UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matter of PACIFIC GAS AND ELECTRIC COMPANY (Diablo Canyon Nuclear Power Plant, Units 1 and 2)	Docket Nos. 50-275 OL 50-323 OL

Prepared Direct Testimony of Steven M. Day
on Behalf of Governor Edmund G. Brown, Jr.
Regarding

APPEAL BOARD QUESTION 7

August 8, 1980

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Prepared Direct Testimony
of
Steven M. Day

Q1. Could you please state your name.

A1. Steven M. Day

Q2. Where are you employed?

A2. I am employed by Systems, Science and Software in La Jolla, California.

Q3. What work do you perform for Systems, Science and Software?

A3. I am a staff geophysicist. My responsibilities include planning and carrying out research projects in computational seismology and involve development application of numerical modeling techniques. A statement of my qualifications is appended which describes in greater detail certain of the work that I have performed.

Q4. What is the purpose of your testimony?

A4. This testimony is to respond to Appeal Board Question 7 that requests participants to analyze the IV-79 records and to relate those records to the possibility that focussing might result in amplified strong ground motion at the Diablo Canyon site. The focus of this testimony is to describe the feasibility and usefulness of modeling as a means of contributing to this analysis. This modeling would incorporate the IV-79 data to refine existing models, and then use the refined model to estimate strong ground motion at a particular site, such as Diablo Canyon, due to a postulated earthquake.

Q5. What is seismic modeling?

A5. By seismic modeling, I refer to the deterministic computer simulation of time histories of ground acceleration at specified locations near a postulated earthquake. Such simulation is distinguished from purely probabilisitic approaches to simulation, in that it is based on physical descriptions of both the faulting process and the propagation and dissipation of seismic energy in the site geologic structure.

Q6. What is the purpose of modeling?

A6. The purpose of modeling is to estimate the level and character of ground motion at particular sites due to an assumed earthquake, and to examine the sensitivity of estimated ground motion to reasonable variations in the earthquake and site parameters. The modeling procedures predict time histories of vertical and horizontal (both components) acceleration at the sites, from which quantities of design interest (e.g., peak acceleration, peak velocity, response spectral ordinates, duration) can be deduced.

Q7. What is the procedure for modeling strong ground motion?

A7. The faulting process is described for modeling purposes by stress drop, which has been widely estimated for earthquakes, and by fault location, orientation, and mode of slip, which are established for a given site on the basis of geologic mapping and geophysical surveys. Geological, geophysical and geotechnical data provide estimates of the required geologic structure parameters, which are the elastic and attenuative properties and densities of soil and rock layers at a site.

Two kinds of computer modeling are distinguishable, "dynamic" modeling and "kinematic" modeling. The former refers to simulation of the motion which occurs along the fault itself during an earthquake. That is, input to dynamic modeling consists of the initial and dynamic stresses acting along the fault, and the rupture process is then modeled to obtain the history of relative motion along the fault itself. In principle, site motion can also be obtained from dynamic model computation, but practical considerations generally dictate that the dynamic analysis be restricted to the immediate region of faulting.

Kinematic modeling simulates wave propagation from the fault to the site through a stratified geologic structure. This modeling procedure assumes that the history of relative motion is known at each point on the fault. The results of the modeling are complete time histories of predicted vertical and horizontal ground acceleration at specified locations in the near-field of the fault.

Q8. What is the relationship between the two kinds of modeling?

A8. The two kinds of modeling are actually complimentary. I have pointed out that dynamic modeling methods by themselves can be practically applied only to compute motion very near the fault itself. The kinematic methods are suited to computing ground motion at particular sites away from the fault, but require <u>a priori</u> specification of the time history of relative motion ("slip") at each point on the fault due to the earthquake. One approach is to use kinematic modeling, and to simply postulate

a form for these slip histories, guided by simplified physical assumptions, and then apply the kinematic modeling procedure to an actual earthquake and site for which strong motion recordings exist. Then, the postulated slip histories are modified to achieve agreement with the recorded data, and the modified slip is employed in the site-specific modeling.

An alternative approach is to use the slip histories obtained from dynamic modeling as the input slip histories to the kinematic modeling. The combined modeling approach is then applied to actual earthquakes and refined in accordance with the data by adjustment of the dynamic model parameters. This combination of dynamic and kinematic modeling removes the principal disadvantages of each, and, in my opinion, provides the most conclusive approach to computer modeling of strong ground motion.

Q9. Has strong motion modeling ever been done?

