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June 18, 2002

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Rules and Directives Branch
USNRC

John R. Tappert,
Acting Program Director,
License Renewal and Environmental Impacts,
Division of Regulatory Improvement Programs,
Office of Nuclear Reactor Regulation.

Good Afternoon,

I am Dr. Sam Augustine, a representative the University of Nebraska Medical Center (UNMC). I am a Board Certified Nuclear Pharmacist and an associate professor at the College of Pharmacy and the College of Medicine. I am also a member of the emergency response team of the Regional Radiation Health Center.

For over thirty years the Omaha Public Power District has proven to be a very good corporate partner with the UNMC. OPPD has supported and cofunded the Regional Radiation Health Center at UNMC. The purpose of the Radiation Health Center is to provide specialized medical services related to the evaluation, treatment, and management of individuals exposed to radioactive materials. Through OPPD's support of the Radiation Health Center, UNMC has been able to obtain state of the art radiation detection instrumentation. The Radiation Health Center, the Nuclear Medicine division of Nebraska Health System (NHS) and UNMC's Colleges of Medicine and Pharmacy are able to utilize this equipment for routine patient care and medical research whenever the facility and instrumentation are not being utilized for radiation accident patients. In fact, routine use of the instrumentation by UNMC and NHS is primarily how it is utilized. Among the list of instrumentation OPPD's support has contributed to includes a gamma camera which has been used for nuclear medicine imaging of patients, a high purity Germanium-

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Lithium detector used in research for analysis of radioactive samples, and various computers, radiation survey meters and personnel monitoring devices used in monitoring patients and equipment. Additionally, OPPD has participated, supported and helped coordinate full scale emergency exercises involving the actuation and implementation of the Radiation Health Center. In the August of 2001 evaluation of the Radiation Health Center the Federal Emergency Management Agency said that the Medical Center's staff is "extremely well-trained, and the equipment is excellent". We feel OPPD's support is a major contributor to the excellence of the Regional Radiation Health Center.

OPPD's emergency preparedness organization also provides considerable equipment, supplies, and training to various organizations in the surrounding vicinity. In addition to the State and County civil defense departments, OPPD has worked with local sheriff departments, fire departments, ambulance crews, schools, nursing homes, and others to ensure that these organizations can properly respond in emergency situations. OPPD has established reception centers for the evaluation and decontamination of members of the general public if an emergency should arise. Coordination with the American Red Cross at these centers has also been developed to provide housing to evacuated individuals if necessary. As a result the areas around the Fort Calhoun Station Emergency Planning Zone have developed a trained, well-coordinated emergency response organization that could be invaluable in any type of emergency situation.

We feel that OPPD is exemplary and committed member of our community.

DOCUMENTS SUBMITTED AT THE

FT. CALHOUN, UNIT 1
LICENSE RENEWAL PUBLIC ENVIRONMENTAL SCOPING MEETING

OMAHA, NEBRASKA

JUNE 18, 2002

DOCUMENTS SUBMITTED DURING THE JUNE 18, 2002
SCOPING MEETINGS REGARDING THE FORT CALHOUN STATION UNIT 1
LICENSE RENEWAL APPLICATION

The following documents were submitted during the June 18, 2002 scoping meetings regarding the Fort Calhoun Station, Unit 1 license renewal application. These documents can be downloaded from the NRC's web page (http://www.nrc.gov) through the NRC's document management system, ADAMS, under accession number ML021820453.

Cullen, S. et al. "Infant Deaths and Childhood Cancer Drop Dramatically after Nuclear Plants Close." Radiation and Public Health Project. Downloaded 6/26/02 from Internet site at http://www.radiation.org/closed.html.

Enron Wind Corporation. "Storm Lake - 193 MW Wind Power Generation Facility, Project Information." 1999.

Gould, J. et al. "Strontium-90 in Baby Teeth as a Factor in Early Childhood Cancer." International Journal of Health Services, Vol. 30, No. 3. Downloaded 6/18/02 from Internet site at http://www.radiation.org/ijhs092000.html.

LaForge, J. "A License to Kill? The Yucca Mountain Rad Waste Dump." Nukewatch Pathfinder. Winter 2000-2001.

Lochbaum, D. "Nuclear Plant Risk Studies: Failing the Grade." UCS, 2000.

"Reactors Kill." Eco-Mole.

UCS. "Aging Nuclear Plants and License Renewal - Updated 09/13/2001." September 13, 2001.

UCS. "Not-So-Happy Anniversary: 10 Years of Band-Aid Fixes for CRDM Nozzle Cracking." August 13, 2001.

Wasserman, H. "Nuclear Power and Terrorism." Earth Island Journal, Spring 2002, p. 37.

In addition to these documents, the copyrighted publication, "Powering the Midwest: Renewable Electricity for the Economy and the Environment." Brower, M. et al. UCS, 1993 was provided to the staff during the meeting. The report is not included in this package because it is copyrighted. The report may be obtained from UCS Publications, Two Brattle Square, Cambridge, MA 02238-9105, e-mail at pubs@ucsusa.org, or by calling (617) 547-5552.

Press Release

Embargoed until April 30, 2002 Contact: Scott Cullen, STAR: (516) 819-4886
Joseph Mangano, RPHP: (718) 857-9825
Kelly MacMillan (Brodsky): (914) 720-5206

INFANT DEATHS AND CHILDOOD CANCER DROP DRAMATICALLY AFTER NUCLEAR PLANTS CLOSE

Long-term health benefits provide another reason to end experiment with nuclear power

[New York, NY] - Dramatic declines in local infant death and childhood cancer rates occurred soon after the closing of eight nuclear power plants, according to a new report announced by New York State Assemblyman Richard Brodsky, Radiation and Public Health Project, and the STAR Foundation. **The study documents a 17.4% reduction in infant mortality in the downwind counties within 40 miles two years after reactor closing, compared to a national decline of just 6.4%.** Large declines occurred in all eight areas near closed reactors, and remained above national trends for at least six years after closing. The information appears as an article published in the March/April 2002 edition of *Archives of Environmental Health.*

"We finally have reliable peer-reviewed accurate data attaching the nuclear power plants to death and injury in the host communities, this is a sobering and significant scientific study and we all need to take it seriously," stated New York State Assemblyman Richard Brodsky. "It is critical that more studies of this type be performed, so that we fully understand the risks posed by nuclear reactors," added Westchester County legislator Thomas Abinanti.

"Nuclear power is a failed experiment that is expensive and dangerous," said Scott Cullen, Executive Director of STAR. "This study confirms the best of public health principles: that when you remove a known cause of illness, health improves," said Cullen. "What is gratifying about the research is that it showed childhood health measures increasing so dramatically and quickly after the reactors closed and provides good news that we can strive towards."

In three of the eight areas with available data, cancer diagnosed in children less than five years of age declined 25.0% in the seven years after reactor closing, compared to a 0.3% increase nationally. Children exposed to radiation are of increased risk for cancer, says Joseph Mangano, MPH MBA, the principal author of the study who is affiliated with the New York research group Radiation and Public Health Project.

This study is most relevant to New York City because over 8% of the nation's population lives within 50 miles of the Indian Point reactor. Counties downwind and within 40 miles of Indian Point include the Bronx, Dutchess, Manhattan, Nassau, Putnam, Queens, and Westchester in New York, and Fairfield County in Connecticut. Over 8.5 million persons live in these counties, where 110,000 babies are born each year.

DECREASE IN INFANT DEATH RATE TWO YEARS BEFORE vs. TWO YEARS AFTER CLOSING OF NUCLEAR REACTOR DOWNWIND COUNTIES

Joseph J. Mangano, Radiation and Public Health Project

CLOSED PERMANENTLY		
REACTOR	YEAR CLOSED	PERCENT CHANGE
LaCrosse, WI	1987	-15.4
Rancho Seco, CA	1989	-16.0
Fort St. Vrain, CO	1989	-15.4
Trojan, OR	1992	-17.9
Big Rock Point, MI	1997	-42.4
Maine Yankee, ME	1997	- 9.3
CLOSED TEMPORARILY (AT LEAST TWO YEARS)		
REACTOR	YEAR CLOSED	PERCENT CHANGE
Pilgrim, MA	1986	-24.3
Millstone, CT	1995	-17.4
TOTAL 8 AREAS		-17.4
U.S. AVERAGE CHANGE	1986-1998	-6.4

Notes:
1. Infant death rate = deaths under age one per 1,000 live births
2. Includes counties located downwind and within 40 miles of closed reactors
3. "Before" period = year before and year of closing
4. After reactor closing, nearest operating reactor is at least 70 miles away
5. Source: National Center for Health Statistics (www.cdc.gov)

Storm Lake – 193 MW Wind Power Generation Facility

Project Information

1999
Celebrate the Wind

- ***Power Purchasers***

  MidAmerican Energy Company - Headquartered in Des Moines, Iowa. In March 1997 Enron Wind Development Corporation (EWDC), a subsidiary of Enron Wind Corp., entered into a long-term agreement with MidAmerican to provide 113 MW of clean, wind generated capacity to the MidAmerican grid.

  IES Utilities, a subsidiary of Alliant Energy - Headquartered in Cedar Rapids, Iowa. In July 1997, EWDC also entered into an agreement with IES Utilities to provide IES with 80 MW of wind generated capacity.

- ***Project Developer, Owner and Operator***

  Subsidiaries of Enron Wind Corp. developed, constructed, own and operate the Storm Lake project. A pioneer and leader in the wind industry since 1980, Enron Wind is a vertically integrated company. The company has developed and constructed over 4,000 wind turbines, comprising more than 1,200 MW. Enron Wind's manufacturing entities, Zond Energy Systems, Inc., in Tehachapi, California, and Tacke Windenergie GmbH, in Salzbergen, Germany, develop and manufacture state-of-the-art wind turbine technology ranging from 550 kW to 2.0 MW.

- ***Project Location***

  Northwestern Iowa, in Buena Vista and Cherokee counties near the community of Alta.

- ***Power Purchase Agreement***

  Signed: March 1997/July 1997
  Term: 20 Years
  Power Capacity: 193 MW (the single largest wind power ject in the world today)
  Annual Generation: approximately 650,000 megawatt hours per year
  # Wind Turbines: 257

- ***Technology***

  Manufacturer: Zond Energy Systems, Inc., a subsidiary of Enron Wind Corp.
  Wind Turbine Type: Zond Z-750 kW Series

  Zond's Z-750 kW Series wind turbines utilize a variable speed, constant frequency configuration providing selectable power factor, improving power quality and increasing the aerodynamic efficiency of the turbines while reducing mechanical loads. The Z-750 is the largest wind turbine manufactured in the United States.

  The project's Z-750 kW wind turbines hold certification by Germanischer Lloyd to IEC Class II for a 30 year fatigue life. IEC Class II requires a wind turbine to withstand hurricane loads of up to 131.1 mph (59.5 meters per second) as a once in a 50 year occurrence, and 99.8 mph (44.6 meters per second) as a yearly occurrence.

  Rated Output: 750 kW

  Foundation:
  Each wind turbine foundation consists of four individually drilled caissons - 5 ft. in diameter and 35 ft. deep.
  Footprint: 40' x 40' - spaced 1 - 2,000 feet apart
  Concrete: 200 tons per foundation (51,400 tons to complete all 257 foundations, or 3060 full concrete truckloads - enough to make a 3' x 3" sidewalk approximately 157 miles long.)
  nforcement: 5 tons per foundation (1,285 tons to complete all 257 foundations)

  Tower: Lattice Configuration
  Height: 208 feet (63 meters) - 12 ft. at base tapering to 8 feet at the top.
  Weight: 57 tons (114,000 lbs.)

Storm Lake – 193 MW Wind Power Generation Facility

Project Information

1999 *Celebrate the Wind*

- *Technology (continued)*

  Blades:
  Length: 79 ft. (24 meters)
  Rotor Diameter: 164 ft. ft. (50 meters) – approximately the size of the wingspan of a MD-11 jumbo jet
  Revolutions per minute: 18-34 (one revolution every 2-3 seconds)

  Swept Area: 21,124 sq. feet per turbine or approximately 5.5 million sq. feet for the two projects combined. To capture the same area of wind, it would take the equivalent of a sailing ship the size of the SuperBowl stadium with a mast over half a mile high.

- *Construction*

  Groundbreaking: October 1998
  Completion: June 1999

  Schedule:
  September 1998 - Grading of roads, turbine pads and foundations began. Collection system lines were placed underground in the farm fields and overhead on poles near roads. Substation was constructed. Turbines and towers began arriving at the site and erection activities began.

  January 1999 - Substation was completed and erected turbines began to be placed on line - turbine erection activities continued.

  June 1999 - Project completed

- *Environmental Benefits:*

  The installation will provide enough electricity to serve approximately 72,000 average Midwestern households, or 192,000 people. If coal were burned to generate the same amount of electricity, over 301,000 tons per year would be required.*

  Annual Offsets:
  The 257 Zond 750 kW wind turbines can be expected to offset 1 billion pounds (502,000 tons) of carbon dioxide, the leading greenhouse gas associated with global warming, based on U.S. average fuel mix. Other emissions offsets include: 5.2 million pounds (2,600 tons) of sulfur dioxide - the major cause of acid rain, pollution of waterways, and air-born particulate pollution; and 3.4 million pounds (1,700 tons) of nitrous oxide.

  Jobs Created:
  Construction Jobs: 150
  Ongoing O&M Jobs: 20-30

* Information provided by the American Wind Energy Association

Enron Wind Corp. ENRON

STRONTIUM-90 IN BABY TEETH AS A FACTOR IN EARLY CHILDHOOD CANCER

Jay M. Gould, Ernest J. Sternglass, Janette D. Sherman,
Jerry Brown, William McDonnell, Joseph J. Mangano

International Journal of Health Services
Volume 30, Number 3, Pages 515-539, 2000

Note: This is the draft of the article.

Abstract

Strontium-90 concentrations in baby teeth of 515 children born mainly after the end of worldwide atmospheric nuclear bomb tests in 1980 are found to equal the level in children born during atmospheric tests in the late 1950s. Recent concentrations in the New York-New Jersey-Long Island Metropolitan area have exceeded the expected downward trend seen in both baby teeth and adult bone after the 1963 ban on atmospheric testing. Sharp rises and declines are also seen in Miami, Florida. In Suffolk County, Long Island, Strontium-90 concentrations in baby teeth were significantly correlated with cancer incidence for children 0 to 4 years of age. A similar correlation of childhood malignancies with the rise and decline of Strontium-90 in deciduous teeth occurred during the peak years of fallout in the 1950s and 1960s. Independent support for the relation of nuclear releases and childhood cancer is provided by a significant correlation with total alpha and beta activities in local surface water in Suffolk County. These results strongly support a major role of nuclear reactor releases in the recent increase of cancer and other immune system related disorders in young American children since the early 1980s.

