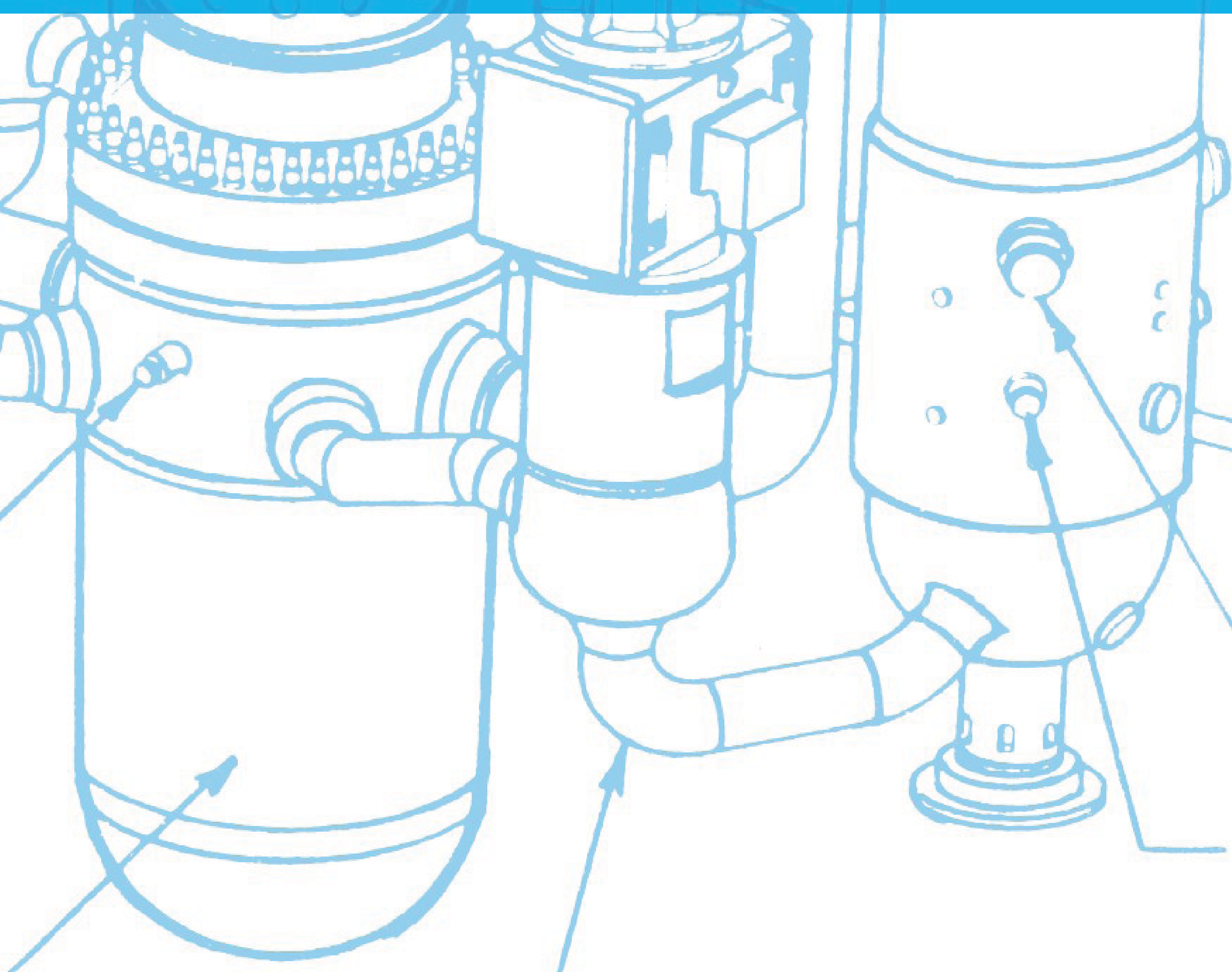
Attachment D

Report – Union of Concerned Scientists
“Risk of a Lifetime”

U.S. Nuclear Plants in the 21st Century

THE RISK OF A LIFETIME



Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

U.S. Nuclear Plants in the 21st Century

THE RISK OF A LIFETIME

David Lochbaum

UNION OF CONCERNED SCIENTISTS

MAY 2004

David Lochbaum is a nuclear safety engineer in the UCS Clean Energy Program. He worked for nearly 20 years in the U.S. commercial nuclear power industry prior to joining UCS in 1996. He holds a degree in nuclear engineering from the University of Tennessee.

The Union of Concerned Scientists is a nonprofit partnership of scientists and citizens combining rigorous scientific analysis, innovative policy development, and effective citizen advocacy to achieve practical environmental solutions.

The UCS Clean Energy Program examines the benefits and costs of the country's energy use and promotes energy solutions that are sustainable both environmentally and economically.

More information about UCS and the Clean Energy Program is available on the World Wide Web at *www.ucsusa.org*.

The full text of this report is available on the UCS website or may be obtained from:

UCS Publications
Two Brattle Square
Cambridge, MA 02238-9105

Or, email *pubs@ucsusa.org* or call (617) 547-5552.

Cover: A line drawing showing the major components of a nuclear power plant. Source: Nuclear Regulatory Commission.

Design: Mary Zyskowski

Printed on recycled paper

CONTENTS

FIGURES AND TABLES

Figures

Tables

ACKNOWLEDGMENTS

The author would like to thank Paul Blanch, Alan Nogee, James Riccio, and Ulrich Witte for reviewing all or parts of the report at various stages in its preparation, Heather Tuttle for editorial assistance, and Mary Zyskowski for design and layout.

We appreciate the valuable advice and information provided by reviewers, but we note that this report does not necessarily reflect their opinions. The Union of Concerned Scientists is solely responsible for the contents of this report.

Executive Summary

The risks for catastrophe change as nuclear reactors age, much like the risks for death by accident and illness change as people get older. Protection schemes must evolve to remain correlated with age if the threat level is to be minimized. For people, it means replacing protective measures for toddlers (such as safety plugs in electrical outlets) with parental watchfulness against teenage drinking and driving. It also means testing for signs of age-related illness (such as glaucoma, heart disease, and osteoporosis) as people get older. For nuclear reactors, it means aggressively monitoring risk during the three stages of plant lifetime: the break-in phase, middle life phase, and wear-out phase. The risk profile for these three phases of life curves like a bathtub. The Union of Concerned Scientists (UCS) identified the best ways to manage the risks from nuclear power at all points along the bathtub curve.

The Break-in Phase

Any new reactors that are built will start out on the high-risk break-in segment of the curve. Several nuclear plant disasters—Fermi, Three Mile Island, and Chernobyl to name just a few—demonstrated the perils of navigating this part of the curve. Literally thousands of unexpected safety problems surfaced at other nuclear plants. These surprises drove safety levels down and nuclear power's costs up unnecessarily. Public intervention in licensing proceedings led to numerous safety improvements, but recent changes to the licensing process limit the public's role to essentially that of a casual observer. If new reactors are built, we must benefit from these hard and expensive lessons by: (1) excluding new reactors from federal liability protection under the Price Anderson Act, thereby removing the current disincentive for vendors to design safety upgrades; (2) verifying safety performance against expectations on prototype reactors before commercial reactors are built; (3) conducting extensive inspections of new reactors during design and construction to verify compliance with safety requirements; and (4) allowing meaningful public participation in the licensing process.

The Middle Life Phase

Increasing the maximum power output while cutting back on safety inspections at existing reactors reduces the margin for error along the middle segment of the bathtub curve. The fact that 27 nuclear reactors have been shut down in the past two decades for safety problems that took a year or longer to fix demonstrates that errors are abundant and margins for error are still necessary. Many of the safety cutbacks at nuclear plants are being justified based on deficient risk assessments. These risk assessments have resulted in poor management decisions, such as the decision in 2001 allowing the Davis-Besse nuclear plant in Ohio to continue operating in an unsafe manner. Risk at existing reactors can be best managed by: (1) improving the oversight of methods used by plant owners to find and fix errors; (2) ending the practice of risk-informed decision making using flawed risk studies; and (3) using risk insights not just to reduce unnecessary regulatory burdens but also to shore up regulatory gaps as well.

The Wear-out Phase

Today's aging reactors, and any reactors granted 20-year extensions to their current 40-year operating licenses, face the high-risk wear-out segment of the bathtub curve. Despite efforts to monitor the condition of aging equipment, there are recent age-related failures caused by monitoring the right areas using the wrong techniques and by monitoring the wrong areas using the right techniques. In addition, nuclear plants seeking license renewal conform not to today's safety standards, but to a unique assortment of regulations dating back nearly 40 years with countless exemptions, deviations, and waivers granted along the way. While each individual exemption or waiver may be justified as not reducing safety margins, the cumulative effect of so many exceptions can adversely affect safety. To properly manage the risk at aging reactors: (1) multiple inspection techniques must be required for high-risk equipment; (2) expanded inspections must be required for equipment currently considered less vulnerable to aging; and (3) all differences between today's safety regulations and the mix of regulations applicable to today's reactors must be identified and reviewed to verify that no safety gaps exist.

What Needs to Be Done

While the risks and reasons for the risks vary along the bathtub curve, the consequences of failing to manage the risks remain nearly constant—potentially massive releases of radioactivity into the atmosphere with devastating harm to people and places downwind.