A9. The basic theoretical developments required for site-specific kinematic modeling, exemplified by the work of Haskell (1953) and de Hoop (1958), are now more than two decades old. Initially, the theoretical methods were applied primarily to synthesize relatively low-frequency components of seismic motion (up to about 1 Hz), using simple point-source representations of the seismic source. Simulation of the high-frequency components (1 to 10 Hz or more) of site-specific ground motion near a propagating fault, which are of interest to aseismic designers, awaited advancements in high-speed computing achieved in the 1960's and 1970's, and advances in numerical methods accomplished in the past three to four years, as exemplified by the

work of Apsel (1979). The requisite computational methods now exist and have been demonstrated.

Computer methods of dynamic modeling have evolved primarily from the one-and two-dimensional methods developed during the past three decades primarily to simulate explosive sources. Application to three-dimensional dynamic modeling of earthquakes has occurred during the past three to four years, and the work of Archuleta and Frazier (1978) and Day (1979), for example, demonstrate this capability and the work of Das and Richards (1979) represents an alternate method of dynamic earthquake modeling.

Site-specific kinematic earthquake modeling is currently being applied by Southern California Edison to the San Onofre Nuclear Generating Station site (Del Mar Technical Associates, 1978, 1979). In this instance, the Nuclear Regulatory Commission commissioned a dynamic modeling study as well, which was carried out by Systems, Science and Software (Day, 1979).

Q10. What are the benefits of modeling?

A10. If a great number of strong motion recordings currently existed for a wide range of site distances, earthquake magnitudes, and site geologic structures, then modeling would be redundant. However, near-field recordings of large earthquakes are very scarce. The modeling approach described provides a means toward (1) extracting maximum information from existing earthquake data, (2) applying that information to predict ground motion for geometric and geologic conditions for which adequate data do not exist, and (3) estimating the sensitivity of the prediction to uncertainties in the inputs.

Q11. Do data from the 1979 Imperial Valley earthquake assist in refining the computer modeling?

A11. The new data set from this event is an important asset in refining the computer modeling, since it represents the most extensive set of near-field recordings yet obtained from a single, large earthquake. The modeling of several recordings from a single event is particularly valuable in reducing uncertainty in the model inputs. Applying the modeling procedure to the circumstances of this event, and refining the model input to give predictions in reasonable accord with these recordings, will increase our confidence in the predictive capability of the modeling approach.

Q12. How long would it take to model strong ground motion at Diablo Canyon?

A12. I would anticipate that once the required data were assembled, six months to one year would be required to perform the strong motion study. Such a study would employ dynamic and kinematic methods using existing computer codes, and would include modeling of the 1979 Imperial Valley earthquake.

Q13. If one were attempting to predict ground motion at a particular site in the near field, such as at Diablo Canyon, do you believe modeling would be helpful?

A13. Yes. I believe modeling to be a helpful means toward extracting maximum information from a sparse near-field data set, applying that information to seismic environments for which data are inadequate, and estimating sensitivities to parameter uncertainties. Modeling establishes a physical basis for

extrapolating ground motion data to the circumstances at a particular site, providing a useful adjunct to the conventional empirical approach.

Professional Qualifications of Dr. Steven M. Day

PRESENT POSITION:

Staff Geophysicist
Systems, Science and Software
La Jolla, California

EDUCATION:

B.A. (Geological Sciences) University of Southern California, 1971

Ph.D. (Earth Sciences) University of California, San Diego, 1977

EXPERIENCE:

Dr. Day joined the Theoretical Geophysics Program at Systems, Science and Software in October, 1977. He is active in several areas of seismological research, including seismic source dynamics, wave propagation in inhomogeneous media and seismic response of nonlinear materials. His technical work in these areas involves the development and application of numerical modeling techniques. Recent work has been primarily in the investigation of earthquake dynamics, with emphasis on applications to the seismic discrimination of explosions from earthquakes and the prediction of earthquake strong ground motion.

He recently conducted a study of the effects of source nonlinearities on the seismic radiation from earthquakes. Other recent work has included the synthesis of teleseismic signals from complex, extended seismic sources, the numerical simulation of small-scale explosions and comparison to experimental data, the interpretation of free field seismic data from a nuclear explosion, and the numerical simulation of strike-slip faulting, including construction of synthetic strong motion seismograms for a stratified earth model. Dr. Day was also responsible for a study of local site response to earthquakes, which included numerical modeling of the nonlinear response of soils and comparison of theoretical ground motion simulations to strong motion data. Previously, Dr. Day developed extensions of the finite element method for analyzing three-dimensional elastodynamic problems, with applications to soil-structure interaction and seismic scattering problems.