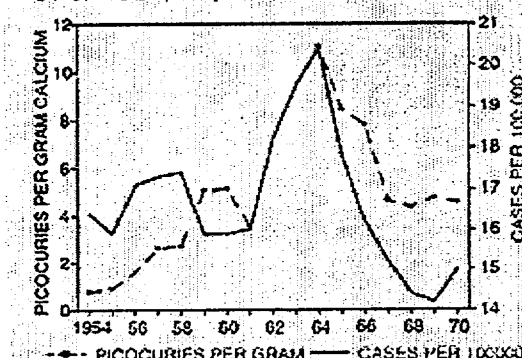
Introduction

In 1954, three years after the initial atmospheric nuclear weapons tests in Nevada, U.S. public health officials began monitoring levels of in vivo radioactivity. (1) (2) (3) Programs focused on measuring Sr-90 in human bone and teeth because of the known biochemical actions and physical behavior of this radioisotope, along with the feasibility of measuring Sr-90, years after it enters the human body due to its long physical half-life (28.7 years). Between 1954 and 1982, the U.S. Atomic Energy Commission (AEC) measured Sr-90 concentrations in the vertebrae of healthy adults who died in accidents in New York City, Chicago, and San Francisco, and also calculated dietary uptake of Sr-90 of adults during this period. (3) From 1962 to 1971, the U.S. Public Health Service's Bureau of Radiological Health operated a program measuring Sr-90 concentrations in vertebrae and ribs of deceased persons under 25 years of age in 34 U.S. locations. (4)

From 1954 to 1964, average picocuries of Sr-90 per gram calcium in the vertebrae of New York adults rose from under 0.1 to 2.2, more than a twenty-fold increase. The estimated dietary uptake of Sr-90 in adults rose thirty-fold, from 1 picocurie per gram of calcium in 1954 to 29.8 in 1964. The 1964 peak in Sr-90 concentration occurred just after ratification of the Partial Test Ban Treaty by the U.S. that ended American, British, and Soviet atmospheric nuclear weapons tests, while a relatively small number of French and Chinese tests continued. (Underground tests replaced atmospheric tests in the nations that signed the treaty). Thereafter, levels in New York and San Francisco declined sharply after the cessation of testing above ground. In the years 1964-70, dietary uptake of Sr-90 in adults declined on average by 15.7 percent each year. The Public Health Service's data show a similar increase and decline before and after the peak of 1964. Federal support for this effort was withdrawn in 1971.

The U.S. government also participated in a study measuring Sr-90 concentrations in the baby teeth of about 60,000 children by the St. Louis-based Committee for Nuclear Information (CNI) begun in 1958. The use of baby teeth made it simple to collect large samples, rather than relying on autopsy results. (5) The baby tooth analysis showed a rise from 0.77 pCi Sr-90/g Ca for 1954 births to a peak of 11.03 for 1964 births, just after the Test Ban Treaty. (6) From 1964 to 1970, Sr-90 in St. Louis baby teeth fell by more than half (Figure 1), about the same average annual rate of decline (15.7 percent) displayed by adult uptake in those years (Figure 2). One exception to this pattern took place from 1958 to 1961, when the U.S. and U.S.S.R. observed a voluntary moratorium on nuclear testing.

Figure 1



Sr-90 Concentration in Baby Teeth, St. Louis vs. Cancer Incidence Age 0-4, Connecticut 1954-1970
* Connecticut cancer rates represent 3-year moving averages

In the early 1950s, average concentrations of Sr-90 in teeth increased moderately, but began to rise more rapidly after 1954 with the sharp elevation of Sr-90 from thermonuclear bomb tests, the fallout from which ascended into the stratosphere and returned to earth via precipitation over a two or three year period. After the moratorium that began in late 1958, atomic and hydrogen bomb tests were resumed in the fall of 1961, with the detonation of a 50 megaton bomb by the U.S.S.R. in northern Siberia, equal to more than 3000 Hiroshima bombs. (7)

Trends in Sr-90 in baby teeth from 1960 to 1970 are significantly correlated (r = .78, P<.001) with temporal changes in cancer incidence among children age 0-4 (each year actually represents a three year moving average) in Connecticut, the only state with an established tumor registry during this period. Because trends in Sr-90 concentrations in St. Louis milk are similar to those in Hartford, Connecticut and elsewhere in the U.S.. (8) similar temporal changes of radioactivity in teeth can be assumed for the entire nation. Childhood cancer in Connecticut reached a peak in 1964, before plummeting in the latter half of the 1960s. The CNI study ended in the early 1970s, when federal support for the project ceased.

The high correlation between radioactivity in baby teeth and cancer in young children in the period 1954-70 is paralleled by a similar relationship with the adult dietary uptake of Sr-90 as estimated by the U.S. Department of Energy, the successor to the AEC, from 1954 to 1982. (3)

In Figure 2 the correlation coefficient between childhood cancer and adult dietary uptake of Sr-90 is .79 (P<.001) for the years 1960 to 1970. the period when the latter indicator reflected the high Sr-90 levels in the diets of pregnant women.

Both Figures 1 and 2 support the well-known fact that exposure to toxic agents is most harmful to the developing embryo and fetus, both in humans and in animals. Throughout intrauterine life, the developing fetus undergoes rapid cell growth, self-programmed cell death (apoptosis), and cell rearrangement. The developing infant is similarly susceptible to cellular and metabolic damage. Unrepaired damage to the rapidly growing and re-arranging fetal cells becomes magnified with time, increasing the risk of cancer, congenital malformations, underweight births, brain damage, and fetal/infant deaths. (9)

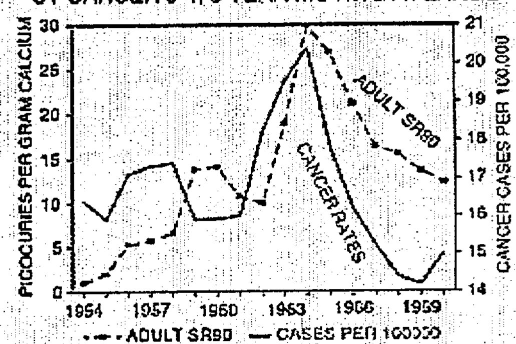
At ten weeks of development when the fetus is a little over 1.5 inches in length, the enamel organs and dental papillae form. Some formation begins two weeks earlier. (10) Stem cells of hematopoietic system originate in the bone marrow at about 12 weeks of prenatal development, (11) giving rise to the B-lymphocytes whose progeny make humeral antibodies, and the T-lymphocytes involved in cellular immune responses. (12)

Fetuses can be harmed by very low dose radiation, first demonstrated in the 1950s when exposure to pelvic X-rays in utero was linked with elevated levels of leukemia and cancer deaths before age ten. (13) (14)

U.S. health officials have not monitored radioactivity in humans since 1982. Moreover, the Environmental Protection Agency (EPA) program of reporting barium-140, cesium-137, and iodine-131 in pasteurized milk for each of 60 U.S. cities ceased in 1990 after 33 years of operation. (15) While the last worldwide atmospheric weapons test was detonated in China in 1980, the presence of nuclear power reactors has grown in the past two decades. From 1982 to 1991, the number of operating U.S. reactors increased from 72 to 111, providing power in 32 of 50 states (in which 85% of the 1990 U.S. population resides), and electricity generation by these plants increased from 278,000 to 613,000 gigawatt hours, before leveling off in the 1990s. (16) During this period, cancer incidence in 11 U.S. states and cities rose 40.4% for children age 0-4, and 53.7% for those under one year, a time when average levels of Cs-137 and I-131 doubled. (17)

Continuing measurements of *in vivo* radioactivity in other nations have revealed unexpected and significant trends. West German researchers documented a ten-fold

Figure 2
SR-90 ADULT DIETARY INTAKE, 1954-70
CT CANCER 0-4, 3 YEAR MOVING AVERAGE



Sr-90 Adult Dietary Uptake, New York City vs. Cancer Incidence Age 0-4, Connecticut 1954-1970
* Connecticut cancer rates represent 3-year moving averages

increase in Sr-90 in baby teeth for children born in 1987 compared to those born in 1983-85, due to fallout from the Chernobyl accident, a relative increase comparable to that observed in St. Louis from 1954-64. (18)

Without a system of monitoring the presence of key radioactive isotopes such as Sr-90 in the human body, no definitive assessment of health effects of exposure to man-made radioactivity can be made. The average annual decline in adult Sr-90 uptake after 1970 was only about five percent, as compared with the 15.7 percent annual decline in Sr-90 uptake levels in adults from 1964-70 (3), reflecting perhaps the proliferation of large nuclear power reactors in the 1970s and emissions from flawed underground tests. Cancer incidence age 0 to 4 in Connecticut - a small state with four operating nuclear reactors - which was as low as 14.42 per 100,000 in the late 1960s, had reached 21.95 per 100,000 in the late 1980s, a jump of over 52%. (19)

This trend suggests that additional recent data on in vivo radioactivity in the U.S. are needed, particularly in the light of the puzzling decision of the DOE to terminate measures of Sr-90 in adults in 1982. In that year, dietary levels of the Sr-90 uptake remained at the same level of 5.6 pCi/g Ca as in 1981, comparable to the late 1950s. The last DOE report observed "There has been some indication of slightly higher values for young adults during the last several years. These individuals were children during the period of greatest Sr-90 deposition." One might presume from this statement that adult Sr-90 levels would rise in the 1980s and 1990s as baby boomers account for increasing proportions of the adult population and as an increasing number of nuclear power plants came on line. (3)

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NUKEWATCH PATHFINDER
WINTER 2000-2001

A License to Kill? The Yucca Mountain Rad Waste Dump

By John LaForge

The Energy Department's Yucca Mountain nuclear waste plan—for "permanent" burial of irradiated nuclear reactor fuel, 100 miles from Las Vegas, Nevada—is ill-conceived, ill-managed and can no longer be defended on scientific grounds. Federal Environmental Protection Agency standards now in place merely hope to limit the dump's release of radiation to levels that will cause 1,000 cancer deaths over 10,000 years. Because the EPA cannot possibly meet these reckless standards, the plan would be a license to kill.

The 1982 Nuclear Waste Policy Act set standards that must be met before the Yucca Mt. site can be licensed to receive at least 77,000 tons of high-level radioactive waste created annually by nuclear power reactors and Pentagon bomb-builders. The water table is only 700 feet below the base of the proposed repository. The Yucca Mountain site, on Western Shoshone land, does not meet the original criteria for a deep geologic repository; the geology of this site cannot prevent waste from leaking into the surrounding environment.

In a 1998 study, the DOE itself acknowledged that the site is a fractured, leaky mountain plagued by earthquakes, and that its proposed waste containers have a badly limited viability. These facts flatly disqualify the site. As Mary Olson of Nuclear Information and Resource Service says, "Yucca Mountain is a sieve."

When the Senate failed to override the waste bill vetoed by President Clinton on April 26, Majority Leader Lott used a parliamentary trick that allows the Senate to reconsider it, so the fight isn't over.

The bill (amendments to the 1982 Act) would have started the process of sending 35,000 to 100,000 shipments of waste aboard trucks and trains through 43 states for 25 years. The DOE itself estimated that between 70 and 310 transportation accidents can be expected during this time, according to the Snake River Alliance. The proposed transit routes go through 109 major cities. That's why the waste bill's been dubbed "Mobile Chernobyl." At least 138 million Americans would be exposed to the risk of dangerous levels of radiation. Dept. of Transportation and NRC regulations allow containers at their surface to emit 100 millirems per hour (equal to the allowable public dose for an entire year). The nuclear industry sees the possible disqualification of the Yucca Mt. dump as a threat to operating reactors, whose sites are being clogged with waste. The industry has aimed its waste at the tiny Goshute Nation in Skull Valley, Utah. The Goshute Reservation has 124 enrolled members. A group of eight utilities led by Excel Energy Inc., of Minn. (formerly Northern States Power) is seeking a license for an open-air "condo" for 40,000 tons of its irradiated fuel. Excel's plan would make the nuclear consortium the slumlord, while U.S. tax payers would cough up the waste's moving fee and rent—and inherit all the material's liability. The proposed "interim" dump would park the waste in Utah until the DOE approves a "permanent" site. Green Party Vice Presidential candidate Winona LaDuke has said of the plan, "This is what 'the best minds in science' have devised for dealing with radioactive waste: truck it along U.S. highways to a spot in Utah, 19 miles down a dirt road and leave it on Indian land."

In November Utah's Governor Michael Leavitt attacked Excel Energy's claim that support for the Goshute dump is growing. "Not only is there opposition," Leavitt wrote, "but it's statewide, it's deep and it's heartfelt. And we're going to fight it by every means possible: legal, political, legislative and environmental." Excel Energy replied that nuclear utilities have an "unparalleled safety record," but Leavitt shot back: "If it's so safe, why don't we just keep it where it is?"

Indeed, the DOE's "interim," and "permanent" plans do not address the nuclear waste problem; they merely transfer the risk to the states of Nevada and Utah—and to communities along transit routes scheduled for thousands of shipments.

An August 1999 DOE report found that leaving the waste where it is—at 72 commercial reactor sites—is as safe as its Yucca Mt. plan, as long as the waste is repackaged every 100 years. According to epidemiologist Rosalie Bertell, the waste must be repackaged every 20 years to ensure it doesn't disperse to the ecosphere. Given the uncertainties about Yucca Mt. and the enormous risks of transporting the waste, it's essential to leave the irradiated fuel at the power reactors where it's produced, says the Nuclear Information and Resource Service, while developing above ground, perpetually monitored storage systems.

Yucca Mt. in trouble

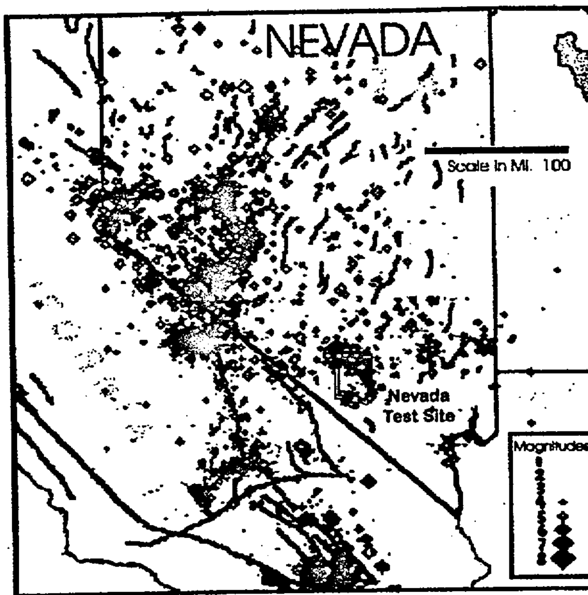
- Aug. 10, 1999: "That would mean hot underground water has invaded the mountain and might again in the time when radioactive waste would still be extremely dangerous. The results would be catastrophic..." Evidence that the inside of the mountain is periodically flooded with water comes from zircon crystals found in calcite veins. "Crystals do not form without complete immersion in water," says Jerry Szymanski, a former DOE geologist whose suggestion that deep water rises and falls inside Yucca Mt. is shrugged off by the DOE.
- March 27, 1998: The Yucca Mt. site may have an earthquake or lava flow every 1,000 years—ten times more frequently than earlier estimated—according to a California Institute of Technology study. The finding means that radiation catastrophes at the Yucca Mt. site are much more likely during the proposed 10,000-year lifetime of the dump—not to mention the 250,000-year-long radioactive hazard period.
- June 20, 1997: DOE researchers have found that rain water has seeped from the top of Yucca Mt. 800 feet into the repository level in a mere 40 years (as dated by chlorine-36). Scientists had said that rainwater would take hundreds or thousands of years to reach the waste cans. Federal guidelines have long required that the existence of fast-flowing water would disqualify the site.
- March 5, 1995: Physicists at Los Alamos dropped a bomb on the Yucca plan, finding that buried wastes might erupt in a nuclear explosion, scattering radioactivity to the winds or ground water or both. Dr.s Charles D. Bowman and Francesco Venneri charged that serious dangers will arise thousands of years from now after steel waste containers dissolve and plutonium slowly begins to disperse into surrounding rock. "We think there's a generic problem with putting fissile materials underground," Bowman said. "So serious a dispute so late in the planning process might cripple the plan or even kill it," the *New York Times* reported.
- July 19, 1990: The National Research Council said the plan for Yucca Mt. is "bound to fail" because it is "a scientific impossibility" to build an underground nuclear waste repository that will be safe for 10,000 years.
- 1989: Sixteen geologists at the U.S. Geologic Survey bluntly charged that the DOE was using stop-work orders to prevent the discovery of problems that would doom the repository. The USGS geologists reported that "There is no facility for trial and error, for genuine research, for innovation, or for creativity." Even the Nuclear Regulatory Commission complained that work at Yucca Mt. seems designed mostly to get the repository built rather than to determine if the site is suitable.
- 1983: The National Academy of Sciences noted that the chemical characteristics of water at Yucca Mt. are such that the wastes would dissolve more easily than at most other places.