An aggressive regulator consistently enforcing federal safety regulations provides the best protection against these risks. Sadly, America lacks such protection. Since UCS began its nuclear safety project nearly three decades ago, we have engaged the Nuclear Regulatory Commission and its predecessor, the Atomic Energy Commission, countless times. We advocated enforcement of existing regulations far more often than for adoption of new regulations. Regulations might provide adequate protection, but only when they are followed. By failing to consistently enforce the regulations, the NRC exposes millions of Americans to greater risk than necessary. The federal government must reform the NRC into a consistently effective regulator so it properly manages the risk at all points along the nuclear bathtub curve.

CHAPTER 1

Introduction

There is renewed debate about the role of nuclear power in America's energy future. Some people see new nuclear power plants on the horizon, citing proposed legislation calling for increased subsidies for an already heavily subsidized industry as evidence of the pending nuclear revival. Others see nuclear power only in America's rearview mirror. As evidence of nuclear power's demise, they cite the eight reactors permanently closed since 1990 due to unfavorable economics and the three new reactor designs certified by the Nuclear Regulatory Commission (NRC) in the late 1990s but collecting dust on the shelf because they are too expensive.

Whatever the future holds for nuclear power, the Union of Concerned Scientists (UCS) identified the best ways to manage the risks from nuclear power. Existing reactors have not reached and will never reach a nuclear nirvana where catastrophes cannot happen. With many of today's reactors being relicensed to operate for up to 60 years, proper risk management becomes essential in preventing the imagined nirvana from turning into a nightmare. None of the proposed new reactor designs is inherently safe, as amply documented by UCS in the early 1990s and recently reaffirmed by the industry's express demand that the 1957 Price-Anderson Act be amended to extend federal liability protection against catastrophes at new reactors. As long as a single nuclear reactor, of any age, operates in the United States, Americans must be protected from the inherent risks.

In this report, UCS deals only with the highest-priority safety problems and recommends steps to start the NRC on the path toward necessary reforms. These reforms would lay the proper foundation for the NRC to resolve long-standing safety problems at the more than 100 nuclear plants operating nationwide. Congress must sustain the NRC reform effort through completion of this entire process, to provide the American public with the protection they expect and deserve.

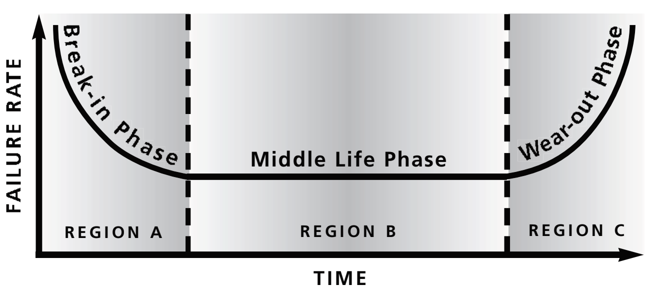
The Bathtub Curve

The risks for catastrophe change as nuclear reactors age, much like the risks for death by accident and illness change as people get older. Protection schemes must evolve to remain correlated with age if the threat level is to be minimized. For people, it means replacing protective measures for toddlers (such as safety plugs in electrical outlets) with parental watchfulness against teenage drinking and driving. It also means testing for signs of age-related illness (such as glaucoma, heart disease, and osteoporosis) as people get older. For nuclear reactors, it means aggressively monitoring risk during the three stages of plant lifetime: the break-in phase, middle life phase, and wear-out phase. The risk profile for these three phases of life curves like a bathtub.

The bathtub curve is drawn from statistical data about lifetimes of both living and nonliving things. If you monitored 10,000 widgets—light bulbs, automobile tires, cats, cell phones, or nuclear reactors—and plotted how many expired in the first month, the second month, the third month, and so on, your graph would curve upward on either end from a flat middle section (like a bathtub.) The graph might not be symmetrical, but it would generally reflect low failure rates in the middle with higher failure rates on the ends.

The left-hand side of the bathtub curve, labeled Region A in Figure 1, represents the infant mortality or break-in phase of life. Infants are vulnerable to numerous illnesses until they grow stronger and build up immunities. Similarly, products may fail soon after being put to use due to manufacturing defects, material imperfections, or poor workmanship (U.S. Army Corps of Engineers, 2001). The steepness of the curve in Region A depends on factors such as the effectiveness of quality control measures applied during product manufacturing.

Figure 1 **The Bathtub Curve**



Source: NASA, 2001.

Region B, the middle portion of the bathtub curve, represents the useful lifetime for products and the peak health years for living things. Accidents and random events still occur, but at a lower rate than in Region A. The height (i.e., how far off the floor) and size (i.e., distance between ends) of the bathtub in Region B depends, for people, on factors such as environment and life-style choices.

The right-hand side of the curve, labeled Region C, is the wear-out phase. Due to aging, it takes less stress to cause failure in this region, just as older people are more prone to breaking bones in a fall than younger people. Thus, the chances of failure increase with time spent in Region C (NASA, 2001).

Applications of the Bathtub Curve

The bathtub curve concept is readily evident in everyday life. A new car comes with a warranty to cover problems during its break-in phase. When money is borrowed from a bank to buy a car, the loan term is typically three or four years—timed to be paid off before the car enters the wear-out phase. New shoes may be uncomfortable until they are worn in and then remain comfortable until worn out. And even the family pet is more fragile as a puppy and when long in the tooth than in the intervening years.

The mathematical exercise used to generate the bathtub curve does not mean the fate of a specific product or individual is preordained. Consider two identical new cars purchased from the same dealer on the same day. The first owner changes the engine oil and performs all other recommended maintenance tasks at the prescribed intervals. The second owner only changes the radio station. It is far more likely—but not guaranteed—that the first owner's car will have a longer useful life.

The bathtub curve concept also applies to nuclear power plants. The following sections examine how Regions A, B, and C of the bathtub curve dictate the risk from nuclear plant operation and recommend how that risk can be best managed.

CHAPTER 2

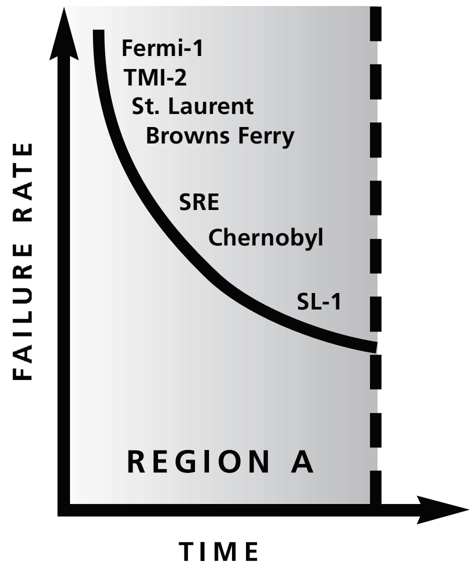
Nuclear Plant Safety in Region A

Every nuclear power reactor starts in Region A, where risk for accident and failure are high. Previously unrecognized vulnerabilities, manufacturing defects, material imperfections, and poor workmanship all contribute to high failure rates in newly operating nuclear reactors. As can be expected, some reactors did not get out of Region A without experiencing failure. Some of the worst failures include:

- The Fermi Unit 1 reactor in Michigan began commercial operation in August 1966. A partial meltdown on October 5, 1966, caused extensive damage to the reactor core. Age at time of failure: two months.
- The Three Mile Island Unit 2 reactor began commercial operation in December 1978. On March 28, 1979, a partial meltdown prompted the evacuation of nearly 150,000 people living near the plant. Age: three months.
- The St. Laurent des Eaux A1 reactor in France started up in June 1969. Nearly 400 pounds of fuel melted on October 17, 1969, when the online refueling machine malfunctioned. Age: four months.[1]
- The Browns Ferry Unit 1 reactor in Alabama began commercial operation in August 1974. A fire on March 22, 1975, caused severe damage to plant control equipment that required nearly a year's repairs to fix. Age: six months.[2]
- The Sodium Research Experiment (SRE) reactor in California first attained full power in May 1958. On July 26, 1959, 12 fuel elements melted when the organic compound used to cool the reactor core decomposed and blocked the cooling flow channels. Age: one year, two months.
- The Chernobyl Unit 4 reactor started up in August 1984. It suffered the worst nuclear plant disaster in history on April 26, 1986, when two explosions destroyed the facility and ignited a reactor fire that burned for more than a week. Dozens of plant workers were killed and thousands of people permanently relocated due to radioactive contamination of the surrounding countryside. Age: one year, seven months.
- The SL-1 reactor in Idaho attained full power for the first time on October 24, 1958. An explosion within the reactor vessel on January 3, 1961, destroyed the reactor core and killed everyone at the site—the first fatal nuclear reactor accident in the United States. Age: two years, three months.

1 The St. Laurent des Eaux A1 reactor resumed operation in 1970.
2 The Browns Ferry Unit 1 reactor resumed operation in 1977.

Figure 2 **Major Failures at Region A Plants**



Source: Adapted from NASA, 2001.

