependent population, forms of opposition, and alternative paths that were tried but did not succeed. The second part details the solidification of the industrial system at the turn of the Century, the development of an appropriate rationale in the form of bureaucratic theory, and the spread of this form of bureaucracy to government, welfare and voluntary organizations up to World War II. The third part deals with the transformation of the system after the war into a highly interdependent society of organizations which consumes most of the non-organizational society, producing dynamics which present theory cannot comprehend. An alternative theory is presented.

Work on this book was interrupted by a request to prepare a paper for the President's Commission on the Accident at Three Mile Island, as a part of a Social Science Research Council package. The issue of uncontrolled interactions in social systems was to be a major theme of the above book, and this turned out to be a chance to explore it in a single system, analyzed as a synergistic accident or "normal accident." Since then I have developed the notion more fully and systematically and am currently investigating accidents in a variety of systems, particularly high risk ones such as chemical plants, air and sea transportation, DNA research, medicine (adverse drug reactions), the World Wide Defense Command System, the space program, and military adventures. A two-year NSF grant will allow considerable field work in these and in other systems used for comparison purposes (assembly and fabricating plants, government bureaucracies,

Current Research and Writing (continued)

universities), and will result in a book, hopefully, at the end of the two-year grant (fall, 1982). Thus, a particular case of the larger book will be expanded considerably because of its policy as well as theoretical relevance.

Memberships and Honors

Phi Beta Kappa; Newhouse Fellowship (University of California)
Public Health Pre-Doctoral Fellowship
Public Health Service, Special Fellowship
Editorial Board Membership: American Sociological Review, Administrative Science Quarterly, American Journal of Health and Social Behavior, Administration and Society
Council Member, Section on Professions and Organizations: American Sociological Association
Vice-President: Eastern Sociological Society
Sociology Panel: National Science Foundation
Senior Research Fellow: Center for Policy Research
Fellow: American Sociological Association
American Association for the Advancement of Science
Industrial Relations Association
Eastern Sociological Society
International Sociological Association
National Research Council, Committee on Human Factor Research

Books and Published Monographs

1. Study on the Non-Segregated Hospitalization of Alcoholic Patients in a General Hospital, (American Hospital Association, Hospital Monograph Series 7, 1959) with Mark Berke, Jack D. Gordon, M.D., and Robert I. Levy, M.D., 120 pages.

2. Organization for Treatment: A Comparative Study of Juvenile Correctional Institutions, (The Free Press, 1966) with David Street and Robert D. Vinter, 330 pages.

3. Organizational Analysis: A Sociological View, (Wadsworth Publishing Co.) 1970, 192 pages. (Chapters have been reprinted).

4. Complex Organizations: A Critical Essay, Scott, Foresman, 1972, 224 pages. (Chapters have been reprinted.) Revised edition, 1978.

5. The Radical Attack on Business. Harcourt Brace Jovanovich, 1972, 278 pages.

Research Articles or Chapters

1. "Are Retirement Adjustment Programs Necessary?," Harvard Business Review, 35:4 (July-August, 1957), 109-15.

2. "Gemeinschaft and Gesellschaft: A Critical Analysis of the Use of a Polar Typology," Berkeley Publications in Institutions and Society, 2:1 (Spring, 1956), 20-43. Also reprinted in Autonomous Group Bulletin, XIII:1, 2 (Autumn-Winter, 1957), 10-16.

3. "Research in a Home Care Program," American Journal of Public Health, 49:1 (January, 1959), 34-44.

4. "Nonsegregated Hospitalization of Alcoholic Patients in a General Hospital," Hospitals, Journal of the American Hospital Association, Vol. 33 (Nov. 16, 1959), 45-48, with Mark Berke, Jack D. Gordon, M.D., and Robert I. Levy, M.D.

5. "Organizational Prestige: Some Functions and Dysfunctions," American Journal of Sociology, 66:4 (January, 1961), 335-41. Reprinted in 3 books.

6. "Analysis of Goals in Complex Organizations," American Sociological Review, 26:6 (December, 1961) 859-66. Reprinted several times and in Bobbs-Merrill Reprint Series.

7. "Reality Shock: A New Organization Confronts the Custody-Treatment Dilemma," Social Problems, 10:4 (Spring, 1963), 374-82.