****

While plutonium-239 in waste fuel is radioactive and deadly for essentially all time, *New York Times* science writer Matthew L. Wald has lately been understating the duration of its toxicity. "The waste . . . is the most concentrated and dangerous [from electric utilities], and some of it remains radioactive for millions of years," Wald reported 11 years ago. In February 1989, Wald wrote, "Though the wastes that would go into the site would be hazardous for millions of years, predictions are limited to 10,000 years." In 1997 Wald reported, "The wastes would be dangerously radioactive for hundreds of thousands of years...and would most likely reach humans through water, flowing underground through the wastes and eventually reaching the surface through springs or wells."

DOE scientists know that the steel canisters will dissolve long before the health and environmental hazards are vented into the underground dump. Their design envisions a mere 10,000-year life span for the dump. Because of the long-lived cancer dangers of radioactive wastes, testing of the whole project is impossible. The largest radiation exposures will not occur until hundreds or thousands of years into the future, so mere "testing of components would require a time machine," says Dr. R. Darryl Banks, biophysicist at World Resources Institute in Washington.

Carl Gertz, a manager of the Nevada Nuclear Waste Storage Investigations Project, told William Kittredge of *Harpers* Magazine in 1988, "This whole thing is an experiment, conducted under public scrutiny, according to law." But, as Kittredge asked, an experiment upon what, and upon whom?



Nevada and California earthquakes: A graph—with 75,794 seismic events through 1992 registered by the University of Nevada, Reno Seismological Laboratory, the U.S. Geological Survey, and the California Institute of Technology—shows so many earthquakes they cannot be individually distinguished.

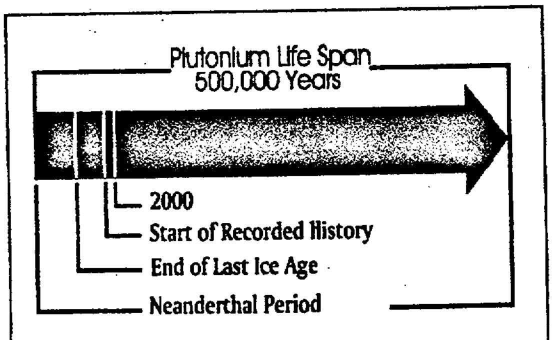
A faulty idea

Earthquakes have regularly rattled Yucca Mountain providing reason enough to end consideration of the area for radioactive waste storage. Seismologists now estimate that the area is ten times more seismically active than earlier estimated, according to a California Institute of Technology study. Three earthquakes last January at the Nevada Test Site were, "another serious warning about instability at the Yucca Mountain site," said U.S. Rep. Jim Gibbons of Nevada.

According to the Nevada Nuclear Waste Project Office, the Sundance fault at Yucca Mountain is a minimum of 700 feet wide with six sub-faults. It is believed that the Sundance fault intersects the Ghost Dance fault, which runs through the middle of Yucca Mountain and is about 840 feet wide. There are 33 known earthquake faults in the Yucca Mountain area.

Recently, quakes have struck the area Jan. 27, 1999; Sept. 17, 1996; and Sept. 20, 1995. —*JL*

Further Reading: "Management of Highly Radioactive Wastes in the U.S.," in *Science for Democratic Action*, Institute for Energy & Environmental Research, May 1999. (Free from IEER—see Resources, p.5)



Nuclear Plant Risk Studies

Failing the Grade

DAVID LOCHBAUM

August 2000
Union of Concerned Scientists

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The Union of Concerned Scientists is a partnership of citizens and scientists working to preserve our health, protect our safety, and enhance our quality of life. Since 1969, we've used rigorous scientific analysis, innovative policy development, and tenacious citizen advocacy to advance practical solutions for the environment.

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Executive Summary

An accident at a US nuclear power plant could kill more people than were killed by the atomic bomb dropped on Nagasaki.[1] The financial repercussions could also be catastrophic. The 1986 accident at the Chernobyl nuclear plant cost the former Soviet Union more than three times the economical benefits accrued from the operation of every other Soviet nuclear power plant operated between 1954 and 1990.[2]

But consequences alone do not define risk. The probability of an accident is equally important. When consequences are very high, as they are from nuclear plant accidents, prudent risk management dictates that probabilities be kept very low. The Nuclear Regulatory Commission (NRC) attempts to limit the risk to the public from nuclear plant operation to less than 1 percent of the risk the public faces from other accidents.

The Union of Concerned Scientists (UCS) examined how nuclear plant risk assessments are performed and how their results are used. We concluded that the risk assessments are seriously flawed and their results are being used inappropriately to increase—not reduce—the threat to the American public.

Nuclear plant risk assessments are really not risk assessments because potential accident consequences are not evaluated. They merely examine accident probabilities—only half of the risk equation. Moreover, the accident probability calculations are seriously flawed. They rely on assumptions that contradict actual operating experience:

- The risk assessments assume nuclear plants always conform with safety requirements, yet each year more than a thousand violations are reported.
- Plants are assumed to have no design problems even though hundreds are reported every year.
- Aging is assumed to result in no damage, despite evidence that aging materials killed four workers.
- Reactor pressure vessels are assumed to be fail-proof, even though embrittlement forced the Yankee Rowe nuclear plant to shut down.
- The risk assessments assume that plant workers are far less likely to make mistakes than actual operating experience demonstrates.

1. US House of Representatives, Committee on Interior and Insular Affairs Subcommittee on Oversight & Investigations, "Calculation of Reactor Accident Consequences (CRAC2) for US Nuclear Power Plants (Health Effects and Costs) Conditional on an 'SST1' Release," November 1, 1982; and Nuclear Regulatory Commission, "A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants," NUREG/CR-6451, Washington, D.C., August 1997.

2. Richard L. Hudson, "Cost of Chernobyl Nuclear Disaster Soars in New Study," *Wall Street Journal*, March 29, 1990.

- The risk assessments consider only the threat from damage to the reactor core despite the fact that irradiated fuel in the spent fuel pools represents a serious health hazard.

The results from these unrealistic calculations are therefore overly optimistic.

Furthermore, the NRC requires plant owners to perform the calculations, but fails to establish minimum standards for the accident probability calculations. Thus, the reported probabilities vary widely for virtually identical plant designs. Four case studies clearly illustrate the problem:

- The Wolf Creek plant in Kansas and the Callaway plant in Missouri were built as identical twins, sharing the same standardized Westinghouse design. But some events at Callaway are reported to be 10 to 20 times more likely to lead to reactor core damage than the same events at Wolf Creek.

- The Indian Point 2 and 3 plants share the same Westinghouse design and sit side by side in New York, but are operated by different owners. On paper, Indian Point 3 is more than 25 percent more likely to experience an accident than her sister plant.

- The Sequoyah and Watts Bar nuclear plants in Tennessee share the same Westinghouse design. Both are operated by the same owner. The newer plant, Watts Bar, was originally calculated to be about 13 times more likely to have an accident than her sister plant. After some recalculations, Watts Bar is now only twice as likely to have an accident.

- Nuclear plants designed by General Electric are equipped with a backup system to shut down the reactor in case the normal system of control rods fails. On paper, that backup system is highly reliable. Actual experience, however, shows that it has not been nearly as reliable as the risk assessments claim.

To make matters worse, the NRC is allowing plant owners to further increase risks by cutting back on tests and inspections of safety equipment. The NRC approves these reductions based on the results from incomplete and inaccurate accident probability assessments.

UCS recommends that the NRC immediately stop cutting safety margins and postpone any further cuts until the faults in the probability assessments are corrected. The US Congress must provide the NRC with the budget it needs to restore the safety margins at America's nuclear power plants.

Nuclear Plant Risk Studies

Failing the Grade

Section 1: Introduction

There is a risk in the use of safety goals in nuclear regulation—and in one sense it cost us the Three Mile Island accident to learn that the risk is real. The nuclear community got hung up on the safety-goal application of probabilistic risk analysis (PRA) at the expense of valid risk management applications, which had anticipated a TMI-type event.

—Robert M. Bernero, Nuclear Regulatory Commission, 1983

The Nuclear Regulatory Commission (NRC) uses rules and regulations to manage nuclear plant risks. The objectives of the rules and regulations are to reduce the chance that a nuclear accident will occur, minimize the severity of an accident, and protect the public from radiation released during an accident. Recognizing that its rules and regulations do not guarantee zero risk, the NRC has defined acceptable risk:

> (1) The risk of an immediate fatality to an average individual in the vicinity of a nuclear power plant that might result from reactor accidents should not exceed 0.1% of the sum of the immediate fatality risks that result from other accidents to which the US population is generally exposed and (2) the risk of cancer fatalities to the population near a nuclear power plant should not exceed 0.1% of the sum of cancer fatality risks from all other causes.[1]

Data on immediate fatality risks from non-nuclear causes are readily available. For example, the federal government releases annual reports detailing the number of Americans dying due to diseases, suicides, homicides, and accidents.[2] No Americans other than workers have yet experienced immediate fatalities from nuclear plant accidents.[3]

The lack of previous immediate fatalities does not correspond to zero risk because a nuclear plant accident can cause hundreds, perhaps thousands, of immediate fatalities. As Bernero observes in the epigraph, "the risk is real." Governmental studies estimate that more people could be killed by a nuclear plant accident than were killed by the atomic bomb dropped on Nagasaki.[4]

When the NRC learns that a nuclear plant does not meet federal safety regulations, it relies on

1. Nuclear Regulatory Commission, "TIP: 12—Nuclear Reactor Risk," Washington, D.C., September 1999.

2. Donna L. Hoyert, Kenneth D. Kochanek, and Sherry L. Murphy, "Deaths: Final Data for 1997," Atlanta, Ga.: Centers for Disease Control and Prevention, June 30, 1999.

3. *Immediate fatalities* is used because it has been alleged that the Three Mile Island accident in 1979 caused cancer-related deaths years later. The courts are still processing this allegation.

4. US House of Representatives, Committee on Interior and Insular Affairs Subcommittee on Oversight & Investigations, "Calculation of Reactor Accident Consequences (CRAC2) for US Nuclear Power Plants (Health Effects and Costs) Conditional on an 'SST1' Release," November 1, 1982; and Nuclear Regulatory Commission, "A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants," NUREG/CR-6451, Washington, D.C., August 1997.

the calculated accident probabilities to assess the risk. The NRC's risk assessment could conclude that the plant must be immediately shut down for repairs. Most often, the NRC decides that the risk is not great enough to require immediate shutdown, so the plant owner is allowed to wait until the next scheduled opportunity to make the necessary repairs. In addition, the NRC—under constant pressure from the nuclear industry—has recently accepted a concept of "risk-informed regulation," in which many safety regulations are eliminated and the scope of other regulations is significantly reduced based on the results of risk assessments. A critical question, then, is whether risk assessments are accurate enough to rely on for these purposes.

This report examines nuclear power plant risk assessments and how their results are being used. Section 2 provides background on risk and describes the relationship of the key factors—probability and consequences—used in risk assessments. Section 3 discusses the safety studies the NRC required each plant owner to prepare and explains why these studies are probability, and not risk, assessments. Section 4 highlights flawed assumptions used in the probability assessments that make their results inaccurate. Case studies, presented in section 5, illustrate how the defective assessment process can lead to grossly inaccurate results. Section 6 outlines the material that has been neglected in the so-called risk assessments; namely, the consequences of nuclear plant accidents. This section also details how, because consequences are neglected, the accident probabilities are not low enough to meet the level of acceptable risk set by the NRC. Section 7 synthesizes this information and explains when the NRC's assessments can, and more importantly cannot, be used to make decisions about public health. The final section recommends actions the NRC should take to improve the quality of plant safety assessments and measures the US Congress should adopt to permit the NRC to efficiently do what is needed.

Section 2: Risk Assessment Basics

The values to society of risks and benefits, as perceived by the people in that society, are not the sums of the values to the individuals affected. The catastrophe that kills 1000 people at a whack is perceived as far more threatening—that is, it has far larger negative value—than 1000 single-fatality auto wrecks.

—Stephen H. Hanauer, Nuclear Regulatory Commission, 1975

Risk is defined as "the potential for realization of unwanted, adverse consequences to human life, health, property, or the environment; estimation of risk is usually based on the expected value of the conditional probability of the event occurring times the consequences of the event given that it has occurred."[5] To put some flesh on the bones of this definition, consider an event that occurs, on average, once a decade and injures 40 people when it happens. Consider another event that happens every other year, but injures only 8 people each time.

Let's say that you could spend a million dollars and totally eliminate the chance of one of these events occurring again. Faced with this decision, you want to spend the money where it will do the most good. Would you eliminate the first event because it injures 40 people as opposed to just 8 people? Or would you eliminate the second event because it happens more often?

In this case, you can't lose. The elimination of either event prevents it from injuring an average of 4 people each year:

- 1 event every 10 years injuring 40 people per event averages 4 injuries per year
- 1 event every 2 years injuring 8 people per event averages 4 injuries per year

These two events have exactly the same risk even though they have different probabilities and different consequences. But what if the second event injured 10 people each time it happened instead of only 8?

- 1 event every 2 years injuring 10 people per event averages 5 injuries per year

It might be tempting to spend the money on the first event because it causes 40 injuries, but it would now be wiser to eliminate the second event because it ultimately injures more people and thus poses greater risk. This exercise shows how critical it is, when evaluating risk, to consider both the probability of an event and the consequences from that event.

But as the epigraph points out, society demands extra protection when it comes to events with high consequences. The airline industry must constantly seek to minimize the probabilities of crashes even though air travel is—on paper—safer than automobile travel. And few technological disasters have higher consequences than a nuclear power plant accident. The next section describes how the nuclear industry determines the probabilities for these accidents.