Lessons Learned by Region A Failures

In some of these cases, the equipment intended to prevent accidents actually caused the accidents themselves or made them worse. For example, workers installed angled metal pieces just below the reactor core before Fermi Unit 1 began operation. This last-minute addition was intended to make the plant safer by dividing the molten core if it melted and slumped to the bottom of the reactor vessel. But one of the metal vanes broke free and blocked the cooling flow through the reactor core, causing—ironically—nuclear fuel to melt. In a far more tragic turn of events, the accident at Chernobyl occurred when workers performed a test of a proposed new backup system intended to allow the plant to operate more safely.

These accidents revealed problems that were not apparent on the blueprints, in the computer models, or in the laboratory. The problems required extensive safety upgrades at the surviving nuclear plants, but helped lower the risk of failure in the future. The fire at Browns Ferry Unit 1, for example, forced the rethinking of fire protection at nuclear power plants. New regulations were put in place to govern the construction of new nuclear plants and existing plants underwent substantial retrofits to reduce fire risk. Likewise, the meltdown at Three Mile Island Unit 2 prompted major changes in the design, maintenance, operation, and regulatory oversight of nuclear power plants. Had these accidents happened in Region B, the remedial efforts might have been more modest.

Nuclear Plant Growing Pains

Generic communications issued by the NRC demonstrate that nuclear power plants have had their fair share of problems. Table 1 (p.7) shows the number of generic communications issued annually by the NRC between 1971 and 2002. While some of these 2,500-plus issuances addressed non-power reactor problems, the majority addressed nuclear plant safety problems caused by bad design, defective manufacturing, faulty installation, unanticipated interactions, imperfect maintenance, and ineffective operation. (See the Appendix for representative examples of these communications.) The shape of the bathtub curve in Region A reflects that unanticipated problems either get flushed out and fixed or result in the permanent shutdown of the flawed reactor.

Price-Anderson: A Disincentive for Safety

The Price-Anderson Act was enacted in 1957 as a supplemental "insurance policy" for nuclear power plants. Private industry could not afford to develop commercial nuclear power plants due to the unprecedented high liability from a catastrophic

Table 1 **NRC Generic Communications, 1971–2002**

Year	Circulars	Generic Letters	Bulletins	Information Notices	Regulatory Issue Summaries	Total
1971	0	0	3	0	0	3
1972	0	0	3	0	0	3
1973	0	0	6	0	0	6
1974	0	0	16	0	0	16
1975	0	0	8	0	0	8
1976	7	0	8	0	0	15
1977	16	8	8	0	0	32
1978	19	42	14	0	0	75
1979	25	70	28	37	0	160
1980	25	113	25	45	0	208
1981	15	40	3	39	0	97
1982	0	31	4	56	0	91
1983	0	43	8	84	0	135
1984	0	24	3	94	0	121
1985	0	21	3	101	0	125
1986	0	17	4	110	0	131
1987	0	16	2	67	0	85
1988	0	20	11	64	0	95
1989	0	23	3	90	0	116
1990	0	7	2	82	0	91
1991	0	19	1	87	0	107
1992	0	9	3	86	0	98
1993	0	8	2	100	0	110
1994	0	4	2	90	0	96
1995	0	10	4	58	0	72
1996	0	7	2	72	0	81
1997	0	6	0	91	0	97
1998	0	5	0	45	0	50
1999	0	2	0	34	6	42
2000	0	0	0	22	25	47
2001	0	0	1	19	25	45
2002	0	0	2	36	23	61
Totals	**107**	**545**	**179**	**1,609**	**79**	**2,519**

accident. *The Wall Street Journal* reported that the cost of the 1986 Chernobyl accident significantly exceeded the collective economic benefits accrued from the dozens of Soviet nuclear power reactors operated between 1954 and 1986 (Hudson, 1990).

No nuclear plant owner wants to see a multi-billion-dollar investment go up in smoke, but Price-Anderson may prevent safety upgrades from being incorporated into new reactor designs. Without Price-Anderson, the added cost of developing and incorporating safety features is offset by reduced annual insurance premiums. With Price-Anderson providing equal liability protection regardless of risk, the cost of additional safety features becomes a financial impediment. The federal government must not encourage new nuclear reactors while discouraging important safety enhancements.

Build Now, Pay Later?

Some new reactor designs represent the next evolutionary step for nuclear power, incorporating features intended to make the plants safer and more economical. These features, however, are largely untested in the field or have very limited operating experience. Other new reactor designs have operated only in cyberspace and have never experienced the trials and tribulations of real-world operation. The gremlins hiding in their designs have not yet been exposed, let alone exorcised.

In order to avoid unnecessary risks, any new reactor design must first undergo a multiyear testing period. The need for and objectives of this testing was explained by a senior executive of the Japanese nuclear industry:

> *Most machinery requires a period of "breaking in," during which the interactions of components are smoothed*

> *and they become well fitted. . . . This start-up period, the period to the achievement of stable normal operations, is important because it is largely responsible for the physical "constitution" and "strength" of the plant thereafter. Thus, as with a new automobile, it is best not to impose excessive demands on the plant and to continue rated operation carefully during this period, which, depending on the plant, can range from a few to several years. We refer to this as the "fostering" stage of the plant.*
>
> *Through periodic inspection carried out during the fostering stage, it is necessary to identify the weaknesses of the plant as well as its strengths. At the same time, any peculiarities of the plant should be understood and reflected in operating methods and maintenance, by which a strong plant constitution can be developed.* (Takuma, 2002)

While the experiment with the prototype is under way, no commercial reactors of that type should be under construction. Instead, results found during the fostering stage should be obtained, analyzed, and factored into design and regulatory improvements. Only then should any new nuclear reactors be licensed and built.

Public Participation in the Licensing Process

Public input on nuclear power plant issues has long played an important role in the NRC's licensing process. The NRC itself has found that public participation greatly enhances safety levels:

> *Public participation in licensing proceedings not only can provide valuable assistance to the adjudicatory process, but on frequent occasions demonstrably has done so. It does no disservice to the diligence of either applicants generally or the regulatory staff to note that many of the substantial safety and environmental issues which have received the scrutiny of licensing boards and appeal boards were raised in the first instance by an intervenor.* (AEC, 1974)

The NRC also enumerated the following benefits:

> *(1) Staff and applicant reports subject to public examination are performed with greater care; (2) preparation for public examination of issues frequently creates a new perspective and causes the parties to reexamine or rethink some or all of the questions presented; (3) the quality of staff judgments is improved by a hearing process which requires experts to state their views in writing and then permits oral examination in detail . . . and (4) Staff work benefits from two decades of hearings and Board decisions on the almost limitless number of technical judgments that must be made in any given licensing application.* (Cotter, 1981)

The NRC's Atomic Safety and Licensing Board has documented many examples of reactor safety improvements resulting from public participation (ASLB, 1984), including:

1. Design and training improvements at the St. Lucie nuclear plant in Florida for coping with offsite power grid instabilities.

2. Upgraded requirements for turbine blade inspections and overspeed detection at the North Anna nuclear plant in Virginia.

3. Improvement and conformation of the plume exposure pathway Emergency Planning Zone at the San Onofre nuclear plant in California.

4. Upgraded effluent-treatment systems at the Palisades nuclear plant in Michigan and the Dresden nuclear plant in Illinois.

5. Control room design improvements at the Kewaunee nuclear plant in Wisconsin.

6. Upgraded requirements for steam generator tube leak plugging at the Beaver Valley nuclear plant in Pennsylvania.

Unfortunately, the NRC, bowing to industry pressure, recently revised its licensing process to virtually eliminate public participation, except in the role of casual observer (NRC, 2004). The lack of public input could drastically curtail discovery of important areas of safety improvement similar to those listed here.

Recommendations

The nuclear power plants operating in the United States today have long since exited Region A. The federal government advocates the construction of new nuclear power reactors to help meet future electricity needs, but any new reactor would have to navigate the same risky part of the bathtub curve that yielded meltdowns or explosions at Fermi, St. Laurent, Three Mile Island, SL-1, and Chernobyl. At best, new reactors might be able to incorporate the lessons learned from these nuclear disasters to lower the left edge of the bathtub curve. At worst, they will add their names to the list of infamous reactors populating Region A.

There are issues specific to new reactors that must be addressed to ensure they are managed and operated in the safest way possible. UCS recommends the following risk management policies:

1. New nuclear reactors must be excluded from liability protection under the Price-Anderson Act.
Promoters of new nuclear reactors contend that they are so safe that traditional measures employed to protect the public, such as warning sirens and emergency preparedness plans for nearby residents, are not needed. They also contend that the 10-mile emergency-planning zone can be reduced to a mere 400 meters. If these new reactors are truly so safe that the public need not be protected from technological disaster, then they are also so safe that their owners need not be protected from financial disaster.

2. New nuclear reactors must not go directly from blueprints to backyards.
The United States experienced the pain of building production reactors before learning lessons from prototype reactors as described by Daniel Ford, executive director of UCS in the 1970s:

> *A carefully managed development effort would also have required the building of prototypes for the large plants, just as Rickover did with his submarine reactor, which was thoroughly tested in a full-scale experimental facility at the A.E.C.'s remote testing station in Idaho. The A.E.C. did not impose such controls on the nuclear industry, which, as officials later acknowledged, rushed "from Kittyhawk to the Boeing 747" in less than two decades. The "experiment" of operating large reactors, whose advanced designs relied on complex, untried technology, was performed not in a faraway desert but at sites chosen by the utilities on the perimeter of the country's major metropolitan areas.* (Ford, 1986)

The safety retrofits to some of today's operating nuclear reactors were less effective and more costly than necessary because of this rushed approach. There's no reason to replicate this imprudent mistake.

