

The NRC and Nuclear Power Plant Safety in 2010

A BRIGHTER SPOTLIGHT NEEDED



Union of Concerned Scientists

Citizens and Scientists for Environmental Solutions

The NRC and Nuclear Power Plant Safety in 2010: A Brighter Spotlight Needed

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Union of Concerned Scientists
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David Lochbaum is the director of the Nuclear Safety Project in the UCS Global Security Program.

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Executive Summary

This report is the first in an annual series on the safety-related performance of the owners of U.S. nuclear power plants and the Nuclear Regulatory Commission (NRC), which regulates the plants. The NRC's mission is to protect the public from the inherent hazards of nuclear power.

In 2010, the NRC reported on 14 special inspections it launched in response to troubling events, safety equipment problems, and security shortcomings at nuclear power plants. This report provides an overview of each of these significant events—or near-misses.

This overview shows that many of these significant events occurred because reactor owners, and often the NRC, tolerated known safety problems. For example, the owner of the Calvert Cliffs plant in Maryland ended a program to routinely replace safety components before launching a new program to monitor degradation of those components. As a result, an electrical device that had been in use for longer than its service lifetime failed, disabling critical safety components.

In another example, after declaring an emergency at its Brunswick nuclear plant in North Carolina, the owner failed to staff its emergency response teams within the required amount of time. That lapse occurred because workers did not know how to activate the automated system that summons emergency workers to the site.

Outstanding Catches by the NRC

This report also provides three examples where onsite NRC inspectors made outstanding catches of safety problems at the Oconee, Browns Ferry, and Kewaunee nuclear plants—before these impairments could lead to events requiring special inspections, or to major accidents.

At the Oconee plant in South Carolina, the owner fixed a problem with a vital safety system on Unit 1 that had failed during a periodic test. However, the owner decided that identical components on Units 2 and 3 could not possibly have the same problem. NRC inspectors persistently challenged lame excuse after lame excuse until the company finally agreed to test the other two units. When it did so, their systems failed, and NRC inspectors ensured that the company corrected the problems.

Poor NRC Oversight

However, the NRC did not always serve the public well in 2010. This report analyzes serious safety problems at Peach Bottom, Indian Point, and Vermont Yankee that the NRC overlooked or dismissed. At Indian Point, for example, the NRC discovered that the liner of a refueling cavity at Unit 2 has been leaking since at least 1993. By allowing this reactor to continue operating with equipment that cannot perform its only safety function, the NRC is putting people living around Indian Point at elevated and undue risk. The NRC audits only about 5 percent of activities at nuclear plants each year. Because its spotlight is more like a strobe light—providing brief, narrow glimpses into plant conditions—the NRC must focus on the most important problem areas. Lessons from the 14 near-misses reveal how the NRC should apply its limited resources to reap the greatest returns to public safety.

Because we have not reviewed all NRC actions, the three positive and three negative examples do not represent the agency's best and worst performances in 2010. Instead, the examples highlight patterns of NRC behavior that contributed to these outcomes. The positive examples clearly show that the NRC can be an effective regulator. The negative examples attest that the agency still has work to do to become the regulator of nuclear power that the public deserves.

Findings

Overall, our analysis of NRC oversight of safety-related events and practices at U.S. nuclear power plants in 2010 suggests these conclusions:

- Nuclear power plants continue to experience problems with safety-related equipment and worker errors that increase the risk of damage to the reactor core—and thus harm to employees and the public.
- Recognized but misdiagnosed or unresolved safety problems often cause significant events at nuclear power plants, or increase their severity.
- When onsite NRC inspectors discover a broken device, an erroneous test result, or a maintenance activity that does not reflect procedure, they too often focus just on that problem. Every such finding should trigger an evaluation of why an owner failed to fix a problem before NRC inspectors found it.
- The NRC can better serve the U.S. public and plant owners by emulating the persistence shown by onsite inspectors who made good catches while eliminating the indefensible lapses that led to negative outcomes.
- Four of the 14 special inspections occurred at three plants owned by Progress Energy. While the company may simply have had an unlucky year, corporate-wide approaches to safety may have contributed to this poor performance. When conditions trigger special inspections at more than one plant with the same owner, the

NRC should formally evaluate whether corporate policies and practices contributed to the shortcomings.

The chances of a disaster at a nuclear plant are low. When the NRC finds safety problems and ensures that owners address them—as happened last year at Oconee, Browns Ferry, and Kewaunee—it keeps the risk posed by nuclear power to workers and the public as low as practical. But when the NRC tolerates unresolved safety problems—as it did last year at Peach Bottom, Indian Point, and Vermont Yankee—this lax oversight allows that risk to rise. The more owners sweep safety problems under the rug and the longer safety problems remain uncorrected, the higher the risk climbs.