5. Society for Risk Analysis, "Glossary of Risk Analysis Terms," McLean, Va. Available online at *www.sra.org/gloss3.htm.*

Section 3: Nuclear Plant Risk Assessment

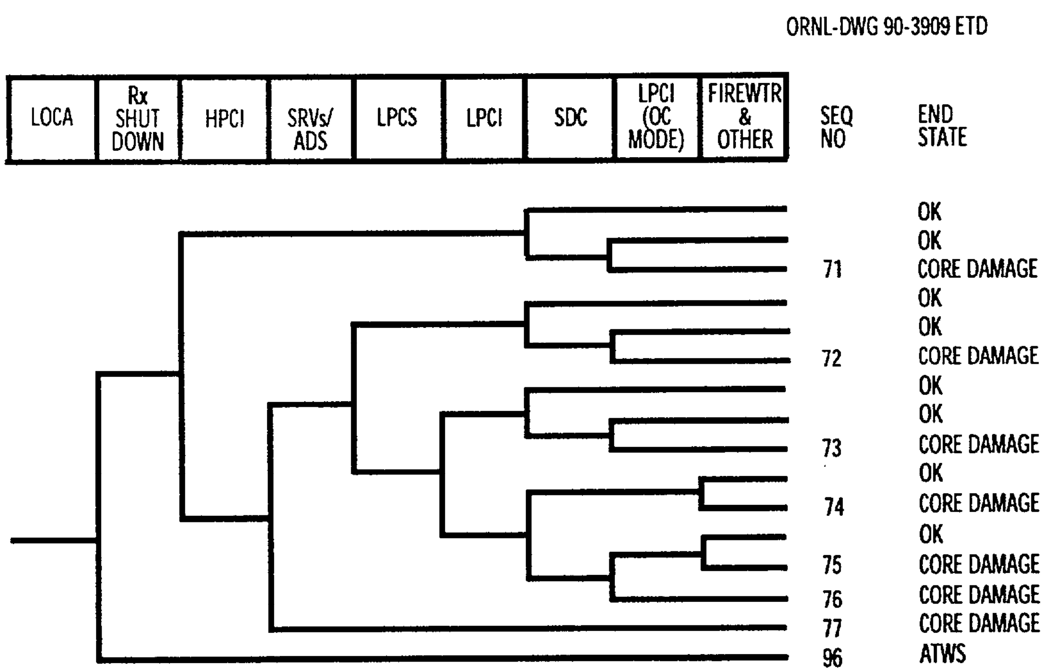
The only people I know who are enthusiastic about quantitative risk assessment are people who want to gain permission to expose other humans to dangerous chemicals so someone can make money. Risk assessment has proven to be an effective way to gain the necessary permissions.

—Peter Montague, Environmental Research Foundation, 1991

In 1988, the Nuclear Regulatory Commission required all nuclear plant owners to develop Individual Plant Examinations (IPEs). An IPE was to be an evaluation of each plant for accident vulnerabilities. All plant owners opted to perform probabilistic risk assessments (PRAs) to satisfy the NRC's request.[6] The NRC compiled the risk assessment information for all the plants and summarized it in a 1996 report.[7]

Probabilistic risk assessment is an analytical technique for evaluating potential accidents. The first level of assessment, Level I, examines events that can cause reactor core damage, such as a pipe break or power failure. Each event is then assessed using a fault-tree, which examines the possible responses to an event. The final product resembles a family tree chart, as the sample in figure 1 illustrates.

Figure 1. BWR Class B Small-Break Loss-of-Coolant Accident



6. Tim Leahy and Alan Kolaczkowski, "PRA for Technical Managers P-107," Washington, D.C.: Nuclear Regulatory Commission, December 1-3, 1998.

7. Nuclear Regulatory Commission, "Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance," NUREG-1560, Vols. 1 and 2, Washington, D.C., November 1996.

The sample chart shows the fault-tree for a break of a small pipe connected to the reactor pressure vessel of a nuclear plant with a boiling water reactor. That event is termed a small-break loss-of-coolant accident (LOCA). The fault-tree moves from left to right asking a series of questions. When the answer is yes, the pathway moves upward. Otherwise, the pathway moves downward. For example, the first question is whether the reactor (Rx) can be shut down following the pipe break. If the answer is no, the fault-tree moves to the extreme right for ATWS (Anticipated Transient Without Scram). The ATWS event, which involves the failure of the normal control rod system to shut down the nuclear chain reaction, has its own fault-tree analysis. When the reactor can be shut down, the fault-tree progresses to the second question—can the high-pressure coolant injection (HPCI) system add enough water to compensate for the water being lost through the broken pipe? The right column shows the condition of the reactor core for each of the fault-tree paths. Some pathways result in core damage, while others do not.

The P in PRA enters into the picture by assigning probabilities for the answers in a fault-tree. The probability that a specific pathway in a fault-tree will occur is determined by multiplying each of the individual probabilities along the way.

A variety of events besides the pipe break illustrated above can lead to core damage. Other examples include the break of a large pipe connected to the reactor pressure vessel, the interruption of cooling water flow to the reactor core, the loss of normal electricity supply to plant equipment, and flooding of plant areas. The PRA includes fault-trees for each event.

The final step in Level I is to calculate the core damage frequency (CDF), i.e., the probability, per reactor year, of an accident leading to core damage.[8] This is done by adding up all the pathways resulting in core damage from all of the fault trees. The CDF is frequently expressed in mathematical form like $5x10^{-5}$ or 5E-05. In plain English, such a CDF value means 5 accidents in 100,000 reactor years (or 1 accident in 20,000 reactor years).

The second level of the probabilistic risk assessment, Level II, explores the ability of the plant's containment systems to cope with a core damage accident. This part of the assessment assumes that the reactor core is damaged and examines the pathways that lead to radioactive material being released to the environment. The fault-tree approach is the same as for Level I, except that the initiating event on the left side of the fault-tree is reactor core damage and the questions probe the plant's ability to deal with it.

Level III examines the impact on public health and the environment from a core damage accident with containment failure. This assessment assumes that reactor core damage has occurred and that radioactive material has been released to the environment. It then examines the pathways that lead to human health consequences. Two major factors in a Level III assessment are weather conditions and how close people live to the plant.

Plant owners submitted the Individual Plant Examinations (IPEs) to the NRC in the early 1990s. These documents are readily available from the NRC's Public Document Room. But they have not been updated to reflect new information and physical changes to the plants.

8. NRC, "Individual Plant Examination Program," Vol. 1, Part 1, p. G-3.

When plants are modified, the owners prepare a second type of document, the Plant Safety Assessment (PSA) to reflect the plant's new configuration. Like the IPEs, the PSAs include probabilistic risk assessments. However, few plant owners have submitted PSAs for their plants to the NRC, so the public has access only to the outdated IPEs.

Furthermore, most plant owners have submitted only Level I and II probabilistic risk assessments (PRAs). Level III assessments have been prepared and submitted for only a small handful of plants. Thus the IPEs for most plants do not contain true risk assessments. Because risk depends on both the probability of an event and its consequences, failure to include Level III evaluations provides an incomplete picture of the risk. At best, the Level I and II PRAs are only probability assessments because their results indicate how often an event is likely to occur without providing any clue about the consequences of that event.

In addition to presenting incomplete risk profiles, fundamental flaws in the Level I and II PRAs provide an inaccurate picture of the probabilities of nuclear plant accidents. The next section describes some of the major flaws in the PRAs. Section 5 explains how the flawed PRAs happened and vividly demonstrates the gross inaccuracy of their results.

Section 4: Unrealistic Assumptions

You can make probabilistic numbers prove anything, by which I mean that probabilistic numbers "prove" nothing.

—Stephen H. Hanauer, Nuclear Regulatory Commission, 1975

All probability analyses make assumptions. For example, when you calculate that the probability of getting heads upon a single flip of a quarter is 50 percent, you are assuming that the coin will not land on its edge. Nuclear plant probabilistic risk assessments (PRAs) rely on numerous assumptions, such as the following:[9]

- The plants are operating within technical specifications and other regulatory requirements.
- Plant design and construction are completely adequate.
- Plant aging does not occur; that is, equipment fails at a constant rate.
- The reactor pressure vessels never fail.
- Plant workers make few serious mistakes.
- Risk is limited to reactor core damage.

History shows there is a greater probability of a flipped coin landing on its edge than of these assumptions being realistic. Unrealistic assumptions in the PRAs make their results equally unrealistic. In computer programming parlance, "garbage in, garbage out." The unrealistic assumptions of nuclear plant PRAs are examined below.

Unrealistic Assumption #1—Plants Always Conform with All Regulatory Requirements

The technical specifications and regulatory requirements are essentially the rules of the road that plant owners are supposed to follow. When they do not, they must report violations to the NRC. As table 1 illustrates, more than a thousand violations are reported every year.

While some comfort might be taken from seeing that fewer reports were submitted at the end of the decade than at its beginning, that comfort dissipates when one remembers that the risk assessments assume that there are *zero* violations.

Table 1
Number of Violations Reported to NRC[a]

1987	2,895
1988	2,479
1989	2,356
1990	2,128
1991	1,858
1992	1,774
1993	1,400
1994	1,279
1995	1,178
1996	1,274
1997	1,473

a. Nuclear Regulatory Commission, "Office for Analysis and Evaluation of Operational Data 1997 Annual Report Reactors," NUREG-1272, Vol. 2, No. 1, Table 5.1, Washington, D.C., November 1998.

Nine nuclear reactors were shut down throughout the entire year of 1997 while their owners repaired safety equipment. Those reactors were Millstone Units 1, 2, and 3 in Connecticut; Salem Unit 1 in New Jersey; Crystal River 3 in

9. NRC, "Individual Plant Examination," Vol. 2, Parts 2–5, p. 14-3.

Florida; and Clinton, LaSalle Units 1 and 2, and Zion Unit 2 in Illinois.[10] The PRAs for each of these reactors, which had been submitted to the NRC before January 1, 1997, assumed that the reactors met *all* technical specifications and other regulatory requirements. Their year-plus outages demonstrate the fallacy of those assumptions.

As a result of this unrealistic assumption, the core damage frequencies (CDFs) calculated in the PRAs are too low. As section 3 explains, CDFs are determined from fault-trees for events that can lead to core damage. The fault-trees examine the plant's ability to respond to those events. By assuming that emergency equipment meets safety requirements when in fact it does not, the PRAs calculate better response capabilities than are supported by reality. In other words, the core damage frequencies are really higher than reported by the PRAs.

Table 2
Number of Safety Problems Caused by Design, Construction, Installation, and Fabrication Errors Reported to NRC[a]

4th quarter 1995	86
1st quarter 1996	107
2nd quarter 1996	116
3rd quarter 1996	101
4th quarter 1996	143
1st quarter 1997	177
2nd quarter 1997	137
3rd quarter 1997	38

a. Nuclear Regulatory Commission, "Office for Analysis and Evaluation of Operational Data 1997 Annual Report Reactors," NUREG-1272, Vol. II, No. 1, Table A-1.14, Washington, D.C., November 1998.

Unrealistic Assumption #2—Plant Design Is Completely Satisfactory

The assumption about plants' design and construction being adequate also defies reality, as table 2 illustrates.

The risk assessments assume that there are *zero* design and construction problems when hundreds of problems are discovered every year. The NRC's Office for Analysis and Evaluation of Operational Data documented 3,540 design errors reported between 1985 and 1994.[11] That means a design error was discovered at a nuclear power plant in the United States almost every single day for an entire decade.

Last year, Public Citizen's Critical Mass Energy Project documented more than 500 design problems found in US nuclear power plants between October 1996 and May 1999.[12] Topping the list was the Vermont Yankee nuclear plant with 42 design problems found during the 31-month period. Many of the design problems had existed since the nuclear plants began operating decades ago.

Moreover, according to the NRC, "Almost every plant-specific PRA has identified design or operational deficiencies."[13] Thus, even though preparation of the risk assessments revealed design problems, the assessments continued to assume that no design problems exist.

10. Nuclear Regulatory Commission, "Plant Status Report for January 2, 1998," Washington, D.C. Available online at *www.nrc.gov/NRR/DAILY/980102pr.htm.*

11. Sadanandan V. Pullani, "Design Errors in Nuclear Power Plants," AEOD/T97-01, Washington, D.C.: NRC Office for Analysis and Evaluation of Operational Data, January 1997.

12. James P. Riccio, "Amnesty Irrational: How the Nuclear Regulatory Commission Fails to Hold Nuclear Reactors Accountable for Violations of Its Own Safety Regulations," Washington, D.C.: Public Citizen, August 1999.

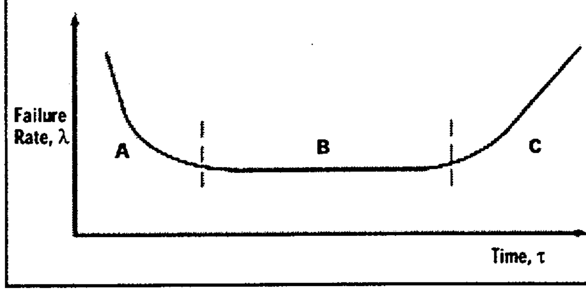
13. Nuclear Regulatory Commission, "Probabilistic Risk Assessment (PRA) Reference Document," NUREG-1050, p. 47, Washington, D.C., September 1984.

The NRC knows that nuclear plants had design problems that were not reflected in their risk assessments. In January 1999, UCS presented its views on risk-informed regulation to the NRC. During that presentation, NRC Chairman Shirley Ann Jackson interrupted UCS's David Lochbaum to ask a question of Ashok Thadani, Director of the NRC's Office of Research:

> *Mr. Lochbaum:* There is no feedback [to change the risk assessments to account] for design failures, just active component failures.
>
> *Chairman Jackson:* There is no feedback for design failures, just for active components?
>
> *Mr. Thadani:* For design failures that is correct. That is an area that is not dealt with in the risk assessments. That's a recognized weakness.
>
> *Chairman Jackson:* So how do you handle that? What do you do about that?
>
> *Mr. Thadani:* Design failure is like—pardon me for using this language—a blunder in my view. It's not really a random issue. At a plant there is or is not a design problem. It is not the sort of thing you can deal with in a probabilistic manner.[14]

So design blunders at nuclear plants are intentionally being ignored in the weakened PRAs even though design failure data are readily available. A nuclear widget needed to prevent or mitigate an accident may fail to perform this vital function if it is broken, if it is mistakenly disabled by plant workers, or if is improperly designed. The PRAs account for the breaks and mistakes, but not for the abundant design blunders.

Figure 2. "Bathtub" Curve of Failure Rate



Unrealistic Assumption #3—Like Dorian Gray, Nuclear Plants Do Not Age

Another incredible assumption is that nuclear plants and their equipment are getting older but not showing any signs of aging. Again the assumption is made in the face of clear evidence to the contrary. The NRC has issued more than one hundred technical reports about the degradation of valves, pipes, motors, cables, concrete, switches, and tanks at nuclear plants caused by aging.[15] These reports demonstrate that parts in nuclear plants follow the "bathtub curve" aging process illustrated in figure 2 above. Region A is the break-in phase, Region C is the wear-out phase, and Region B is the peak-health phase. The PRAs assume equipment failure rates from the flat portion (Region B) of the "bathtub curve," where the chance of failure is the lowest. And the NRC knows it. During a three-day training course in December 1998, NRC supervisors and managers were informed: "Most PRAs assume constant failure rates—in the

14. Nuclear Regulatory Commission, "Briefing on Risk-Informed Initiatives," transcript, Washington, D.C., January 11, 1999.

15. Nuclear Regulatory Commission, "NRC Research Program on Plant Aging: Listing and Summaries of Reports Issued Through September 1993," NUREG-1377, Rev. 4, Washington, D.C., December 1993.

'flat' portion of bathtub curve. This implies aging of components is not modeled in most PRAs."[16]

A telling demonstration of the effects of age occurred in 1986. Four workers were killed at a nuclear power plant in Virginia because a section of pipe eroded away with time until it broke and scalded them with steam.[17] Yet most PRAs assume *no* aging effects.

Unrealistic Assumption #4—Reactor Pressure Vessels Can Never Fail

The assumption about the reactor pressure vessel never failing is based on necessity, not science. The reactor pressure vessel is a large, metal "pot" containing the reactor core. The majority of a plant's emergency systems are intended to prevent water from leaking out of this pot or to quickly refill the pot if it leaks. The pot must remain filled with water to keep the reactor core from overheating. If the metal pot were to break open, water would pour out faster than *all* of the emergency pumps together could replenish. This would result in a reactor core meltdown and the release of huge amounts of radiation. Because there is no backup to the reactor pressure vessel and because the plant's emergency systems cannot prevent meltdown if it breaks, the risk assessments conveniently assume that it cannot fail—ever—under any circumstances.