3. The NRC must conduct extensive verifications of reactor design and construction to find and correct as many safety problems as possible before startup. The nuclear power industry's chronic quality control problems during design and construction are legendary, as is the NRC's consistent inability to do anything about it. The NRC's own reports[3] on the daunting problems concluded:

> *The principal conclusion of this study is that nuclear construction projects having significant quality-related problems in their design or construction were characterized by the inability or failure of utility management to effectively implement a management system that ensured adequate control over all aspects of the project. . . . The major quality problems that have arisen in design were related to shortcomings in management oversight of the design process, including failure to implement quality assurance controls over the design process that were adequate to prevent or detect mistakes in an environment of many design changes. . . . The NRC made a tacit but incorrect assumption that there was a uniform level of industry and licensee competence. . . . Limited NRC inspection resources were so prioritized to address operations first, construction second, and design last, that inadequate inspection of the design process resulted.* (NRC, 1984)

Poor quality stopped the Marble Hill, Midland, and Zimmer nuclear power reactors from starting up despite nearly being completed. Similar woes didn't stop the South Texas Project, Grand Gulf, Diablo Canyon, and Palo Verde nuclear plants, but they added vast and totally unnecessary sums to the price tags. And design problems contributed to the severity of the SL-1, Fermi Unit 1, Browns Ferry Unit 1, and Three Mile Island Unit 2 accidents. The safety and financial implications of shoddy construction are still evident today. It must not be repeated.

4. The licensing process for new nuclear reactors must permit meaningful public participation. Public participation in the NRC's licensing process will help to ensure that new reactors are operating as safely as possible. The NRC should allow public meetings for residents in and around towns where new reactors are slated for construction, allow public input on new or revised regulations pertaining to local plants, and provide opportunities for public comment on revised regulations that affect nuclear plants nationwide.

3 For examples, see U.S. House, 1984; U.S. House, 1982; and U.S. House, 1981.

CHAPTER 3

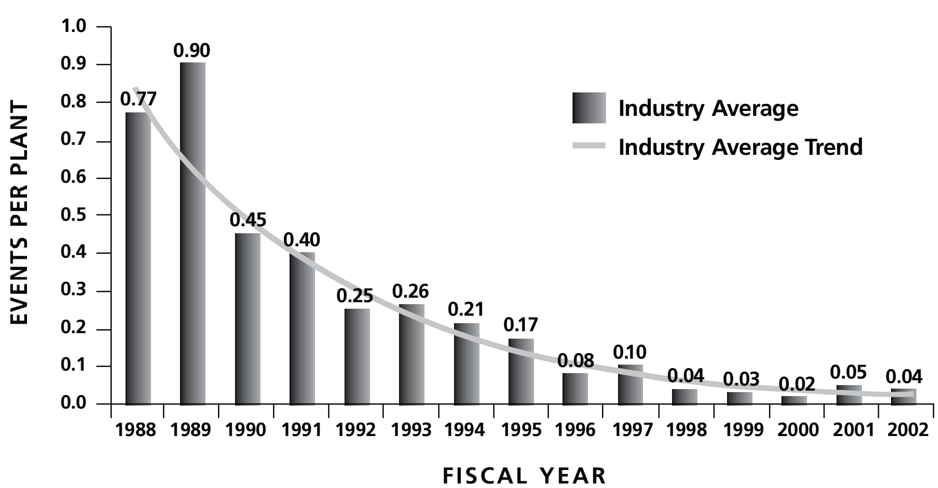
Nuclear Plant Safety in Region B

The NRC monitors trends in several areas of nuclear plant operation, including safety system failures, unplanned reactor shutdowns, emergency system starts, and significant events such as degraded fuel integrity and unplanned releases of radioactivity (Collins, 2003). The decreased occurrence of significant events over the past 15 years or so reflects the normal and expected transition of nuclear power plants from Region A to Region B (Figure 3).

Risk in Region B is lower than in Regions A or C, but it is not zero and it can increase if safety measures are not followed properly. For comparison purposes, middle-aged drivers are involved in fewer fatal motor vehicle accidents than younger and older drivers (Figure 4). But a 45-year-old who drinks and drives a car with bad brakes is probably a greater risk than a sober 16-year-old behind the wheel of a well-maintained car.

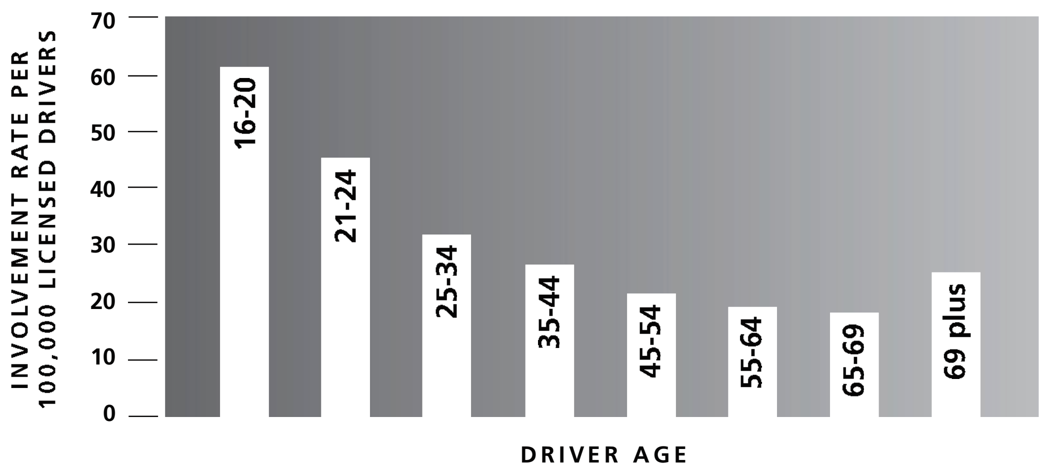
Some steps taken by the NRC over the years probably prevented plants from lingering too long in Region A. For example, in the late 1980s, the NRC determined that safety equipment was being called upon too often because of poor maintenance on equipment used to make electricity at the plant ("balance-of-plant" equipment). The NRC's regulations at that time required safety equipment to be highly reliable, but the regulations did not govern how often plant owners could put themselves in need of that safety equipment. Concerned that even highly reliable equipment will fail if called upon too often, the NRC issued its Maintenance

Figure 3 **Significant Events at Nuclear Plants, 1988-2002**



Source: Dyer, 2004.

Figure 4 **Driver Involvement Rate in Fatal Crashes by Age, 2001**



Source: NHTSA, 2002.

Rule in July 1991. This rule requires plant owners to perform better maintenance on equipment whose failure challenges safety equipment (Callan, 1997).

Problem Identification and Resolution Programs

"Problem identification and resolution" is how plant owners find and fix safety problems. As shown by Table 2 (p. 13), 27 nuclear power reactors have been shut down since 1984 for more than a year for extensive repairs to safety equipment. The year-plus durations of these shutdowns are *prima facie* evidence that problem identification and resolution programs at these facilities were seriously flawed if not totally dysfunctional. Years of overlooking problems and applying "band-aid" fixes at these plants resulted in a backlog of safety problems that took a long time to resolve. Effective problem identification and resolution programs could save plant operators time and money in the long term.

Risk Assessment Studies: Ineffective and Inconsistent

Probabilistic risk analyses (PRAs) attempt to calculate the odds of specific events occurring (such as the breaking of a pipe that carries cooling water to the reactor) and the odds of a plant's numerous safety systems being unable to prevent damage to the reactor core. All plant owners have conducted risk assessment studies for their facilities. But as reported by the NRC's Inspector General:

> *Senior NRC officials confirmed that the agency is highly reliant on information from licensee risk assessments. Agency officials also noted that there are no PRA standards, no requirements for licensee's PRAs to be updated or accurate, and that the quality of the assessments varies considerably among licensees.* (NRC, 2002)

The Davis-Besse reactor in Ohio is the most recent example of the consequences of deficient risk studies (see box, p. 15). UCS documented many instances in which the lack of PRA standards