While none of the safety problems in 2010 caused harm to plant employees or the public, their frequency—more than one per month—is high for a mature industry. The severe accidents at Three Mile Island in 1979 and Chernobyl in 1986 occurred when a handful of known problems—aggravated by a few worker miscues—transformed fairly routine events into catastrophes. That plant owners could have avoided nearly all 14 near-misses in 2010 had they corrected known deficiencies in a timely manner suggests that our luck at nuclear roulette may someday run out.

CHAPTER 1

THE COP ON THE NUCLEAR BEAT

The Nuclear Regulatory Commission (NRC) is to owners of nuclear reactors what local law enforcement is to a community. Both are tasked with enforcing safety regulations to protect people from harm. A local police force would let a community down if it investigated only murder cases while tolerating burglaries, assaults, and vandalism. The NRC must similarly be the cop on the nuclear beat, actively monitoring reactors to ensure that they are operating within regulations, and aggressively engaging owners and workers when even minor violations occur.

The Union of Concerned Scientists (UCS) has evaluated safety at nuclear power plants for nearly 40 years. We have repeatedly found that NRC enforcement of safety regulations is not timely, consistent, or effective. Our findings match those of the agency's internal assessments, as well as of independent agents such as the NRC's Office of the Inspector General, and the federal Government Accountability Office. Seldom does an internal or external evaluation conclude that a reactor incident or unsafe condition stemmed from a lack of regulations. Like UCS, these evaluators consistently find that NRC enforcement of existing regulations is inadequate.

With study after study showing that the NRC has the regulations it needs but fails to enforce them, we decided that another report chronicling only the latest examples of lax enforcement would be futile. Instead, this report—the first in an annual series on NRC performance—chronicles what the agency is doing right as well as what it is doing wrong.

The Reactor Oversight Process

When an event occurs at a reactor, or workers or NRC inspectors discover a degraded condition, the NRC evaluates whether the chance of damage to the reactor core has risen (NRC 2001). If the event or condition has not affected that risk—or if the risk has increased only incrementally—the NRC relies on its reactor oversight process (ROP) to respond. The ROP features seven cornerstones of reactor safety (see Table 1). In this process, the NRC's inspectors continually monitor operations and procedures at nuclear plants, attempting to detect problems before they lead to more serious violations and events. The NRC issued nearly 200 reports on such problems in 2010 alone.

Most safety-related incidents and discoveries at nuclear power plants are low risk. However, when an event or condition increases the chance of reactor core damage by a factor of 10, the NRC is likely to send out a special inspection team (SIT). When the risk rises by a factor of 100, the agency may dispatch an augmented inspection team (AIT). And when the risk increases

by a factor of 1,000 or more, the NRC may send an incident inspection team (IIT). The teams go to the sites to investigate what happened, why it happened, and any safety implications for other nuclear plants. These teams take many weeks to conduct an investigation, evaluate the information they gather, and document their findings in a report, which they usually make public.

Both routine inspections and those of the special teams identify violations of NRC regulations. The NRC classifies these violations into five categories, with Red denoting the most serious, followed by Yellow, White, Green, and Non-Cited Violations (NCVs).

The Focus of This Report

Chapter 2 investigates all 14 “near-misses” at nuclear reactors that the NRC reported on in 2010: events that spurred the NRC to dispatch an SIT, AIT or IIT. In these events, a combination of broken or impaired safety equipment and poor worker training typically led operators of nuclear plants down a pathway toward potentially catastrophic outcomes.

After providing an overview of these events, this chapter shows how one problem led to another in more detail. The chapter then describes the “tickets” the NRC wrote for the numerous safety violations that contributed to each near-miss. Finally, the chapter suggests how the NRC can prevent plant owners from accumulating problems that will conspire to cause next year’s near-misses—or worse.

This review of near-misses provides important insights into trends in nuclear safety as well as the effectiveness of the NRC’s oversight process. For example, if many near-misses stem from failed equipment, such as emergency diesel generators, the NRC could focus its efforts in that area until it arrests declining performance.

With these near-misses attesting to why enforcement is vital to the safety of nuclear power, the next two chapters highlight NRC performance in monitoring safety through the onsite reactor oversight process. Chapter 3 describes three occasions in which effective NRC oversight produced three positive outcomes—preventing safety problem from snowballing into even more dangerous near-misses. Chapter 4, in turn, describes three occasions in which ineffective NRC oversight failed to prevent negative outcomes.¹

Chapter 5 summarizes findings from the near-misses in Chapter 2, the examples of positive outcomes in Chapter 3, and the examples of negative outcomes in Chapter 4. This chapter notes which oversight and enforcement strategies worked well for the NRC in 2010 and which did not. This chapter also recommends steps the agency should take to reinforce behavior patterns leading to commendable outcomes, and steps it should take to avoid condemnable outcomes.