Experience has shown that this assumption has as many cracks and flaws as the reactor pressure vessels themselves. In 1995, UCS issued a report on the fragile condition of reactor pressure vessels at nuclear power plants.[18] For example, the Yankee Rowe plant in Massachusetts closed in 1992 because its reactor pressure vessel had become brittle over time. Brittle metal can shatter, much like hot glass, when placed in cold water. Despite the closure of the Yankee Rowe plant and documented embrittlement at many other nuclear plants, the risk studies continue to assume a *zero* chance of reactor pressure vessel failure.

Unrealistic Assumption #5—Plant Workers Will Not Make Serious Mistakes

PRAs make bold assumptions about human performance during the periods of high stress and information overload associated with accidents and near-misses. Sometimes, the assumptions are totally unjustified. For example, the NRC commissioned a risk analysis of the spent fuel pool when engineers working on the Susquehanna nuclear plant raised concerns about its safety. That PRA assumed that workers immediately begin taking actions to restore cooling when the spent fuel pool temperature reaches 125 degrees Fahrenheit (°F).[19] When the engineers challenged that assumption, the NRC reported that plant's operating license required the spent fuel pool temperature to remain below 125°F and that workers were trained to conform to the rules of the operating license. Even after the engineers pointed out that the plant did not even have temperature instruments for the workers to use, the NRC retained this blatantly false

16. Leahy and Kolaczkowski, "PRA for Technical Managers P-107."

17. Brian Jordan, "NRC Finds Surry Accident Has 'High Degree' of Safety Significance," *Inside NRC*, Washington, D.C.: McGraw-Hill, January 5, 1987.

18. Robert Pollard, "US Nuclear Power Plants—Showing Their Age—Case Study: Reactor Pressure Vessel Embrittlement," Cambridge, Mass.: Union of Concerned Scientists, December 1995.

19. Joseph W. Shea, Project Manager, Nuclear Regulatory Commission, to David A. Lochbaum and Donald C. Prevatte, "Susquehanna Steam Electric Station, Units 1 and 2, Draft Safety Evaluation Regarding Spent Fuel Pool Cooling Issues," October 25, 1994. Available from the NRC Public Document Room, Washington, D.C.

assumption.[20] This had the effect of lowering the calculated probability by a factor of at least 10 and maybe 100.

A report issued in February 2000 by the Idaho National Engineering and Environmental Laboratory (INEEL) demonstrates that unjustified assumptions about worker behavior continue to be a problem. Researchers at INEEL examined 20 recent operating events at nuclear power plants and concluded:

> Most of the significant contributing human performance factors found in this analysis of operating events are missing from the current generation of probabilistic risk assessments (PRAs), including the individual plant examinations (IPEs). The current generation of PRAs does not address well the kinds of latent errors, multiple failures, or the type of errors determined by analysis to be important in these operating events.
>
> In the PRAs, human performance accounts for 5–8% of risk (i.e., contributes to less than 10% of core damage frequency estimates). ... In the 20 operating events analyzed to date using qualitative and quantitative SPAR [standardized plant analysis risk] methods, the average contribution of human performance to the event importance was over 90%. ... In nearly all cases, plant risk more than doubled as a result of the operating event—and in some cases increased by several orders of magnitude over the baseline risk presented in the PRA. This increase was due, in large part, to human performance.[21]

PRAs assume that workers will make fewer mistakes when responding to accidents than is justified by actual experience.

Unrealistic Assumption #6—Nuclear Plant Risk Is Limited Exclusively to Reactor Core Damage

Even if nuclear plant PRAs properly accounted for violations of regulatory requirements, design and construction errors, equipment aging, potential failure of the reactor pressure vessel, and actual human performance capabilities, they would still be flawed. The PRAs only determine the probabilities of events leading to reactor core damage. They do not calculate the probabilities of other events that could lead to releases of radiation, such as fuel going critical in the spent fuel pool or rupture of a large tank filled with radioactive gases. Some of these overlooked events can have serious consequences. For example, researchers at the Brookhaven National Laboratory estimated that a spent fuel pool accident could release enough radioactive material to kill tens of thousands of Americans.[22]

Thus, even the best nuclear plant PRA is incomplete because it neglects events that can release significant amounts of radiation. The effect of this incompleteness is to introduce

20. David A. Lochbaum and Donald C. Prevatte to Chairman Ivan Selin, Nuclear Regulatory Commission, "Susquehanna Steam Electric Station Units 1 and 2 / Comment on Draft Safety Evaluation Regarding Spent Fuel Pool Cooling Issues," November 29, 1994. Available from the NRC Public Document Room, Washington, D.C.

21. Jack E. Rosenthal to John T. Larkins, "Meeting with the Advisory Committee on Reactor Safeguards Human Factors Subcommittee, March 15, 2000, on SECY-00-0053, NRC Program on Human Performance in Nuclear Power Plant Safety," Washington, D.C.: Nuclear Regulatory Commission, March 6, 2000.

22. Nuclear Regulatory Commission, "A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants," NUREG/CR-6451, Washington, D.C., August 1997.

additional uncertainty into the results of the PRAs:

> Completeness is not in itself an uncertainty, but a reflection of scope limitations. The result is, however, an uncertainty about where the true risk lies. The problem with completeness uncertainty is that, because it reflects an unanalyzed contribution, it is difficult (if not impossible) to estimate its magnitude.[23]

Summary

Each of the unrealistic assumptions covered in this section causes the probabilistic risk assessments to underestimate the chances of a nuclear plant accident. In some cases, the accident probabilities are falsely lowered by a factor of 100. But the full extent of the underestimation is unknown.

The next section uses case studies to illustrate how unrealistic assumptions, along with lack of quality standards for the risk assessments, cause grossly inaccurate results.

23. Nuclear Regulatory Commission, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," Regulatory Guide 1.174, p. 1.174-13, Washington, D.C., July 1998.

Section 5: Missing Quality Standards

The results of the Oak Ridge-SAI work and the INPO [Institute for Nuclear Power Operations] review of the Oak Ridge effort show clearly the reason why PRAs are not good measures of safety adequacy. So much subjective judgement is involved in the probability evaluation that the results cannot be trusted for absolute risk measurement. —Myer Bender, Nuclear Regulatory Commission, 1983

Probabilistic risk assessments (PRAs) determine the probability of nuclear plant accidents resulting in reactor core damage as described in section 3. The nuclear industry uses this calculated core damage frequency (CDF) to rank safety threats—the larger the CDF, the greater the threat.

The whole purpose of the PRA is to calculate the CDF. The CDF is used extensively as a plant safety gauge. In reviewing the PRAs submitted by plant owners in their Individual Plant Examinations (IPEs), the NRC learned that

> One factor that can influence both the success criteria and the accident progression is the definition of core damage, which varied substantially in the IPEs from definitions involving vessel level to definitions involving fuel cladding temperature or oxidation.[24]

In other words, one plant owner could define core damage one way while another plant owner could define core damage in a completely different manner. How could something so vitally important to a PRA as the definition of core damage be left to such subjective interpretation? In the NRC's own words: "The NRC has not developed its own formal standard nor endorsed an industry standard for a PRA."[25]

The lack of a PRA standard gives plant owners free rein. That freedom manifests itself in PRA results for virtually identical nuclear plants being completely different. It also allows PRA results to be significantly more optimistic than reality. UCS prepared the following case studies to demonstrate these points:

- Wolf Creek and Callaway
- Indian Point Units 2 and 3
- Sequoyah and Watts Bar
- Standby Liquid Control Systems

These case studies are presented below.

Case Study #1—Wolf Creek and Callaway

Decades ago, the Westinghouse Electric Corporation designed what it called the Standardized Nuclear Unit Power Plant System (SNUPPS). Westinghouse sought to reduce costs, and thus make its reactors more saleable, by developing a plant design that could be replicated again and again. The Wolf Creek plant in Kansas and the Callaway plant in Missouri are the only two SNUPPS orders that were completed.[26] The plants were built using the exact same blueprints and materials. Callaway was licensed to operate by the NRC in October 1984, while Wolf Creek was licensed in June 1985.[27]

24. NRC, "Individual Plant Examination Program," Vol. 2, Parts 2–5, p. 15-3.
25. NRC, "An Approach for Using Probabilistic Risk Assessment," p. 1.174-10.
26. One of the two reactors ordered at Callaway was canceled during its construction.
27. Nuclear Regulatory Commission, "Information Digest," NUREG-1350, Vol. 10, Washington, D.C., November 1998. Available online at *www.nrc.gov/NRC/NUREGS/SR1350/V10/index.html.*

Both plant owners provided the NRC with risk assessments of postulated internal events, such as pipe breaks and valve failures, that could lead to reactor core damage. The risk assessments for core damage caused by external events, such as tornadoes and floods, are expected to vary because the plants are located in different states. But the internal event risk should be similar because Callaway and Wolf Creek were intentionally built to be identical twins.

In this case, however, the identical twins seem as different as Dr. Jekyll and Mr. Hyde. The most probable event leading to reactor core damage at Callaway is identified as a pipe break that causes Room 3101 to be flooded. Room 3101 contains electrical equipment that doesn't work well when submerged. Wolf Creek also has a Room 3101 housing plenty of electrical equipment. But when Wolf Creek's Room 3101 is flooded, it is reportedly 10 times less likely to result in reactor core damage.[28]

The fifth most likely event leading to reactor core damage at Callaway is a small-break loss-of-coolant accident, in which a small diameter pipe connected to the reactor pressure vessel breaks, leading to inadequate core cooling. Wolf Creek also has small diameter piping that can break and lead to reactor core damage. But the small-break loss-of-coolant accident at Wolf Creek is supposedly 20 times less likely to result in core damage and is estimated to be the eighteenth most likely event.[29]

The numbers make it look like Wolf Creek is the good twin and Callaway the bad twin. In reality, these risk assessments cannot be used to decide this sibling rivalry. They were developed using different methods and different assumptions. It is therefore no surprise that their results differ so radically. The data do not allow the safety levels of these identical plants to be evaluated, even on a relative basis.

This case study demonstrates a deeper problem: plant-specific risk assessments provide no meaningful insight into relative risks within a plant. Callaway and Wolf Creek have identical designs. Yet the Achilles' heel on Callaway seems no more than the funny bone on Wolf Creek. The input assumptions for the risk assessment at either plant could be tweaked and cause the numbers to flip-flop. The *actual* risks at the plants would be unchanged, but the *perceived* risks would change significantly.

Case Study #2—Indian Point

Indian Point Unit 2 (IP2) and Indian Point Unit 3 (IP3) are pressurized water reactors designed by the Westinghouse Electric Corporation. These plants are located side by side along the Hudson River in Buchanan, New York, about 35 miles north of New York City. The NRC issued operating licenses on September 28, 1973, for IP2 and on April 5, 1976, for IP3.[30] The individual plant examinations (IPEs) were completed in August 1992 for IP2[31] and in June 1994 for IP3.[32]

28. Wolf Creek Nuclear Operating Corporation, "Wolf Creek Generating Station Individual Plant Examination Summary Report," September 1992; and Union Electric Company, "Individual Plant Examination," October 9, 1992. Both documents are available from the NRC Public Document Room, Washington, D.C.

29. Wolf Creek Nuclear Operating Corporation, "Wolf Creek Generating Station"; and Union Electric Company, "Individual Plant Examination."

30. NRC, "Information Digest."

31. Consolidated Edison Company of New York, Inc., "Individual Plant Examination for Indian Point Unit No. 2 Nuclear Generating Station," August 1992. Available from the NRC Public Document Room, Washington, D.C.

32. New York Power Authority, "Indian Point 3 Nuclear Power Plant Individual Plant Examination," June 1994. Available from the NRC Public Document Room, Washington, D.C.

These two nuclear plants were designed by the same company and built in the same geographic location in the same era. One would expect these nuclear "sisters" would have comparable risks. That expectation appears incorrect, if one believes the risk numbers, which were both published at about the same time.

The overall chance of events leading to reactor core damage was calculated to be 27.3 percent higher for IP3 than for IP2. The disparity was even wider for individual events. One such event—the interfacing system loss-of-coolant accident—was calculated to be 89 percent more likely to occur at IP3 than at IP2.[33]

According to IP3's owner:

> A detailed comparison of the IPEs performed on IP2 and IP3 is made difficult by the difference in the methodologies used. The IPE prepared for IP3 employed the small event-tree/large fault-tree methodology used in the NUREG-1150 studies, considerable effort being devoted to the delineation of accident sequences. In contrast, the IPE prepared for IP2 used a large event-tree/small fault-tree methodology.[34]

IP3's owner concluded—paradoxically—that despite the different methodologies employed, "the core damage frequencies predicted for IP3 and IP2 are basically similar though significant differences do exist."[35]

Case Study #3—Sequoyah and Watts Bar

The two case studies above compare risk assessment results for nuclear plants that are very similar to each other. In each case, the nuclear plants were operated by different owners. The disparities in the results might be attributed to different approaches taken by the owners. However, analysis of two other plants suggests another explanation.

This case study looks at the risk assessments for the Sequoyah and Watts Bar nuclear power plants. Sequoyah and Watts Bar are sister plants. Each is a four-loop pressurized water reactor designed by Westinghouse with an ice-condenser containment. The two reactors at Sequoyah were licensed to operate by the NRC in 1980 and 1981.[36] The NRC issued TVA an operating license for Watts Bar in 1996.[37]

The Tennessee Valley Authority (TVA) operates both of these plants and prepared their risk assessments. Sequoyah has a core damage frequency of 1 in 26,525 years.[38] The original core damage frequency that TVA calculated for Watts Bar was 1 in 3,030 per year.[39] These numbers suggest that the newer plant, which TVA built using the lessons learned from Sequoyah, was nearly 10 times more likely to have a nuclear accident. One would hope that the passage of

33. NY Power Authority, "Indian Point 3," Table 1.5.1.1, p. 1-10.

34. NY Power Authority, "Indian Point 3," p. 1-23.

35. NY Power Authority, "Indian Point 3," p. 1-23.

36. NRC, "Information Digest."

37. NRC, "Information Digest."

38. Tennessee Valley Authority, "Sequoyah Nuclear Plant Units 1,2 Probabilistic Safety Assessment Individual Plant Examination," Vol. 1, February 20, 1998. Available from the NRC Public Document Room, Washington, D.C.

39. Tennessee Valley Authority, "Watts Bar Nuclear Plant Unit 1 Probabilistic Risk Assessment Individual Plant Examination Update, " Vol. 5, May 2, 1994. Available from the NRC Public Document Room, Washington, D.C.

15 years would have enabled TVA to make safety improvements or at least maintain the same safety levels as had been found at Sequoyah.

TVA later recalculated the core damage frequency for Watts Bar. By tweaking here and adjusting there, TVA reduced the core damage frequency for Watts Bar to 1 in 12,500 years.[40] Watts Bar is now only twice as unsafe as Sequoyah.

The saga of Sequoyah and Watts Bar clearly exposes the problem with probabilistic risk assessments (PRAs) performed by the nuclear industry. TVA, unsatisfied with Watts Bar's risk being 300 percent higher than the NRC's safety goal, waved its magic wand (in this case, it closely resembled a pencil eraser) until Watts Bar's risk dropped *lower* than the safety goal.