Table 2 **Reactors Shut Down for Year-Plus Safety Repairs**

Reactor	Location	Shut Down	Restarted
Browns Ferry Unit 2	Alabama	September 1984	May 1991
Davis-Besse	Ohio	June 1985	December 1986
Sequoyah Unit 1	Tennessee	August 1985	May 1988
Sequoyah Unit 2	Tennessee	August 1985	November 1988
Pilgrim	Massachusetts	April 1986	January 1989
Peach Bottom Unit 2	Pennsylvania	March 1987	April 1989
Peach Bottom Unit 3	Pennsylvania	March 1987	November 1989
Nine Mile Point Unit 1	New York	December 1987	July 1990
Surry Unit 2	Virginia	September 1988	September 1989
Calvert Cliffs Unit 2	Maryland	March 1989	May 1991
Palo Verde Unit 1	Arizona	March 1989	June 1990
Calvert Cliffs Unit 1	Maryland	May 1989	April 1990
FitzPatrick	New York	November 1991	January 1993
Indian Point Unit 3	New York	March 1992	June 1995
South Texas Project Unit 1	Texas	February 1993	February 1994
South Texas Project Unit 2	Texas	February 1993	May 1994
Salem Unit 1	New Jersey	May 1995	April 1998
Salem Unit 2	New Jersey	June 1995	July 1997
Millstone Unit 2	Connecticut	February 1996	May 1999
Millstone Unit 3	Connecticut	March 1996	June 1998
Crystal River	Florida	September 1996	January 1998
LaSalle Unit 1	Illinois	September 1996	August 1998
LaSalle Unit 2	Illinois	September 1996	April 1999
Clinton	Illinois	September 1996	May 1999
DC Cook Unit 1	Michigan	September 1997	December 2000
DC Cook Unit 2	Michigan	September 1997	June 2000
Davis-Besse	Ohio	February 2002	March 2004

Source: Adapted from Lochbaum, 1999.

resulted in safety problems and allowed widely disparate results for virtually identical reactors (Lochbaum, 2000). Of particular concern is the NRC's treatment of generic safety issues. While plant-specific issues are routinely noted and resolved as one would expect them to be, generic safety issues affecting a large number of plants are assumed *not* to exist *until* they are resolved. Incredible as it may seem, the risk assessment studies assume there is zero chance that the generic safety issue will disable safety systems until the issue is resolved, at which time the studies continue to assume zero chance because the problem has been fixed.

The problems with risk assessment studies are well known, yet the NRC still makes regulatory decisions based in large part on their suspect results. And in the case of generic safety issues, the findings are clear, yet the NRC is sweeping them under the rug. It's "garbage in, garbage out," with millions of American lives in the balance.

Technical Specifications: Important, but Often Ignored

Technical Specifications, or Tech Specs in industry parlance, are part of the operating license issued by the NRC to the owner of each power reactor. Among other things, the Tech Specs define the minimum complement of safety equipment needed for safe reactor operation and how long the reactor can continue running when one or more pieces of the minimum complement are unavailable.

In the case of Davis-Besse, the NRC lacked absolute proof that Tech Specs were violated and allowed the reactor to continue operating despite overwhelming circumstantial evidence that cooling water was leaking from the reactor vessel, warranting a shutdown within six hours. Yet when the NRC has absolute proof that Tech Specs are violated, they rely on circumstantial evidence to allow reactors to continue operating. The following are just a few of many recent examples:

- In March 2003, the DC Cook Unit 2 reactor in Michigan was operating at full power when workers determined that the motor-driven auxiliary feedwater pump would be out of service to repair a broken motor longer than the 72 hours permitted by Tech Specs. The plant's owner requested permission for the reactor to remain at full power for an additional 36 hours while the broken safety pump was repaired. The NRC authorized this request based in large part on circumstantial evidence that the risk associated with extended plant operation was "less than the risk associated with performing a plant shutdown" (Grant, 2003).

- In August 2002, the Diablo Canyon Unit 2 reactor in California was operating at full power when workers determined that a faulty power cable had disabled one of the component cooling water pumps. The Tech Specs only allowed the reactor to continue operating for 72 hours with this pump broken. The NRC permitted the reactor to continue operating for an additional 72 hours while the power cable was replaced. The NRC determined that the additional operating time "will not involve a net increase in radiological risk" (Merschoff, 2002). It was later discovered that an isolation valve between the two redundant component cooling water headers had been damaged years ago and would have leaked excessively if closed following the rupture of one header (Becker, 2003).

- In April 2001, workers testing an emergency diesel generator at Prairie Island Unit 2 in Minnesota discovered a damaged engine cylinder. The Tech Specs permitted the reactor to operate for up to seven days with one broken emergency diesel generator. The NRC granted three more days for the reactor to operate without its full complement of emergency diesel generators. The NRC's decision was based on the plant owner's risk calculation reporting a "low likelihood" of an accident coinciding with an independent failure of the other emergency diesel generator (Grant, 2001a). After the broken emergency diesel generator was fixed and returned to service, the plant's owner discovered the engine cylinder damage had been caused by an incompatibility between its fuel oil and lubricating oil. The Calvert Cliffs nuclear plant in Maryland previously experienced this incompatibility problem in 1996 and the NRC warned all other plant owners about it. But Prairie Island's owner had not taken steps to avoid this known problem and as a result, *both* emergency diesel generators were damaged.

Davis-Besse: The Reactor with a Hole in its Head

Pressurized-water reactors (PWRs) in the United States have been widely found to leak cooling water from their control rod drive mechanism (CRDM) nozzles. In late 2001, the NRC had compelling evidence that one such PWR, the Davis-Besse nuclear plant in Ohio, had cooling water leaks. The Tech Specs for Davis-Besse allowed the plant to operate for only six hours with such leakage. Every other similar PWR had already inspected their CRDM nozzles and found safety problems, but Davis-Besse had not yet looked for the leaks. Because the problem was so well known and had the potential for severe reactor damage, the NRC drafted an order requiring Davis-Besse to be shut down for CRDM nozzle inspections. The last time the NRC drafted and issued such a shutdown order was in March 1987 to the Peach Bottom reactor in Pennsylvania.

To delay the costly shutdown, Davis-Besse's owner provided the NRC with a risk assessment study that concluded the reactor could safely operate until its next refueling outage on March 30, 2002. On November 28, 2001, the NRC decided not to issue to shutdown order, instead allowing Davis-Besse to operate until February 16, 2002, provided the company dedicate one worker to turning on a vital safety system in case a damaged CRDM nozzle failed and drained cooling water from the reactor vessel.

Relying on Luck

When the postponed inspections were finally done, workers found leaks. In addition, they found the leaks had severely damaged the reactor vessel, one of the plant's most important safety barriers. As the cooling water leaked out of the reactor vessel, boric acid ate completely through the vessel's six-inch-thick carbon steel exterior, leaving only a thin layer of stainless steel to contain the cooling water in the reactor. The stainless steel was bulging outward due to the high pressure in the reactor vessel but, luckily, did not rupture.

It was indeed fortunate that the stainless steel held, for the NRC's compensatory measure, the dedicated worker, would have proved futile. Later in 2002, Davis-Besse's owner informed the NRC that:

> *[T]he existing amount of unqualified coatings and other debris inside containment could have potentially blocked the emergency sump intake screen, rendering the sump inoperable, following a loss of coolant accident. With the emergency sump inoperable, both independent Emergency Core Cooling Systems (ECCS) and both Containment Spray (CS) systems are inoperable, due to both requiring suction from the emergency sump during the recirculation phase of operation. This could prevent both trains of ECCS from removing residual heat from the reactor and could prevent CS from removing heat and fission product iodine from the containment atmosphere.* (Myers, 2002)

In other words, the NRC's dedicated worker would have turned on a safety system that did not work. This outcome should not have surprised either the NRC or Davis-Besse's owner; the NRC has issued 11 separate warnings about this problem since May 1988 (Table 3).

An NRC senior manager involved in the decision to allow Davis-Besse to continue operating explained why he felt the agency's hands were tied:

Table 3 **Generic Communications on PWR Containment**

Date Issued	Information Notice/ Bulletin Number	Title
5/88	IN 88-28	Potential for Loss of Post-LOCA Recirculation Capability Due to Insulation Debris Blockage
11/89	IN 89-77	Debris in Containment Emergency Sumps and Incorrect Screen Configurations
1/90	IN 90-07	New Information Regarding Insulation Materials Performance and Debris Blockage of PWR Containment Sumps
9/92	IN 92-71	Partial Plugging of Suppression Pool Strainers at a Foreign BWR
4/93	IN 93-34	Potential for Loss of Emergency Cooling Function Due to a Combination of Operational and Post-LOCA Debris in Containment
5/93	IEB 93-02	Debris Plugging of Emergency Core Cooling Suction Strainers
10/95	IEB 95-02	Unexpected Clogging of a RHR Pump Strainer While Operating in Suppression Pool Cooling Mode
10/95	IN 95-47	Unexpected Opening of a Safety/Relief Valve and Complications Involving Suppression Pool Cooling Strainer Blockage
5/96	IEB 96-03	Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-Water Reactors
10/96	IN 96-059	Potential Degradation of Post Loss-of-Coolant Recirculation Capability as a Result of Debris
5/97	IN 97-027	Effect of Incorrect Strainer Pressure Drop on Available Net Positive Suction Head

Source: Adapted from NRC, 2003.

"We can argue this, but this agency does not take precipitous action to shut down a nuclear plant because we have a suspicion of something without enough evidence to warrant it," said Brian Sheron, who, as an associate director in the NRC's office of nuclear reactor regulation, helped lead the staff evaluation of Davis-Besse. "If we were in the same situation again, we'd probably make the same decision" to allow them to operate until Feb. 16. (Mangels and Funk, 2002)

Davis-Besse reminded nearly everyone that the risk of nuclear plant operation in Region B is real. Davis-Besse also demonstrated that the risk will increase when a poor problem identification and resolution program along with misleading results from risk assessment studies permit Tech Specs to be tossed aside.

Consequently, Unit 2 was shut down that day for repairs (Grant, 2001b).