UCS’s primary aim in creating this and ensuing annual reports is to spur the NRC to improve its own performance as well as that of reactor owners and operators. Future reports will highlight steps the agency took to reinforce effective oversight and eliminate lax enforcement, and to ensure that plant owners comply with NRC safety regulations.

¹ The utility of the examples as models was more important than the number. Future reports may include a different number of examples.

Table 1: Seven Cornerstones of the Reactor Oversight Process	
Initiating events	Conditions that, if not properly controlled, require the plant's emergency equipment to maintain safety. Problems in this cornerstone include improper control over combustible materials or welding activities, causing an elevated risk of fire; degradation of piping, raising the risk that it will rupture; and improper sizing of fuses, raising the risk that the plant will lose electrical power.
Mitigating systems	Emergency equipment designed to limit the impact of initiating events. Problems in this cornerstone include ineffective maintenance of an emergency diesel generator, degrading the ability to respond to a loss of offsite power; inadequate repair of a problem with a pump in the emergency core cooling system, reducing the reliability of cooling during an accident; and non-conservative calibration of an automatic set point for an emergency ventilation system, delaying startup longer than safety studies assume.
Barrier integrity	Multiple forms of containment preventing the release of radioactive material into the environment. Problems in this cornerstone include foreign material in the reactor vessel, which can damage fuel assemblies; corrosion of the reactor vessel head from boric acid; and malfunction of valves in piping that passes through containment walls.
Emergency preparedness	Measures intended to protect the public if a reactor releases significant amounts of radioactive material. Problems in this cornerstone include emergency sirens within 10 miles of the plant that fail to work; and underestimation of the severity of plant conditions during a simulated or actual accident, delaying protective measures.
Public radiation safety	Design features and administrative controls that limit public exposure to radiation. Problems in this cornerstone include improper calibration of a radiation detector that monitors a pathway for the release of potentially contaminated air or water to the environment.
Occupational radiation safety	Design features and administrative controls that limit the exposure of plant workers to radiation. Problems in this cornerstone include failure to properly survey an area for sources of radiation, such that workers receive unplanned exposures; and incomplete accounting of individuals' radiation exposure.
Security	Protection against sabotage that aims to release radioactive material into the environment, which can include gates, guards, and guns. After 9/11, the NRC removed discussion of this cornerstone from the public arena.

CHAPTER 2

NEAR-MISSES AT NUCLEAR POWER PLANTS IN 2010

In 2010, the NRC reported on 14 significant safety- and security-related events at nuclear reactors that resulted in special or augmented inspections (see Table 2). (Some of the events actually occurred in 2009, but the reports appeared in 2010.) Thirteen of these events triggered an SIT, one triggered an AIT, and none triggered an IIT.

These events are near-misses because they raised the risk of damage to the reactor core—and thus to the safety of workers and the public. Lessons from these 14 near-misses reveal how the NRC can apply its limited resources to reap the greatest returns to public safety.

Table 2: Nuclear Near-Misses in 2010

Reactor and Location	Owner	Highlights
<u>Arkansas Nuclear One</u> Russellville, AR	Entergy	SIT: Security problems prompted the NRC to conduct a special inspection. Details of the problems, their causes, and their fixes are not publicly available.
<u>Braidwood</u> Joilet, IL	Exelon	SIT: The plant owner knew about several problems but did not correct them, leading to a near-miss. The problems included a poor design that led to repeated floods in buildings with safety equipment, a poor design that allowed vented steam to rip metal siding off containment walls, and undersized electrical fuses for vital safety equipment.
<u>Brunswick</u> Southport, NC	Progress Energy	SIT: Equipment failure prompted the plant owner to declare an emergency. Workers did not know how to operate the computer systems that automatically notified offsite workers to report immediately to emergency response facilities. Staffing and preparing these facilities took far longer than required.