Case Study #4: Standby Liquid Control Systems

Our final case study explains just how the PRA wizards are able to dial in any risk number they want. The fault-trees have many branches. The branches represent the performance of emergency equipment and plant workers in response to the potential events.

The standby liquid control (SLC) system is a backup system in boiling water reactors designed by the General Electric (GE) Company, which is designed to stop the nuclear reaction if the control rods fail to do so. The SLC system is kept in standby mode when the nuclear plant is running. It consists of a large storage tank, two pumps, piping, and valves. Only one pump is required for the SLC system to fulfill its intended function—the second pump serves as a fully redundant backup. The system can be manually initiated by the operator to shut down the reactor when the normal reactivity-control system, the control rod drive system, fails. The SLC system injects a solution into the reactor vessel to absorb neutrons and end the fission chain reaction. The NRC ranked the SLC system as the eighth most important out of 30 safety systems it evaluated.[41]

Pennsylvania Power & Light, a nuclear plant owner with two boiling water reactors, calculated the chances that the SLC system would be unable to perform its vital safety function to be 1 in 16,666.[42] That means the system is expected to function properly 16,665 times out of 16,666 tries. Such high reliability for an important safety system would be comforting, if it were true. It is neither true nor comforting.

There are 35 boiling water reactors operating in the United States. If the SLC systems at these nuclear plants were tested every day and the reported system reliability were accurate, there would be one SLC system failure every 1.3 years. But the SLC systems are not tested every day. According to the NRC, the SLC system is routinely tested on a quarterly basis and nonroutinely tested following system maintenance.[43] The average frequency of SLC system testing at US nuclear plants falls between once per month and

40. TVA, "Watts Bar."

41. Nuclear Regulatory Commission, "Aging Assessment of BWR Standby Liquid Control Systems," NUREG/CR-6001, Washington, D.C., August 1992.

42. Harold W. Keiser, Senior Vice President—Nuclear, Pennsylvania Power & Light Company, to C. L. Miller, Project Manager, Nuclear Regulatory Commission, "Susquehanna Steam Electric Station—Submittal of the IPE Report," December 13, 1991. Available from the NRC Public Document Room, Washington, D.C.

43. Nuclear Regulatory Commission, "Standard Technical Specifications for General Electric Boiling Water Reactor 4, Section 3.1.7 and Bases Section 3.1.7, Standby Liquid Control System," NUREG-1433 Rev. 1, Washington, D.C., April 1995.

once per quarter. Thus, for the entire fleet of US boiling water reactors, there will be one SLC system failure reported every 39.7 to 119.0 years, *if* the SLC system reliability is as high as reported.

A cursory check of the NRC's Public Document Room revealed these reports:

- In August 1998, the owner of the Big Rock Point nuclear plant informed the NRC that its SLC system had been totally incapacitated for the past 13 to 18 years.[44]
- In January 1998, the owner of Susquehanna Unit 1 (i.e., the same entity that reported the extremely reliable SLC system) informed the NRC that both pumps of the SLC system were inoperable.[45]
- In December 1996, the owner of the FitzPatrick boiling water reactor informed the NRC that both pumps of the SLC system were inoperable.[46]

Thus, the SLC system is *not* as reliable as claimed in the plant risk assessments. Consequently, the actual risks from nuclear power plant operation are higher than reported in the risk assessments. Many branches of the fault-trees are similarly afflicted, rendering the results of the risk assessments virtually useless.

Summary

These case studies showed how the lack of quality standards for the risk assessments—particularly regarding the unrealistic assumptions described in section 4—enables the nuclear industry to subjectively "calculate" lower core damage frequencies. Decisions on public health must not be based on falsely optimistic accident probabilities. The consequences from a nuclear plant accident, as described in the next section, are potentially catastrophic.

44. Kenneth P. Powers, Site General Manager, Consumers Energy, to Nuclear Regulatory Commission, "Docket 50-155—License DPR-6—Big Rock Point Plant—Licensee Event Report 98-0001: Liquid Poison Tank Discharge Pipe Found Severed During Facility Decommissioning," August 6, 1998. Available from the NRC Public Document Room, Washington, D.C.

45. Pennsylvania Power & Light Company to Nuclear Regulatory Commission, "Licensee Event Report No. 50-387/97-025-00, Loss of Both Trains of Standby Liquid Control," January 2, 1998. Available from the NRC Public Document Room, Washington, D.C.

46. Michael J. Colomb, Plant Manager, New York Power Authority, to Nuclear Regulatory Commission, "Licensee Event Report: LER-96-011—Both Standby Liquid Control Subsystems Inoperable Due to Inoperable Pump Discharge Pressure Relief Valves," December 2, 1996. Available from the NRC Public Document Room, Washington, D.C.

Section 6: Consequences of a Nuclear Accident

Nuclear power is a business that can lose $2 billion in half an hour.

—Wall Street Journal, 1983

As the preceding sections indicate, the risk of a major accident at any nuclear power plant is unknown, because although the probability of an accident has been assessed (albeit with flawed assumptions, and inconsistent definitions and procedures), the consequences have not been assessed. This section draws on other sources to provide the missing piece of the risk puzzle.

A nuclear plant accident can harm the public by releasing radioactive materials. Radioactive materials emit alpha particles, beta particles, gamma rays, and/or neutrons. These emissions are called "ionizing radiation" because the particles produce ions when they interact with substances. Other materials can emit nonionizing radiation such as radio waves, microwaves, and ultraviolet light.[47]

Cells can be damaged or even killed by ionizing radiation. At high radiation exposures, tissues and organs can be damaged due to the large number of cells affected. Workers were killed by the radiation they received following the 1986 accident at Chernobyl in the Ukraine and the 1999 accident at Tokaimura in Japan. At lower exposures, it may take 5 to 20 years for radiation-induced effects, like cancer, to develop. Ionizing radiation can also produce genetic effects that appear in the individual's children or even several generations later.[48]

Following the Three Mile Island (TMI) accident in 1979, the Sandia National Laboratory estimated the potential consequences from reactor accidents that release large amounts of radiation into the atmosphere. Essentially, Sandia performed the equivalent of the Level III PRAs described in section 3 of this report: they assumed that reactor core damage occurred and that the containment buildings failed to prevent the release of radiation.

For each nuclear plant then in operation and nearing completion, Sandia determined the amount of radiation that could be released following a major accident, the area's weather conditions, and the population downwind of the plant. Then Sandia estimated how many Americans would die and be injured within the first year due to their radiation exposure. Sandia also estimated how many Americans would later die from radiation-induced illnesses like cancer. Table 3 provides a summary of Sandia's results.

The consequences vary because larger plants can release more radiation than smaller plants and because some plants are located near large population centers.[49] But in all cases, a nuclear accident was estimated to cause hundreds to thousands of immediate fatalities and thousands of subsequent cancer deaths.

47. Code of Federal Regulations, Title 10, Energy, Section 20.1003, Definitions.

48. Nuclear Regulatory Commission, "Biological Effect of Radiation," Technical Issue Paper 36, Washington, D.C., September 1999.

49. Decades ago, the forerunner of the NRC advocated higher safety standards for nuclear plants near high-population centers than for plants in remote areas. UCS contends now, as we did then, that all Americans deserve to be protected by the highest safety standards.

Table 3
Operating Nuclear Plant Accident Consequences[a]

Plant / Location	Early Fatalities	Injuries	Cancer Deaths
Beaver Valley / Shippingport, Penn.	19,000	156,000*	24,000
Browns Ferry / Decatur, Ala.	18,000	42,000	3,800
Byron / Rockford, Ill.	9,050	79,300	15,300
Callaway / Callaway, Mo.	11,500	32,000	9,600
Calvert Cliffs / Lusby, Md.	5,600	15,000	23,000
D C Cook / Bridgman, Mich.	1,950	84,000	13,000
Fermi / Laguna Beach, Mich.	8,000	340,000*	13,000
Harris / Apex, N.C.	11,000	31,000	6,000
Hatch / Baxley, Ga.	700	4,000	3,000
Indian Point 3 / Buchanan, N.Y.	50,000	167,000*	14,000
Limerick / Montgomery, Penn.	74,000*	610,000*	34,000
Millstone 3 / Waterford, Conn.	23,000	30,000	38,000
Nine Mile Point 2 / Oswego, N.Y.	1,400	26,000	20,000
Perry / Painesville, Ohio	5,500	180,000*	14,000
Pilgrim / Plymouth, Mass.	3,000	30,000	23,000
Salem / Salem, N.J.	100,000*	70,000	40,000
Susquehanna / Berwick, Penn.	67,000	47,000	28,000
Vermont Yankee / Vernon, Vt.	7,000	3,000	17,000

*For comparison, the atomic bomb dropped on Hiroshima killed 140,000 people, and the one dropped on Nagasaki killed 70,000 people.[b]

a. US House of Representatives, Committee on Interior and Insular Affairs Subcommittee on Oversight & Investigations, "Calculation of Reactor Accident Consequences (CRAC2) for US Nuclear Power Plants (Health Effects and Costs) Conditional on an 'SST1' Release," November 1, 1982.

b. Richard Rhodes, *The Making of the Atomic Bomb*, New York: Simon & Schuster, pp. 734 and 740, 1986.

How do these estimates relate to the NRC's policy of limiting the risk from a nuclear plant accident to less than 0.1 percent of the risk from other accidents?[50] During 1997, accidents claimed the lives of 95,644 Americans.[51] An accident at the Salem nuclear plant in New Jersey could—by itself—kill more than that many Americans. Yet the NRC's policy is to limit the number of deaths from nuclear plant accidents to less than 95 each year on average.

50. NRC, "TIP: 12."

51. Center for Disease Control and Prevention, "Fastats: Accidents/Unintentional Injuries," Atlanta, Ga., August 31, 1999. Available online at *www.cdc.gov/nchs/fastats/acc-inj.htm.*

As discussed in section 2, risk depends on both the probability and the consequences of an event. The NRC's risk goal can only be met if the probability of an accident is very, very low. How low? An accident causing 100,000 deaths must have a probability of less than 1 in 1,045 years to meet the NRC's risk goal of no more than 95 deaths from nuclear plant accidents.

In other words, nuclear power plants are acceptably safe under the NRC's goal so long as they kill no more than about 100 people per year, or 1,000 people every decade. A 50 percent chance of a nuclear accident killing 10,000 people every century would be acceptable. And the NRC's goal would accept a nuclear accident killing 100,000 people, provided that, on average, there would be no more than one accident per millennium.

This nuclear safety goal, of course, has never been explicitly approved by the American people or their representatives, the US Congress. As observed in section 2, society regards potential accidents with high consequences more seriously than the same consequences spread out over a long period of time. And few, if any, other technological disasters, whether dam breaks, airline crashes, bridge collapses, or train derailments, can result in such high consequences as a nuclear plant accident.

As the previous sections have shown, the PRAs cannot be relied upon to estimate the true probability of a nuclear accident. There are simply too many factors they do not consider and too many discrepancies that are not explained. As discussed in the next section, proper risk management strategies are neglected when accident probabilities are not well understood.

Section 7: Conclusions

There is no scientific or mathematical formula that can adequately measure risk.
—John H. Gibbons, Office of Technology Assessment, 1980

The risk from any event depends upon the probability of it occurring and the consequences if it were to occur. As explained in section 2 of this report, looking at only probability or only consequences results in an incorrect understanding of risk.

However, it is possible to properly manage risk without knowing much about the probability and/or consequences of an event. When every possible measure is implemented to prevent an event from occurring and every possible step taken to minimize the consequences should it occur, then the risk is as low as possible. But it is not possible to properly manage risk when only *reasonable*—instead of *all possible*—measures are taken to prevent and mitigate events unless the probabilities and consequences are accurately known.

The NRC required nuclear plant owners to prepare risk assessments in the early 1990s. But as section 3 reveals, these assessments merely evaluate the *probability* of reactor accidents. The plant-specific accident *consequences* have not been updated since a study done in 1982 using 1980 population information. Thus, the NRC has limited insight into nuclear plant risks.

The value of the NRC's partial insight is further diminished by the poor quality of the probability assessments. The probability assessment calculations rely on several assumptions that simply do not reflect reality, as documented in section 4. Thus, accident probabilities are higher than reported by the plant owners, and yet the NRC relies on them.

In large part, the probability assessments yield bogus results because the NRC never established minimum standards that plant owners had to meet. As the case studies in section 5 indicate, the lack of standard definitions and procedures for preparing probability assessments resulted in widely varying accident probabilities for virtually identical plants.

That a nuclear plant accident can have disastrous consequences may be known intuitively, but section 6 details the potential body counts. More people could be killed by a nuclear plant accident than were killed by the atomic bomb dropped on Nagasaki. The NRC attempts to manage this awesome risk by limiting the probability of an accident. But accident probabilities are not known with sufficient certainty to permit only *reasonable* instead of *all possible* safety precautions to be taken.

If this were just a historical observation, it would be bad enough. Unfortunately, the sad story gets worse.

The nuclear industry and the NRC are slashing safety regulations at a frenetic pace in an effort to make nuclear power plants more economical to operate. Nuclear plants must generate electricity at competitive prices if they are to survive in a deregulated electricity marketplace. In the past decade, plant owners made numerous changes to increase productivity (i.e., profitability). Refueling outages are an example. Nuclear power plants shut down every 18 to 24 months to load fresh fuel into the reactor core. Refueling outages that averaged 101 days in 1990 were performed in only 51.1 days in 1998.[52] Consequently, the average output from nuclear plants rose from about 67 percent of capacity in 1990 to 79.5 percent in 1998.[53]

The remaining option for additional cost-savings is simply to do less. Plant owners are downsizing staff sizes by eliminating work. Fewer tests and inspections are performed at nuclear plants today than five years ago. For example, the NRC recently approved a request by the owner of the Duane Arnold nuclear plant in Iowa to test valves that limit the release of radioactive liquid every ten years instead every two years.[54] The NRC also allowed the owner of the San Onofre nuclear plant in California to relax the maintenance check on the valves that protect the main steam lines from bursting from too much pressure.[55] As a direct result, fewer problems are found and fewer repairs are needed. Plant owners save lots of money by reducing staffing levels and repair bills.

The NRC is approving these cost-cutting measures based on evaluations purporting to show that the reduced number of inspections does not increase the probability of accidents. But the incomplete and inaccurate probability assessments cannot identify the true risk of nuclear plant operation, nor can they provide a clue as to how far the results are from reality. How can that be possible? Imagine balancing a checkbook without having all of the deposit slips or all of the check amounts written against the account. You can calculate a balance, but it tells you nothing about how much money is in the account. And you can only guess if the number is higher or lower than the actual balance. Likewise, the NRC is guessing when it makes safety decisions using the results from incomplete and inaccurate probabilistic assessments.

The NRC is now proposing to move to so-called *risk-informed regulation.* This is the NRC's term for allowing plant owners to cut back on inspections and tests of safety equipment when risk assessment "shows" that such cutbacks would not increase risk. For example, the NRC has approved changing a test interval for a piece of equipment from once per month to once per quarter when risk information gathered and submitted by the plant's owner suggested that the equipment's failure will not significantly increase the probability of reactor core damage.