- In January 2001, workers testing the Division II emergency diesel generator at the Clinton nuclear plant in Illinois discovered damaged engine bearings. The Tech Specs permitted the reactor to operate for up to three days with one broken emergency diesel generator. The NRC granted 11 more days for the reactor to operate without its full complement of emergency diesel generators because the plant's owner promised not to test the Division I emergency diesel generator (and thus determine whether it also had the engine bearing problem) until after the known problem was fixed. (Bajwa, 2001). Clinton is a boiling-water reactor model 5 (BWR/5). According to the NRC, 90 percent of the overall threat for reactor core damage at BWR/5 plants is station blackout, which occurs when the plant is disconnected from its electrical grid and both the Division I and Division II emergency diesel generators are unavailable (NRC, 1996).

- In November 2000, one of three component cooling water pumps at the Fort Calhoun nuclear plant in Nebraska failed when its aged motor broke down. The Tech Specs permitted the reactor to operate for up to seven days with one component cooling water pump unavailable. The NRC granted 14 additional days to procure and install a replacement pump motor after determining that the extended outage time for the cooling water pump resulted in "minimal increase in core damage frequency" (Merschoff, 2000). Fort Calhoun is a combustion engineering PWR. According to the NRC, support systems such as the component cooling water system play an extremely important safety role because their failure "can compromise front-line system redundancy, leaving few options for successful plant shutdown" (NRC, 1996).

Recommendations

U.S. nuclear power plants are now operating in Region B of the bathtub curve. Just as the NRC's actions probably influenced how quickly nuclear plants traveled from Region A to Region B, the agency's actions—and inactions—can affect how quickly nuclear plants travel from Region B to Region C. Risk in Region B is not zero, but given that risk increases in Region C, the NRC must work to keep plants operating in Region B as long as possible, and properly manage them to keep risks at a minimum. To best manage the risk while in Region B:

1. The NRC must overhaul how it assesses problem identification and resolution programs.

A problem identification and resolution program is the most important measure of safety performance at a nuclear power plant, and should find problems before they become self-revealing and properly fix them the first time. Inadequate problem identification and resolution programs were a common cause for the 27 year-plus plant shutdowns listed in Table 2 (p.13). The NRC downplays evidence that these programs are inadequate unless they involve equipment that nearly caused a meltdown. There should be no exceptions. The NRC must do a better job of judging the health of these vital programs and force them to be fixed and properly used at all times.

2. The NRC must stop making risk-informed decisions using flawed risk assessment studies. Sound, risk-informed decisions about the nation's nuclear power plants must be made based on consistent, accurate risk assessment studies, especially with regard to generic safety issues. But this will not happen with the NRC's current risk assessment system. The NRC must adopt a system of standards for all power plants and enforce the system across the board—for all plants and for all types of safety issues—to ensure known risks are properly managed and resolved.

3. The NRC must back up its talk about a "double-edged sword" in risk-informed regulation. The NRC often states that risk insights cut both ways—they can trim regulations having little or no safety merit and they can also impose requirements in previously undervalued areas.[4] But in practice, the NRC's risk-informed sword is razor-sharp on the side that slashes regulations and dull on the side that enforces regulations.

The examples given earlier, and dozens like them, show that the NRC abides by or abandons its absolute proof standard as necessary to allow nuclear plants to continue operating. The NRC must immediately stop admitting or rejecting circumstantial evidence based on the answer it is seeking. The data must determine the outcome, not vice versa.

4 For examples, see King, 1999; NRC, 1999; and McGaffigan, 2001.

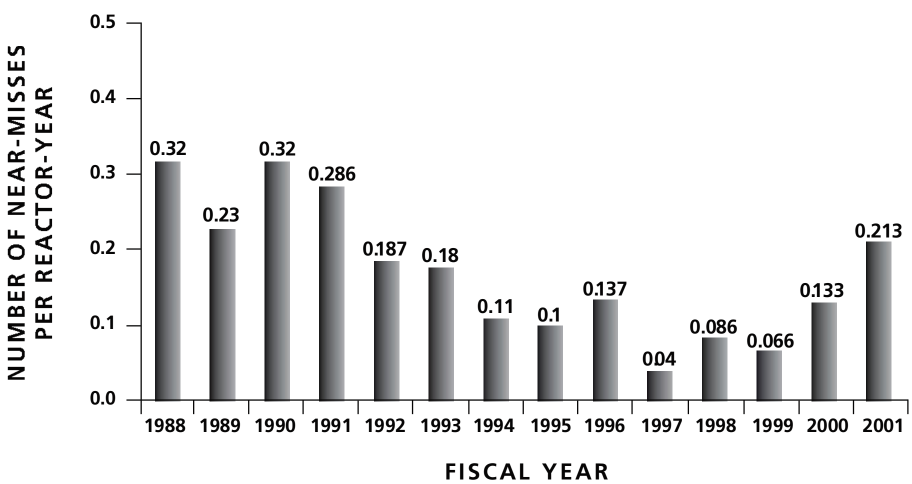
CHAPTER 4

Nuclear Plant Safety in Region C

In some respects, nuclear power plants are like cars. A car that is routinely maintained, washed and waxed regularly, and kept out of the elements will stay rust-free and reliable for years. But even with the best care, a car that is driven every day will eventually develop engine problems. Likewise, a properly maintained nuclear plant takes longer to enter Region C than a poorly maintained nuclear plant. But even the best-maintained nuclear plant enters Region C if operated long enough.

What is known with absolute certainty is that every nuclear plant operating in the United States today is moving toward Region C (if not already in it). While the number of significant events has decreased in recent years, the rate of "near-misses" (elevated risks of reactor meltdown) appears to have increased in recent years (Figure 5). In other words, while the number of events is decreasing, their severity is increasing, with the near-misses getting nearer and nearer to disaster. This upward trend may simply reflect normal statistical fluctuations or increasing risk in Region B from the NRC's flawed risk-informed decisions. More likely, the data suggest that some nuclear plants have entered Region C and are experiencing higher failure rates as expected.

Figure 5 **Significant Near-Misses at Nuclear Power Plants, 1988-2001**



Source: Collins, 2003.

Inadequate Aging Management Programs

As reactors approach or enter Region C and become more vulnerable to failure, aging management programs monitor the condition of equipment and structures so as to effect repairs or replacements before minimum safety margins are compromised. Unfortunately, age-related degradation is being found too often by failures than by condition-monitoring activities.

In recent years, there have been ample reports of age-related failures. Here are some examples:

- On February 18, 2001, workers at Oconee Unit 3 in South Carolina noticed boric acid on the exterior surface of the reactor vessel head around two CRDM nozzles. Further investigation found through-wall circumferential cracks in the nozzles above the j-groove weld areas where the nozzles were attached to the reactor vessel head. These weld areas, and not the nozzles, were routinely inspected on the premise that cracks, if they were going to occur, would occur there first (NRC, 2001).

- On January 9, 2002, operators shut down Quad Cities Unit 1 in Illinois following indication that one of the jet pumps inside the reactor vessel had failed. Subsequent investigation determined that the hold-down beam for jet pump #20 had cracked apart and pieces had damaged the impeller of the recirculation pump, causing it to shut off. The jet pump hold-down beam was routinely inspected for cracks, but only at its two ends. The hold-down beam for jet pump #20 cracked in the middle. Workers also discovered two other hold-down beams with cracks in their middle regions (Grobe, 2002).

- On October 7, 2000, workers at the Summer nuclear plant in South Carolina found boric acid on the containment floor. This led to the discovery of a through-wall crack where a major pipe was welded to the reactor vessel nozzle. This location was specifically examined during the 10-year in-service inspection in 1993, but the crack, which was present at the time, was missed because an air gap between the pipe weld area and the inspection detector, a sonar-like device, created "noisy" output. This noise masked the indications of a crack and prevented workers from noticing the problem (Casto, 2001).

- On February 15, 2000, a steam generator tube broke at Indian Point Unit 2 in New York and caused the uncontrolled release of radioactivity into the atmosphere. Under its revamped oversight process, the NRC issued its first red finding—a failing grade—to Indian Point for this event because the near-miss was avoidable. The NRC cited the plant's owner for having detected signs of degradation exceeding federal regulations during the steam generator tube inspections in 1997 but failing to do anything about it (Miller, 2000).

These examples illustrate two fundamental flaws in current aging management programs: (1) looking in the wrong spots with the right inspection techniques (as happened with the Oconee and Quad Cities plants), and (2) looking in the right spots with the wrong inspection techniques (as happened with the Summer and Indian Point plants). Aging management programs should find these problems before they become self-revealing, but they are not. As problems in Region C have the potential to be much more severe than problems in Region B, strong aging management programs must be in place to help prevent these failures from occurring.

Reactor License Renewal: Ignoring the Generation Gap

Nuclear plants were originally licensed for 40-year operating lifetimes. Several plant owners have already sought and obtained 20-year license extensions from the NRC, and many more owners are queuing up to do so. The NRC's license renewal process is based on an assumption that all U.S. nuclear plants conform to their current licensing basis, the industry term for the set of federal safety regulations that apply to a specific nuclear power plant,[5] and a determination that plant owners have effective aging management programs for all equipment and structures with an important safety function. However, this assumption and determination, even if valid, may not be enough to adequately ensure that nuclear reactors can operate safely in Region C.