8. "Goals and Authority Structures, A Historical Case Study," Chapter 4 in The Hospital in Modern Society, Eliot Freidson, (ed.), (The Free Press, 1963), 112-46.

9. "Sociological Perspective and Political Pluralism," Social Research, 31:4 (Winter, 1964-65), 411-22. Reprinted.

10. "The Reluctant Organization and the Aggressive Environment," (with John Maniha), Administrative Science Quarterly, 10:2 (September, 1965), 238-57. Reprinted.

11. "Hospitals: Technology, Goals and Structure," Chapter 22 in Handbook of Organizations, James March (ed.), Rand McNally, 1965), 910-71.

12. "Reality Adjustment: A Young Institution Settles for Humane Care," Social Problems, 14:1 (Summer, 1966), 69-79.

13. "Organizational Goals," International Encyclopedia of the Social Sciences, revised edition, (MacMillan Co., 1968), Vol. 11, 305-11.

Research Articles or Chapters (continued)

14. "Technology and Organizational Structure," Proceedings of the 19th Annual Meeting of the Industrial Relations Research Association, December 1966, 156-63.

15. "A Framework for the Comparative Analysis of Organizations," American Sociological Review, (April, 1967), 194-208. Reprinted several times and in Bobbs-Merrill Series.

16. "The Professional Army in the War on Poverty," "Focus Article" in Poverty and Human Resources Abstracts, (January-February, 1968).

17. "Technology and Structural Changes in Business Firms," Industrial Relations: Contemporary Issues, B.C. Roberts, (ed.), (MacMillan Co., 1968), 205-19.

18. "Some Reflections on Technology and Organizations," in A. R. Negandhi, et al. (eds.), Comparative Administration and Management, Comparative Administration Research Series, No. 1 (Kent State University Press, Kent, Ohio, 1969).

19. "Members as a Resource in Voluntary Organization," in Organization and Clients, W. Rosengren and M. Lefton, (eds.), Charles E. Merrill, 1970, 93-116.

20. "Departmental Power and Perspective in Industrial Firms," in Power in Organizations, edited by Mayer Zald (Vanderbilt University Press, 1970), 59-89.

21. "The Short and Glorious History of Organizational Theory," Organizational Dynamics, (Summer 1973), 2-16. (Reprinted)

22. "Zoo Story, or Life in the Organizational Sandpit," Chapter in course text, People and Organizations, Open University (England), 1974. Revision for 1980 edition.

23. "Is Business Really Changing?" Organizational Dynamics (Summer, 1974). (Reprinted)

24. "The Bureaucratic Paradox: The Efficient Organization Centralizes in Order to Decentralize," Organizational Dynamics, Spring, 1977, pp. 2-14. (Reprinted)

25. "Three Types of Organizational Effectiveness," in Paul S. Goodman and Johannes M. Pennings, ed. New Perspectives on Organizational Effectiveness, Jossey-Bass, 1977, pp. 96-105.

26. "Insurgency of the Powerless: Farm Worker Movements, 1946-1972" (with Craig Jenkins), American Sociological Review, 42, (April, 1977), pp. 249-68.

Research Articles or Chapters (continued)

27. "Demystifying Organizations" in Rosemary C. Sarri and Yeheskel Hasenfeld eds. The Management of Human Services, (New York: Columbia University Press, 1978).

28. "The Sixties Observed," in Mayer M. Zald and John D. McCarthy, eds., The Dynamics of Social Movements, Cambridge, Mass., Winthrop Publishers, 1979, pp. 192-211.

29. "The President's Commission and the Normal Accident," in David Sills, et al. (eds.) The Accident at Three Mile Island: The Human Dimensions, Boulder, Colorado: The Westview Press, 1981.

30. "Disintegrating Social Sciences," New York University Education Quarterly, vol. 12, no. 2 (Winter, 1981), pp. 2-9.

31. "Markets, Hierarchies and Hegemony: A Critique of Chandler and Williamson," in Andrew Van de Ven and William Joyce, eds. Perspectives on Organization Design and Behavior, New York: Wiley Interscience, 1981, 371-386, 403-404.

32. "This Week's Citation Classic," Current Contents, 14 (April 6, 1981), p. 14 (A reflection on item 15-"Framework . . .")

33. "Normal Accident at Three Mile Island," Society, vol. 18, no. 5 (July/August, 1981), pp. 17-26.