The NRC conceded that it cannot demonstrate the move to risk-informed regulation is necessary or will improve safety, the two criteria necessary to justify its use:

> More fundamentally, it may be very difficult to show that the risk informed changes, in any form, either: (i) will result in a substantial increase in overall protection of the

52. Nuclear Energy Institute, "Refueling Outages at US Nuclear Plants (Average Duration)," Washington, D.C., 1999. Available online at *www.nei.org.*

53. Nuclear Energy Institute, "US Nuclear Power Plant Average Capacity Factors 1980–1998," Washington, D.C., 1999. Available online at *www.nei.org.*

54. Brenda L. Mozafari, Project Manager, Nuclear Regulatory Commission, to Eliot Protsch, President, IES Utilities, Inc., "Duane Arnold Energy Center—Issuance of Amendment Re: Revised Excess Flow Check Valve Surveillance Requirements," Washington, D.C., December 29, 1999.

55. L. Raghavan, Senior Project Manager, Nuclear Regulatory Commission, to Harold B. Ray, Executive Vice President, Southern California Edison Company, "San Onofre Nuclear Generating Station, Units 2 and 3—Issuance of Amendments on Small Break Loss-of-Coolant Accident Charging Flow and Main Steam Safety Valve Setpoints," Washington, D.C., February 22, 2000.

> public health and safety or common defense and security, the initial backfit threshold finding; or (ii) are *necessary* for adequate protection.[56] [emphasis in original]

Yet the NRC continues to apply considerable resources to the move simply because it may save plant owners a few dollars. The public would be better served if these resources were applied to restoring safety margins at nuclear power plants. For example, the NRC could use these funds for additional inspections at nuclear power plants to seek out and correct more of the design blunders described in section 4 of this report.

56. William D. Travers, Executive Director for Operations, Nuclear Regulatory Commission, to Commissioners, Nuclear Regulatory Commission, "Options for Risk-Informed Revisions to 10 CFR Part 50—Domestic Licensing of Production and Utilization Facilities," SECY-98-300, Washington, D.C., December 23, 1998.

Section 8: Recommendations

The TMI accident revealed that perhaps reactors were not "safe enough," that the regulatory system has some significant problems (as cited in both the Kemeny and Rogovin investigations), that the probability of serious accident was not vanishingly small, and that new approaches were needed.

—Nuclear Regulatory Commission, 1984

The incomplete and inaccurate state of nuclear plant risk assessments does not provide a solid foundation for the NRC to move towards risk-informed regulation. Before the NRC takes another step towards risk-informed regulation, the NRC must complete the following tasks:

1. Establish a minimum standard for plant risk assessments that includes proper methods for

   a) handling the fact that nuclear plants may not conform with all technical specification and regulatory requirements

   b) handling the fact that nuclear plants may have design, fabrication, and construction errors

   c) handling equipment aging

   d) treating the probability of reactor pressure vessel failure

   e) handling human performance

   f) handling events other than reactor core damage in which plant workers and members of the public may be exposed to radioactive materials (e.g., spent fuel pool accidents and radwaste system tank ruptures)

   g) handling nuclear plant accident consequences to plant workers and members of the public

   h) justifying the assumptions used in the risk assessments

   i) updating the risk assessments when assumptions change

2. Require all plant owners to develop risk—not probability—assessments that meet or exceed the minimum standard.

3. Require all plant owners to periodically update the risk assessments to reflect changes to the plant and/or plant procedures.

4. Require all plant owners to make the risk assessments publicly available.

5. Conduct inspections at all nuclear plants to validate that the risk assessments meet or exceed the minimum standards.

6. Disallow any use of risk assessment results to define a line between acceptable and unacceptable performance until all of the steps listed above are completed.

It will take considerable effort on the part of the NRC to implement these recommendations. Unfortunately, the NRC may be unable to take these safety steps because it is under attack from the US Congress to reduce its budget. Why? The NRC is a fee-based agency. Most of the NRC's budget is paid not by taxpayers but by the plants' owners. These plant owners lobbied Congress to slash the NRC's budget. Congress listened and slashed. In 1987, the NRC had 850 regional and 790 headquarters staff members. Ten years later, chronic budget cuts had reduced the NRC to 679 regional and 651 headquarters staff members.[57] During a decade that began with 101 licensed nuclear power plants and ended with 109 plants, the NRC lost 20 percent of its safety inspectors.[58]

The US Congress must provide the Nuclear Regulatory Commission with the budget and resources necessary to implement the recommended safety steps.

This course of action was first advocated by Henry Kendall 25 years ago:

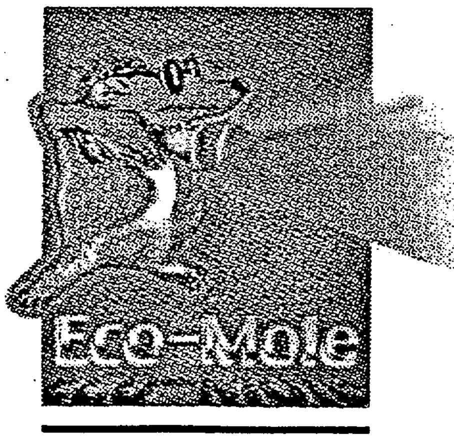
> Safety in the nuclear program must stem from a full understanding of potential mishaps and from the greatest diligence in applying that knowledge to design, construction, operation, maintenance and safeguarding of nuclear materials and facilities. With such care it might prove possible to protect against damaging accidents, arising from error and irresponsibility, equipment malfunctions, acts of God, and acts of intentional ill-will. Public acceptance of nuclear power depends not only on meeting the above requirements but also, in an important addition, on insuring that public concerns are abated by forthright disclosure of all safety issues together with convincing evidence of their full resolution.[59]

The old adage of "better late than never" certainly applies in this case.

57. NRC Office of Nuclear Reactor Regulation, "Regulatory Trends," Washington, D.C., April 1997.

58. Sadanandan V. Pullani, "Design Errors in Nuclear Power Plants."

59. Henry W. Kendall, "Public Safety and Nuclear Power," testimony before the US House Committee on Interior and Insular Affairs Subcommittee on Energy and the Environment, April 29, 1975. Available from the Union of Concerned Scientists, Cambridge, Mass.



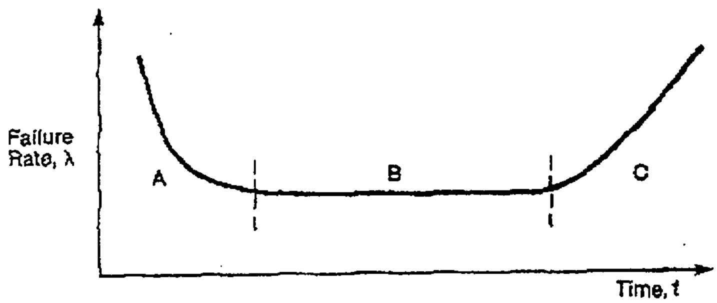
Reactors Kill

In a little-noted "correction" published in the July 30, 2001 *Federal Register*, the Nuclear Regulatory Commission (NRC) confirmed that relicensing aging US reactors to operate for another 20 years would release 14,800 person-rems of radiation per plant. The NRC calculated this exposure could cause 12 cancer deaths per reactor. With as many as 100 reactors seeking operating extensions, that means 1,200 cancer deaths. The estimate does not include deaths from the storage, transport and disposal of radioactive materials. The Nuclear Information and Research Service [*1424 16th St. NW, No. 404, Washington, DC 20036, (202) 328-0002, www.nirs.org*] suggests that "instead of relicensing atomic reactors, we should be closing them and accelerating… [the shift to] renewable energy technologies."

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

Aging Nuclear Plants and License Renewal - Updated 09/13/2001

The NRC allows nuclear plant owners to cut back on the number of safety tests and inspections. The NRC justifies this safety rollback on the notion that experience demonstrates improved equipment reliability. But the fact remains that nuclear plant equipment—just like virtually all living and inanimate objects—follows what is called the "bathtub" curve. Region A, or the break-in phase, and Region C, the wear-out phase, have high failure rates while Region B reflects peak reliability during middle life. The NRC uses the lower failure rate for equipment in Region B to relax testing intervals from once per quarter to once per year. Mathematical magic then falsely "proves" safety gains. For example, consider a component that fails every time it is tested. Going from quarterly to annual tests reduces the number of failures per year from four to one. On paper, safety is greatly improved. But in the plant, safety is unchanged. Every nuclear plant in the United States is in Region B heading towards Region C, if it is not already into the wear-out phase. Cutting back on safety checks saves plant owners money, but it may someday cost lives.



"Bathtub" Curve of Failure Rate

The NRC originally licensed nuclear plants for 40 years. Plant owners have the option of seeking a 20-year extension. The Nuclear Regulatory Commission (NRC) renews licenses after determining plant owners have aging management programs to monitor the condition of important equipment and structures so that repairs and/or replacements will take place to prevent failures. But failures are simply <u>not</u> being prevented because many nuclear plants have been forced to shut down since January 1, 2000, after aging equipment broke:

1. March 7, 2000: The owner reported that Nine Mile Point Unit 2 in New York had automatically shut down when the system controlling the level of water over the reactor core failed. The owner attributed the failure as "Specifically, the manual-tracking card failed to provide an output signal when the feedwater master controller was switched from automatic to manual mode of operation … The manual-tracking card failed due to **<u>aging</u>**." [emphasis added]

2. March 14, 2000: The owner reported that Catawba Unit 1 in South Carolina had automatically shut down due to an inadvertent electrical ground problem. The owner reported "A detailed failure analysis determined that the root cause of the connector failure was the misapplication of the connector insert insulating material which is made of neoprene. … The neoprene insert at the failure point on the connector exhibits signs of **<u>accelerated aging</u>** [emphasis added]. The inserts are hardened and there are charred deposits on the end of the inserts which are indications of electrical tracking."

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3. March 17, 2000: The owner reported that Indian Point Unit 2 in New York had been forced to declare an emergency condition and shut down after a steam generator tube failed and resulted in approximately 19,197 gallons leaking from the reactor coolant system. The owner stated "Preliminary analysis indicates that the cause of the tube failure is primary water stress corrosion cracking (PWSCC)" [i.e., aging].

4. March 27, 2000: The owner reported that Catawba Unit 2 in South Carolina had automatically shut down due to an inadvertent electrical ground problem. The owner reported "A detailed failure analysis determined that the root cause of the connector failure was the misapplication of the connector insert insulating material which is made of neoprene. ... The neoprene insert at the failure point on the connector exhibits signs of **accelerated aging** [emphasis added]. The inserts are hardened and there are charred deposits on the end of the inserts which are indications of electrical tracking."

5. September 12, 2000: The owner reported that Oyster Creek in New Jersey had been forced to shut down because a system needed to provide containment integrity had failed a periodic test. The owner determined "The cause of the degradation in Secondary Containment was **age-related degradation** [emphasis added] of the automatic ventilation exhaust valve seals."

6. September 27, 2000: The NRC reported that Diablo Canyon Unit 1 in California had automatically shut down after an electrical transformer failed and interrupted the supply of electricity to the reactor coolant pumps. The NRC stated "The licensee's evaluation concluded that a center bus bar overheated at a splice joint, which caused a polyvinyl chloride boot insulator over the splice joint to smoke. Eventually, heat-induced failure of fiberglass insulation on adjacent phases resulted in phase-to-phase arcing" [i.e., aging].

7. February 16, 2001: The owner reported that North Anna Unit 2 in Virginia had been forced to shut down due to leakage exceeding ten gallons per minute from the reactor coolant system. The owner determined "The cause of the stem packing material failure below the lantern ring is attributed to **aging**" [emphasis added].

8. April 2, 2001: The owner reported that San Onofre Unit 3 in California automatically shut down after an electrical breaker failed and started a fire. The failed breaker was reportedly 25 years old and scheduled for inspection *next* year. The owner "will implement modifications to appropriate **preventative maintenance** [emphasis added] procedures to address the apparent failure causes."

9. April 23, 2001: The owner reported that South Texas Project Unit 2 in Texas had been forced to shut down after actions in the plant's electrical switchyard tripped all three pumps supplying cooling water to the main condenser. The pumps stopped running after workers took one electrical circuit out of service thinking that a backup circuit was available to take up the load. However, the backup circuit was also out of service because an electrical breaker had remained opened after workers tried to close it. The breaker's failure was attributed by the owner to "accelerated wear of the components" [i.e., aging].

10. April 24, 2001: The owner reported that Limerick Unit 2 in Pennsylvania had been forced to shut down when a pressure relief valve spuriously opened and remained open. The owner attributed the failure to "a sudden loss of material from the first stage pilot valve due to erosion and oxidation of the Stellite disc material in the area of the seating surface" [i.e. aging]. The owner additionally reported that "The SRV [safety relief valve] Leakage Determination Monitoring Process did not consider all possible failure mechanisms."

11. May 9, 2001: The owner reported that Beaver Valley Unit 2 in Pennsylvania had automatically shut down after a motor-driven pump supplying cooling water to the steam generator failed. The pump's failure was attributed by the owner to "a combination of long term heating, **accelerated oxidation** [i.e., aging], and marginal sizing of the motor cable and terminal lugs." [emphasis added]

12. July 17, 2001: The owner reported that Nine Mile Point Unit 2 in New York had automatically shut down after a relay in the reactor protection system failed. The relay manufacturer had notified its customers four years earlier that the relay was vulnerable to oxide buildup [i.e., aging] and recommended a modification to the relays along with periodic replacement. The owner opted not to implement either recommendation; at least, not until after this event.

13. August 13, 2001: The owner reported that Beaver Valley Unit 1 in Pennsylvania had been forced to shut down when the instrument air system pressure declined to the point where air-operated valves throughout the plant began closing. The owner attributed the pressure loss to "**mechanical aging/cyclic fatigue**" of the spring in a valve that caused the output from the air compressor to be vented rather than directed to the system piping. [emphasis added]

14. August 14, 2001: The owner reported that the Kewaunee nuclear plant in Wisconsin had automatically shut down due to insufficient instrument air supply to the regulating valve for feedwater flow to the steam generator. The regulating valve closed when the instrument air pressure dropped. The owner attributed the air pressure loss to a tear in a neoprene diaphragm that had not been detected due to a "running to failure" maintenance schedule. In other words, the part wore out and broke.

15. August 20, 2001: The owner reported that the Perry nuclear plant in Ohio had automatically shut down after a blown fuse stopped the flow of cooling water to the reactor core. The owner determined that the fuse blew from high electrical resistance "**due to age related oxidation.**" [emphasis added]

Nuclear power plants generate revenue by producing electricity. If their owners are unable to properly maintain the equipment needed to make them money, why should the public believe that they are able to properly maintain the equipment needed to make us safe?

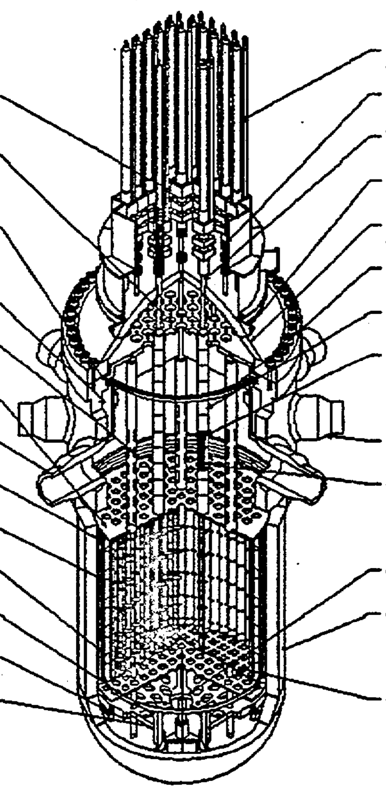
Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions | issue brief

Not-So-Happy Anniversary:
10 Years of Band-Aid Fixes for CRDM Nozzle Cracking

Workers testing the integrity of the reactor vessel at France's Bugey Unit 3 in September 1991 found something that had never been seen before — cracks extending completely through the wall of a control rod drive mechanism nozzle that permitted reactor cooling water to leak out. Subsequent examinations discovered cracks of up to two inches long.[1] Nearly ten years later, the U.S. Nuclear Regulatory Commission is seeing what it said would not be seen — even more serious cracking of CRDM nozzles at nuclear reactors in the United States. And we are belatedly seeing what should have been seen at least six years ago — efforts by the NRC to address this nuclear safety hazard. But we have not yet seen what foreign countries have done to solve CDRM nozzle cracking — replacement of the reactor vessel heads.