The current licensing basis varies from plant to plant. Nuclear plants licensed in the same year have different current licensing bases due to varying exemptions and license conditions. New regulations are constantly being generated and existing regulations revised so that, for example, the applicable regulations in 1985 differ significantly from the applicable regulations in 1975. The NRC cannot issue or revise its regulations unless it determines the regulatory changes either maintain or increase safety levels. Therefore, today's regulations are as good as, or better than, the 1975 or 1985 regulations from a safety perspective.

If a new nuclear power plant were to be built and operated today, it would have to meet the federal safety regulations in effect today. But the NRC's license renewal process fails to define the generation gap between today's safety requirements and the current licensing basis for an existing nuclear power plant, making it difficult—if not impossible—to determine whether an aging plant will operate safely for 20 more years. A prudent regulator would want to know just how far away from today's safety standards an aging nuclear plant seeking license renewal is and why it is acceptable for that plant *not* to meet today's safety standards for two more decades. The NRC's license renewal process fails to ask and answer that crucial question. This shortfall must be fixed if aging reactors are to operate for 20 more years.

Recommendations

The NRC's license renewal process questions whether plant owners have effective aging management programs, and the answer has always been "yes" despite considerable evidence to the contrary. It is well known that "two wrongs don't make a right," but it takes two rights to make a right in aging management—looking in the right spots with the right techniques. If today's existing nuclear reactors are to be in service for another 20 years, there needs to be strong aging management programs at all reactors to ensure failures are found before it is too late. UCS recommends the following reforms:

1. The NRC must overhaul how it assesses problem identification and resolution programs.

Diverse inspection methods lessen the chances of overlooking problems when looking in the right spots.

2. The NRC must require periodic inspections of areas considered less vulnerable to degradation and deemed outside the inspection scope.

Out-of-scope inspections increase the chances of

5 Code of Federal Regulations. "Definitions." Title 10, §54.3.

finding problems that would have otherwise been overlooked.

3. The NRC must formally review all differences between today's safety regulations and the regulations applicable to an aging reactor before granting license renewals.

It is unacceptable to grant license extensions to reactors that lag woefully behind in regulations. The NRC must confirm that adequate safety margins exist for reactors up for license renewal and require safety and regulatory upgrades as necessary to remedy any shortfalls.

Actually, the best way to prevent recurrent problems at aging nuclear plants would be for the NRC to suspend the issuance of license renewals until the nuclear industry has demonstrated that it takes plant safety seriously. Plant owners will continue to follow lax aging management programs and allow failures to reveal themselves unless the NRC imposes stronger standards. If the NRC required truly effective aging management programs as a condition for license renewal, plant owners would have no choice but to adhere to stronger safety regulations, regardless of cost. Right now, they have no incentive to do so.

CHAPTER 5

Conclusion

The risk profile for nuclear power reactors varies from cradle to rocking chair just as it does for people. Because the risk is never zero, it must be properly managed at all times to protect against undue risk. The best way to manage nuclear reactor risk is to have an aggressive regulator consistently enforcing federal safety regulations.

At least this is what UCS considers to be the best way; we've never actually observed such NRC performance. We have observed, all too often, the consequences that arise from a lack of enforcement of federal safety regulations. When this happens, safety margins drop unnecessarily low and the risk to people living near the reactors climbs unacceptably high.

The late Henry Kendall, Nobel laureate and former chairman of the UCS board of directors, once said, "You can't have one end of a ship sink." This quote is fitting for U.S. nuclear reactors, which are essentially in this very ship. A serious accident at any U.S. reactor, at any point in its lifetime, would likely dim the future for all reactors. To prevent unwarranted risk to the American public, Congress must reform the NRC into a consistently effective enforcer of federal safety regulations.

The suggested reforms outlined in this report would lay the proper foundation for the NRC to resolve long-standing safety problems at the more than 100 nuclear plants operating nationwide. Congress must sustain the NRC reform effort through completion of this entire process, to provide the American public with the protection they expect and deserve.

References

Atomic Energy Commission (AEC). 1974. "Gulf States Utility Co. (River Bend Units 1 and 2)." Atomic Safety and Licensing Appeal Board. ALAB-183, RAI-74-3, pp. 10–12. March 12.

Atomic Safety and Licensing Board Panel. 1984. "Reactor Safety Improvements Resulting from the Hearing Process." Findings presented to the Advisory Committee on Reactor Safeguards. August 10.

Bajwa, S.S., Nuclear Regulatory Commission. 2001. "Notice of Enforcement Discretion for Amergen Energy Company, LLC, Regarding Clinton Power Station, TAC No. MB0960, NOED No. 01-6-001." Letter to Mike Reandeau, Clinton Power Station. January 18. Online at *www.nrc.gov/reading-rm/doc-collections/enforcement/notices/2001/noed01-6-001.html.*

Becker, J.B., Pacific Gas and Electric Company. 2003. "Licensee Event Report 2-2003-002-00/ Unanalyzed Condition in the Unit 2 Component Cooling Water System Due to a Valve Liner Failure." Letter to Nuclear Regulatory Commission. April 17.

Callan, L.J., Nuclear Regulatory Commission. 1997. "Maintenance Rule States, Results, and Lessons Learned." Memo to the Chairman and Commissioners, Nuclear Regulatory Commission. SECY-97-055. March 4. Online at *www.nrc.gov/reading-rm/doc-collections/commission/secys/1997/secy1997-055/1997-055scy.html.*

Casto, C., Nuclear Regulatory Commission. 2001. "Virgil C. Summer Nuclear Station—NRC Special Inspection Report No. 50-395/00-08, Exercise of Enforcement Discretion." Letter to Stephen A. Byrne, South Carolina Electric & Gas Company. March 15. Online at *www.nrc.gov/reactors/operating/ops-experience/alloy600/alloy600-files/ml010740293.pdf.*

Collins, S.J., Nuclear Regulatory Commission. 2003. "Breakout Results/Feedback." Presented at the 15th annual NRC Regulatory Information Conference. April 18. Online at *www.nrc.gov/public-involve/conference-symposia/ric/past/2003/slides/f5-collins.pdf.*

Cotter Jr., B.P., Atomic Safety and Licensing Board. 1981. Memo to John Ahearne, Nuclear Regulatory Commission. p. 8. May 1.

Dyer, J., Nuclear Regulatory Commission. 2004. "Regulatory Trends." Presentation Slides. March 10. Online at *www.nrc.gov/public-involve/conference-symposia/ric/past/2004/slides/w3-dyer.pdf.*

Ford, D. 1986. *Meltdown: The Secret Papers of the Atomic Energy Commission*. New York: Simon & Schuster. p. 66. August.

Grant, G.E., Nuclear Regulatory Commission. 2003. "Notice of Enforcement Discretion for Indiana Michigan Power Company Regarding D.C. Cook, Unit 2 (NOED-03-3-003)." Letter to A.C. Bakken III, American Electric Power Company. March 13. Online at *www.nrc.gov/reading-rm/doc-collections/enforcement/notices/2003/noed03-3-003.html.*

Grant, G.E., Nuclear Regulatory Commission. 2001a. "Prairie Island Nuclear Generating Plant—Notice of Enforcement Discretion (NOED), NOED No. 01-3-002 (TAC No. MB1710)." Letter to J. Sorensen, Nuclear Management Company LLC. April 18. Online at *www.nrc.gov/reading-rm/doc-collections/enforcement/notices/2001/noed01-3-002.html.*

Grant, G.E., Nuclear Regulatory Commission. 2001b. "Prairie Island Nuclear Generating Plant, Unit 2/NRC Special Inspection Report 50-306/01-13." Letter to J. Sorensen, Nuclear Management Company LLC. June 22. Online at *www.nrc.gov/NRR/OVERSIGHT/ASSESS/REPORTS/prai_2001013.pdf.*

Grobe, J.A., Nuclear Regulatory Commission. 2002. "Quad Cities Nuclear Power Station/NRC Special Inspection Report 50-254/02-03(DRS)." Letter to Oliver D. Kingsley, Exelon Nuclear. April 7.

Hudson, R.L. 1990. "Cost of Chernobyl Nuclear Disaster Soars in New Study: 1986 Reactor Accident Dwarfs Other Soviet Peacetime Catastrophes," *The Wall Street Journal*. March 29.

King, T., Nuclear Regulatory Commission. 1999. "Briefing on Risk-Informed Initiatives." Presentation to the Chairman and Commissioners, Nuclear Regulatory Commission. Transcript p. 21 line 25 to p. 22 line 12. January 11.

Lochbaum, D. 2000. *Nuclear Plant Risk Studies: Failing the Grade.* Cambridge, MA: Union of Concerned Scientists. August. Online at *www.ucsusa.org/clean_energy/nuclear_safety/page.cfm?pageID=181.*

Lochbaum, D. 1999. *The NRC's New Oversight Process: On the Road to Effective Regulation?* Cambridge, MA: Union of Concerned Scientists. October.

Mangels, J. and J. Funk. 2002. "NRC's Flip-Flop," *The Plain-Dealer.* August 4.