What is a CRDM Nozzle?

In pressurized water reactors like Bugey and roughly two-thirds of the nuclear plants operating in the United States, control rods enter the reactor core from the top. The control rods are withdrawn when the plant is operating, but can be fully inserted within seconds to stop the nuclear chain reaction and shut down the reactor.



Each control rod is attached to its own control rod drive mechanism (CRDM). The CRDM is basically a long pole and equipment that is used to position the control rod. The pole is so long that it extends through the domed metal enclosure head to the reactor vessel. Above the vessel head, CRDM equipment moves the long pole. By sequentially energizing a number of electromagnets, the pole can be lifted or lowered, which in turn withdraws or inserts the attached control rod. If the electromagnets are de-energized, their grip on the pole is released and the control rod drops fully into the reactor core by gravity.[2]

The holes cut in the metal vessel head for the long poles receive special attention because the pressure inside the reactor vessel during operation exceeds 2,000 pounds per square inch. The CRDM nozzles are hollow tubes containing the long poles. The upper end of the nozzle is capped while the lower end, located inside the reactor vessel, is open. The nozzles, made of steel called Alloy 600, are welded to the vessel head. The reactor vessel and the nozzles form the reactor coolant pressure boundary.

[1] V. N. Shah, A. G. Ware, and A. M. Porter, Idaho National Engineering Laboratory, "Assessment of Pressurized Water Reactor Control Rod Drive Mechanism Nozzle Cracking," NUREG/CR-6245, October 1994.
[2] The University of California at Berkeley, System Training Guide A-3a, "Rod Control System," 1996.

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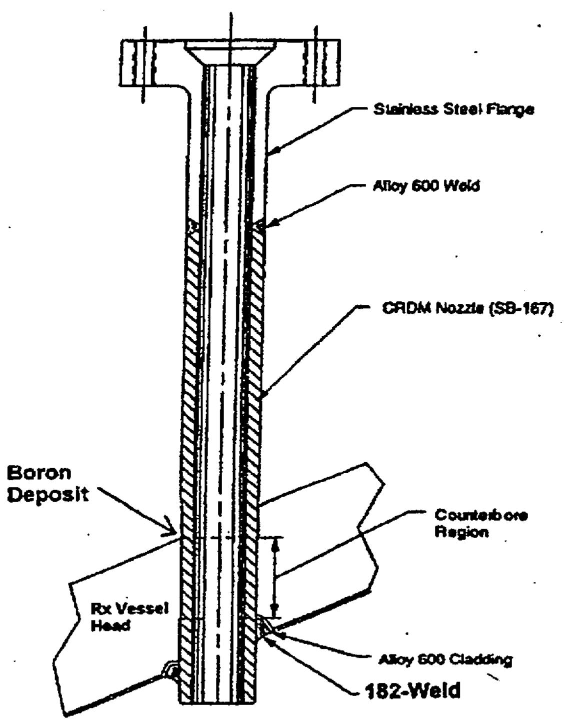
Not-So-Happy Anniversary:
10 Years of Band-Aid Fixes for CRDM Nozzle Cracking

Why are the CRDM Nozzles Cracking?
CRDM nozzles are susceptible to degradation by Primary Water Stress Corrosion Cracking (PWSCC). The PWSCC occurs when stress causes material imperfections to get "pulled." High temperatures of up to 600°F during reactor operation create stress. Metal expands as its temperature increases. The reactor vessel is not at the same temperature because some parts are closer to the reactor core and air conditioning flow outside the reactor vessel is different. Temperature differences create stress as parts of the reactor vessel expand at different rates. Stress can cause a crack at any minor imperfection in the metal leftover from the manufacturing or installation processes. Once a crack develops, stress causes it to grow larger.

What Happens When CRDM Nozzles Crack?
CRDM nozzle cracking can lead to rupture of the nozzle followed by ejection of the CRDM/control rod or leakage of reactor water onto the unprotected outer surface of the vessel head causing its failure.

In April 2001, the owner of Oconee Unit 3 in South Carolina reported finding through-wall leaks on nine of sixty-nine CRDM nozzles. Workers found the leaks after observing boron deposits at the base of the CRDM nozzle as shown in the figure. Boron deposits are clear signs that borated reactor water is leaking out. The cracking extended nearly 45 percent of the way around the circumference of nozzle-to-vessel head welds on two CRDM nozzles.[3]



At some point, cracks can grow so large that the CRDM nozzle no longer remains intact with over 2000 pounds per square inch pressure inside and zero pressure outside. The catastrophic rupture of the CRDM nozzle causes a loss-of-coolant accident. In addition to the reactor water pouring out the hole, the CRDM could be ejected, pulling its control rod out of the reactor core.

The inner surface of the reactor vessel head is covered by stainless steel (represented in the figure by the thin gray region at the bottom edge). The stainless steel protects the reactor vessel head from corrosion by borated water (i.e., dilute boric acid). The outer surface of the reactor vessel head is unprotected. Borated water can weaken the reactor vessel metal through corrosion, particularly when evaporation causes the boron concentration to increase. If the weakened reactor vessel fails, water may leak out faster than the emergency systems can replace it.

[3] Duke Energy, Licensee Event Report No. 50-287/2001-001 Rev. 0, April 18, 2001, and Nuclear Regulatory Commission, Bulletin No. 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles," August 3, 2001.

Not-So-Happy Anniversary:
10 Years of Band-Aid Fixes for CRDM Nozzle Cracking

What Has the NRC Done About CRDM Nozzle Cracking?

After CRDM nozzle cracking was reported at Bugey Unit 3 in 1991, the NRC initiated a research program to examine the issue for US reactors. As the NRC research program was plodding along, Greenpeace International petitioned the NRC on March 24, 1993, to require inspections of CRDM nozzles at all US reactors and to make the inspection results publicly available. Greenpeace also sought to shut down all reactors with cracked nozzles. The NRC denied Greenpeace's requests nearly two years later.[4]

The NRC's denial was based in large part on the research report prepared by the Idaho National Engineering Laboratory for the NRC. This report, released in October 1994, concluded "CRDM nozzle cracking is not a short-term safety issue. All the detected cracks on the nozzle inside surface are axially oriented. ... Some analyses have shown that short, circumferential cracks on the outside surface are possible; however, these cracks are not expected to grow through-wall...". At the time of this conclusion, a grand total of one (1) US nuclear plant (Point Beach Unit 1in Wisconsin) had been inspected for CRDM nozzle cracking.[5]

After large, through-wall, circumferential cracking was found on the outside surface of 2 CRDM nozzles at Oconee Unit 3, the NRC asked plant owners to write them about inspections of CRDM nozzles and the extent of identified cracking. In essence, the NRC is doing *part* of what Greenpeace asked eight years ago.

What Should the NRC Do About CRDM Nozzle Cracking?

After the NRC's letter collecting campaign is out of the way, the NRC should take real steps to protect public health and safety. As a bare minimum, the NRC should do what has already been done in foreign countries to protect non-Americans from CRDM nozzle cracking:[6]

1. "In Japan, the three most susceptible vessel heads are being [have been] replaced because of safety considerations, even though no cracks were found in the nozzles of these heads."

2. "In France, EDF has found it economical to replace the vessel heads having defective nozzles; several heads have been replaced or are planned to be replaced."

3. "In Sweden, replacement of the Ringhals 2 vessel head is planned."

4. "Removable insulation on the vessel head and N-13 monitoring systems are installed at French and Swedish plants for early detection of leakage from through-wall cracks in the nozzle wall." "Installation of a N-13 leak monitoring system can provide a continuous and accurate monitoring of a leak as small as 0.2 L/h (0.001 gpm) from a cracked CRDM nozzle."

What Will the NRC Probably Do About CRDM Nozzle Cracking?

It is highly unlikely that the NRC will require any of the safety measures that already have been taken at foreign reactors; at least not until after an accident at a US reactor demonstrates that the band-aid fix experiments are inadequate.

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[4] Nuclear Regulatory Commission, Director's Decision under 10 CFR 2.206, DD-95-02, January 26, 1995.
[5] V. N. Shah, A. G. Ware, and A. M. Porter, Idaho National Engineering Laboratory, "Assessment of Pressurized Water Reactor Control Rod Drive Mechanism Nozzle Cracking," NUREG/CR-6245, October 1994.
[6] V. N. Shah, A. G. Ware, and A. M. Porter, Idaho National Engineering Laboratory, "Assessment of Pressurized Water Reactor Control Rod Drive Mechanism Nozzle Cracking," NUREG/CR-6245, October 1994.

AMERICA'S SELF-IMPOSED NUCLEAR THREAT

Nuclear Power and Terrorism

by Harvey Wasserman

As US bombs and missiles began to rain on Afghanistan, the certainty of terror retaliation inside the US has turned our 103 nuclear powerplants into potential weapons of apocalyptic destruction, just waiting to be used against us.

One or both planes that crashed into the World Trade Center on September 11 could have easily obliterated the two atomic reactors now operating at Indian Point, about 40 miles up the Hudson River.

Indian Point-Unit One was shut long ago by public outcry. But Units 2 and 3 have operated since the 1970s. Reactor containment domes were built to withstand a jetliner crash but today's jumbo jets are far larger than the planes that were flying in the 1970s.

Had one of those hijacked jets hit one of the operating reactors at Indian Point, the ensuing cloud of radiation would have dwarfed the ones at Hiroshima and Nagasaki, Three Mile Island and Chernobyl.

The intense radioactive heat within today's operating reactors is the hottest anywhere on the planet. Because Indian Point has operated so long, its accumulated radioactive burden far exceeds that of Chernobyl.

The safety systems are extremely complex and virtually indefensible. One or more could be wiped out with a small aircraft, ground-based weapons, truck bombs or even chemical/biological assaults aimed at the work force.

A terrorist assault at Indian Point could yield three infernal fireballs of molten radioactive lava burning through the earth and into the aquifer and the river. Striking water, they would blast gigantic billows of horribly radioactive steam into the atmosphere. Thousands of square miles would be saturated with the most lethal clouds ever created, depositing relentless genetic poisons that would kill forever.

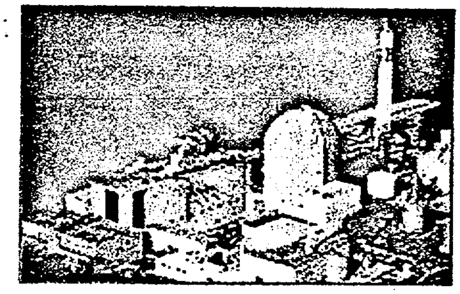
Infants and small children would quickly die en masse. Pregnant women would spontaneously abort or give birth to horribly deformed offspring. Ghastly sores, rashes, ulcerations and burns would afflict the skin of millions. Heart attacks, stroke and multiple organ failure would kill thousands on the spot. Emphysema, hair loss, nausea, inability to eat or drink or swallow, diarrhea and incontinence, sterility and impotence, asthma and blindness would afflict hundreds of thousands, if not millions.

America's 103 nuclear reactors are ticking time bombs that must be shut down.

Then comes the wave of cancers, leukemias, lymphomas, tumors and hellish diseases for which new names will have to be invented.

Evacuation would be impossible, but thousands would die trying. Attempts to quench the fires would be futile. More than 800,000 Soviet draftees forced through Chernobyl's seething remains in a futile attempt to clean it up are still dying from their exposure. At Indian Point, the molten cores would burn uncontrolled for days, weeks and years. Who would volunteer for such an American task force?

The immediate damage from an Indian Point attack (or a domestic accident) would render all five boroughs of New York City an



A "terrorist's-eye" view of the Indian Point reactor.

apocalyptic wasteland.

As at Three Mile Island, where thousands of farm and wild animals died in heaps, natural ecosystems would be permanently and irrevocably destroyed. Spiritually, psychologically, financially and ecologically, our nation would never recover.

This is what we missed by a mere 40 miles on September 11. Now that we are at war, this is what could be happening as you read this.

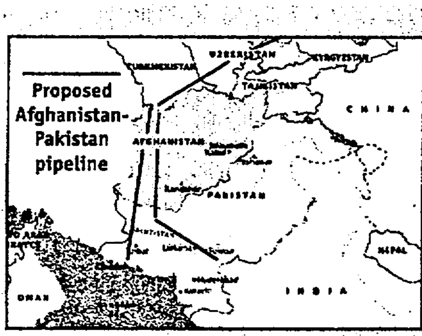
There are 103 of these potential Bombs of the Apocalypse operating in the US. They generate a mere 8 percent of our total energy. Since its deregulation crisis, California cut its electric consumption by some 15 percent. Within a year, the US could cheaply replace virtually all the reactors with increased efficiency.

Yet, as the terror escalates, Congress is fast-tracking the extension of the Price-Anderson Act, a form of legal immunity that protects reactor operators from liability in case of a meltdown or terrorist attack.

Do we take this war seriously? Are we committed to the survival of our nation?

If so, the ticking reactor bombs that could obliterate the very core of our life and of all future generations must be shut down.

Harvey Wasserman is author of The Last Energy War *and co-author of* Killing Our Own: The Disaster of America's Experience with Atomic Radiation.



Afghanistan: It's About Oil

In 1998, Dick Cheney (then CEO of Halliburton, a major US oil-services company) commented: "I cannot think of a time when we have had a region emerge as suddenly to become as strategically significant as the Caspian." Cheney was looking ahead to the day when some 50 billion barrels of oil and natural gas lying beneath the dry earth of Kazakstan would begin flowing into US-controlled terminals in the Caspian Sea.

Unfortunately, the most direct and cost-efficient pipeline route would cross through Iran, America's nemesis. (While Washington was loath to bargin with Iran, one private US consortium was prepared to deal: It was a British Virgin Islands firm headed by none other than former US Secretary of State Alexander Haig.)

"From the US standpoint," Brown University anthropologist William O. Beeman observed, "the only way to deny Iran everything is for the anti-Iranian Taliban to win in Afghanistan and to agree to the pipeline through their territory." That is exactly what happened – thanks to the CIA.

The first proponent of the Afghan oil route was the Bridas Group, an Argentine company. Competition quickened with the entry of Unocal's John Imle who proposed a US-controlled pipeline paralleling Bridas' route. In 1998, Unocal signed a deal with the Taliban to build an 890-mile natural gas pipeline from Turkmenistan to Pakistan, but the plan was thwarted by continuing civil war. Unocal informed the Department of Energy that the gas pipeline would not proceed until "an internationally recognized government was in place in Afghanistan."

By 2050, the US expects to import more than 80 percent of its petroleum from this region and much of that oil would be extracted from beneath the deserts of Afghanistan and Pakistan. The struggle for control of this last great deposit of oil has been called "the Great Game."

In 1998, Unocal Vice President John J. Maresca told a US House Subcommittee that an oil route to the Arabian Sea would prove a "new 'Silk Road' [linking]... the Central Asia supply with the demand." This would also stymie the dreams of Iran's oil investors. A December 2000 US Energy Information fact sheet noted that, while

Continued on next page