McGaffigan Jr., E., Nuclear Regulatory Commission. 2001. "SECY-00-0198—Status Report of Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.44 (Combustible Gas Control)." Comments in Nuclear Regulatory Commission Voting Record. January 19.

Merschoff, E.W., Nuclear Regulatory Commission. 2002. "Notice of Enforcement Discretion for Pacific Gas and Electric Company Regarding Diablo Canyon Power Plant, Unit 2, NOED No. 02-4-003." Letter to Gregory M. Rueger, Pacific Gas and Electric Company. August 23. Online at *www.nrc.gov/reading-rm/doc-collections/enforcement/notices/2002/noed02-4-003.html.*

Merschoff, E.W., Nuclear Regulatory Commission. 2000. "Notice of Enforcement Discretion for Omaha Public Power District Regarding the Fort Calhoun Station, NOED-00-4-002." Letter to S.K. Gambhir, Omaha Public Power District. November 28. Online at *www.nrc.gov/reading-rm/doc-collections/enforcement/notices/2000/noed00-4-002.html.*

Miller, H.J., Nuclear Regulatory Commission. 2000. "Final Significance Determination for a Red Finding and Notice of Violation at Indian Point 2 (NRC Inspection Report 05000247/2000-010)." Letter to John Groth, Consolidated Edison Company of New York, Inc. EA-00-179. November 20. Online at *www.nrc.gov/reading-rm/doc-collections/enforcement/actions/reactors/ea00179.html.*

Myers, L.A., FirstEnergy Nuclear Operating Company. 2002. "LER 2002-005-01/Davis-Besse Nuclear Power Station, Unit No. 1/Date of Occurrence—September 4, 2002." Letter to the Nuclear Regulatory Commission. December 11.

National Aeronautics and Space Administration (NASA). 2001. "Using Reliability-Centered Maintenance As The Foundation For An Efficient And Reliable Overall Maintenance Strategy." Presentation slides.

National Highway Traffic Safety Administration (NHTSA). 2002. *Traffic Safety Facts 2001: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*. Washington, D.C.: NHTSA, National Center for Statistics and Analysis. U.S. Department of Transportation. p. 98. December.

Nuclear Regulatory Commission. 2004. "Final Rule: Changes to Adjudicatory Process," *Federal Register* 69(9). January 14.

Nuclear Regulatory Commission. 2003. "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors." BL-2003-01. June 9. Online at *www.nrc.gov/reading-rm/doc-collections/gen-comm/bulletins/2003/bl03001.pdf.*

Nuclear Regulatory Commission. 2002. "Review of NRC's Significance Determination Process." Office of the Inspector General. OIG-02-A-15. August 21. Online at *www.nrc.gov/reading-rm/doc-collections/insp-gen/2002/02a-15/02a-15.pdf.*

Nuclear Regulatory Commission. 2001. "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles." BL-01-01. August 3. Online at *www.nrc.gov/reading-rm/doc-collections/gen-comm/bulletins/2001/bl01001.html.*

Nuclear Regulatory Commission. 1999. "All Employees Meeting B." Transcript p. 48 lines 10–24. June 15.

Nuclear Regulatory Commission. 1996. "Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance." NUREG-1560 Vol. 2, Parts 2–5, pp. 11-37 to 11-40, 11-71. November.

Nuclear Regulatory Commission. 1984. "Improving Quality and the Assurance of Quality in the Design and Construction of Nuclear Power Plants." NUREG-1055. May.

Takuma, M., Japan Atomic Industrial Forum, Inc. 2002. "Japan's Policy on Nuclear Power Plant Life Management." Presentation at the International Atomic Energy Agency Scientific Forum. September 17–18.

U.S. Army Corps of Engineers. 2001. "Reliability Analysis of Navigation Lock and Dam Mechanical and Electrical Equipment." Technical Letter No. 1110-2-560. June 30. Online at *www.usace.army.mil/publications/eng-tech-ltrs/etl1110-2-560/tl.pdf.*

U.S. House, Committee on Interior and Insular Affairs, Subcommittee on Energy and the Environment. 1984. "Licensing Process at Grand Gulf Nuclear Powerplant." Hearing Proceedings. July 24.

U.S. House, Committee on Interior and Insular Affairs, Subcommittee on Energy and the Environment. 1982. "Quality Assurance at the Zimmer Nuclear Station." Hearing Proceedings. September 14.

U.S. House, Committee on Interior and Insular Affairs, Subcommittee on Energy and the Environment. 1981. "Quality Assurance in Nuclear Powerplant Construction." Hearing Proceedings. November 19.

APPENDIX

Selected Examples of NRC Generic Communications

Manufacturing Defects

- BL-74-06: Defective Westinghouse Type W-2 Control Switch Component. Bulletin. May 22, 1974.
- CR-80-17: Fuel Pin Damage Due to Water Jet from Baffle Plate Corner. Circular. July 23, 1980.
- IN-80-40: Excessive Nitrogen Supply Pressure Actuates Safety-Relief Valve Operation to Cause Reactor Depressurization. Information Notice. November 7, 1980.
- CR-81-01: Design Problems Involving Indicating Pushbutton Switches Manufactured by Honeywell Incorporated. Circular. January 23, 1981.
- GL81011: BWR Feedwater Nozzle and Control Rod Drive Return Line Nozzle Cracking (NUREG-0619). Generic Letter. February 28, 1981.
- IN-82-43: Deficiencies in LWR Air Filtration/Ventilation Systems. Information Notice. November 16, 1982.
- BL-86-03: Potential Failure of Multiple ECCS Pumps Due to Single Failure of Air-Operated Valve in Minimum Flow Recirculation Line. Bulletin. October 8, 1986.
- IN-88-76: Recent Discovery of a Phenomenon Not Previously Considered in the Design of Secondary Containment Pressure Control. Information Notice. September 19, 1988.
- IN-89-44: Hydrogen Storage on the Roof of the Control Room. Information Notice. April 27, 1989.

Material Imperfections

- BL-79-26: Boron Loss from BWR Control Blades. Bulletin. November 20, 1979.
- GL85022: Potential for Loss of Post-LOCA Recirculation Capability Due to Insulation Debris Blockage. Generic Letter. December 3, 1985.
- GL88005: Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants. Generic Letter. March 17, 1988.
- GL89008: Erosion/Corrosion-Induced Pipe Wall Thinning. Generic Letter. May 2, 1989.
- GL91015: Operating Experience Feedback Report, Solenoid-Operated Valve Problems at U.S. Reactors. Generic Letter. September 23, 1991.
- IN-97-84: Rupture in Extraction Steam Piping as a Result of Flow-Accelerated Corrosion. Information Notice. December 11, 1997.

Poor Workmanship

- BL-73-06: Inadvertent Criticality in a Boiling Water Reactor. Bulletin. November 27, 1973.
- BL-77-04: Calculational Error Affecting the Design Performance of a System for Controlling pH of Containment Sump Water Following a LOCA. Bulletin. November 4, 1977.
- CR-78-04: Installation Error That Could Prevent Closing of Fire Doors. Circular. May 15, 1978.
- CR-79-18: Proper Installation of Target Rock Safety-Relief Valves. Circular. September 6, 1979.
- IN-85-96: Temporary Strainers Left Installed in Pump Suction Piping. Information Notice. December 23, 1985.
- IN-90-77: Inadvertent Removal of Fuel Assemblies from the Reactor Core. Information Notice. December 12, 1990.
- IN-2001-06: Centrifugal Charging Pump Thrust Bearing Damage Not Detected Due to Inadequate Assessment of Oil Analysis Results and Selection of Pump Surveillance Points. Information Notice. May 11, 2001.

NOTE: *The generic communications cited herein, and hundreds like them, are available through the NRC's Electronic Reading Room. Online at* www.nrc.gov/reading-rm/doc-collections/gen-comm/.

U.S. Nuclear Plants in the 21st Century

THE RISK OF A LIFETIME

Union of Concerned Scientists

Citizens and Scientists for Environmental Solutions

National Headquarters
Two Brattle Square
Cambridge, MA 02238-9105
Phone: 617-547-5552
Toll-Free: 800-666-8276
Fax: 617-864-9405

Washington, DC Office
1707 H Street NW, Suite 600
Washington, DC 20006-3962
Phone: 202-223-6133
Fax: 202-223-6162

West Coast Office
2397 Shattuck Avenue, Suite 203
Berkeley, CA 94704-1567
Phone: 510-843-1872
Fax: 510-843-3785

Email
ucs@ucsusa.org

Web
www.ucsusa.org

Nuclear power in the United States has, throughout the industry's history, been less safe and more expensive than necessary because of ineffective oversight. The Nuclear Regulatory Commission's (NRC) poor regulatory performance has contributed to several major disasters and countless close calls at nuclear plants.

Nuclear plants are at highest risk for failure when they begin operation and when they approach the end of their useful life. With new reactor designs proposed for construction, and more than 100 aging U.S. nuclear plants seeking extensions to their operating licenses, the need for an effective regulator has never been greater.

In this report, the Union of Concerned Scientists describes nuclear plant risks from cradle to grave and makes recommendations on how to reform the NRC into a consistently effective enforcer of federal safety regulations. With strong regulatory standards and enforcement measures in place, the NRC can provide the American public with the protection they expect and deserve.