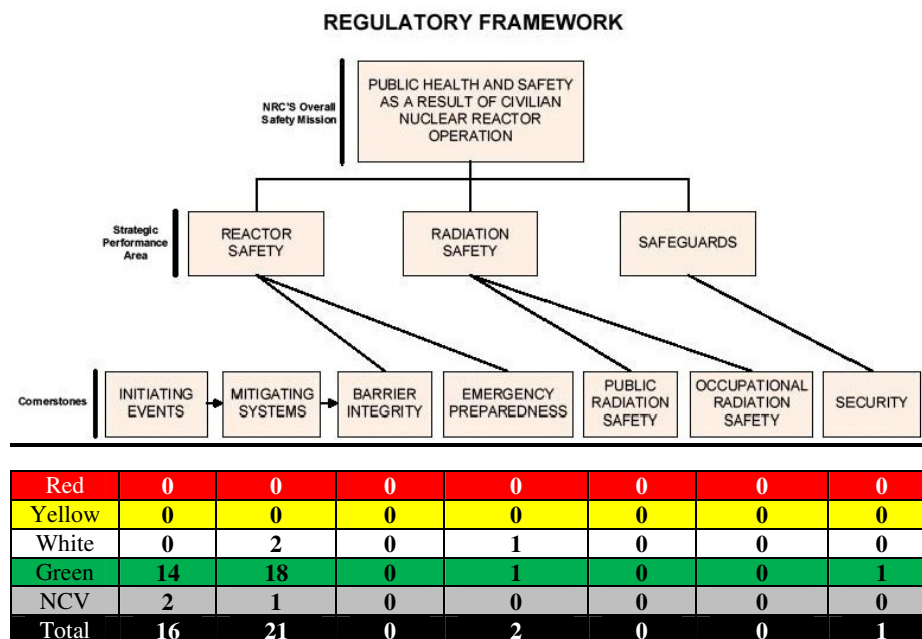
Reactor and Location	Owner	Highlights
<u>Calvert Cliffs</u> Annapolis, MD	Constellation Energy	SIT: A roof known for years to leak when it rained allowed rainwater to short out electrical equipment. One reactor automatically shut down. A worn-out protective device that workers had not replaced because of cost-cutting efforts allowed the electrical problem to trigger an automatic shutdown of a second reactor.
<u>Catawba</u> Rock Hill, SC	Duke Energy	SIT: Security problems prompted the NRC to conduct a special inspection. Details of the problems, their causes, and their fixes are not publicly available.
<u>Crystal River 3</u> Crystal River, FL	Progress Energy	SIT: Workers severely damaged thick concrete reactor containment walls when they cut a hole to replace steam generators. The ensuing inquiry concluded that the workers had applied more pressure than the concrete could withstand—a mistake that cost more than \$500 million.
<u>Davis-Besse</u> Toledo, OH	FirstEnergy	SIT: Workers discovered through-wall cracks in metal nozzles for control rod drive mechanisms in a replacement reactor vessel head. These cracks leaked because workers did not properly account for peak temperatures inside the reactor vessel.
<u>Diablo Canyon</u> San Luis Obispo, CA	Pacific Gas & Electric	SIT: A misguided repair to valves that would not open fast enough prevented other key valves from opening. Tests after the valve repairs failed to detect the problem. The reactor operated for nearly 18 months with vital emergency systems disabled.
<u>Farley</u> Dothan, AL	Southern Nuclear	SIT: A replacement pump had a part with a manufacturing defect. Excessive vibration levels caused the pump to fail when workers did not ensure that it met key parameters specified in the purchase order.
<u>Fort Calhoun</u> Omaha, NE	Omaha Public Power District	SIT: Pumps in an emergency water makeup system failed repeatedly over several years. The plant owner never identified the true cause of the failures, and therefore did not take the right steps to prevent their recurrence.

Reactor and Location	Owner	Highlights
<u>HB Robinson</u> Florence, SC	Progress Energy	AIT: On the 31 st anniversary of Three Mile Island, this event revisited nearly all the problems that caused that meltdown: bad design, poor maintenance of problematic equipment, inadequate operator performance, and poor training.
<u>HB Robinson</u> Florence, SC	Progress Energy	SIT: The same problems (see above) caused this reactor's second near-miss in six months: bad design, nonconforming equipment, inadequate operator performance, and poor training. This baggage reflected years of programmatic failures.
<u>Surry</u> Newport News, VA	Dominion Generation	SIT: After an inadvertent shutdown of the Unit 1 reactor, a fire began in the control room due to an overheated electrical component. A similar component in the Unit 2 control room had overheated and started a fire six months earlier. The company did not take steps to protect Unit 1 from the problem identified in Unit 2.
<u>Wolf Creek</u> Burlington, KS	Wolf Creek Nuclear	SIT: Seven hours after the reactor shut down automatically because of a problem with the electrical grid, an NRC inspector found water leaking from the system that cools the emergency diesel generators and virtually all other emergency equipment. An internal study in 2007 had forecast such leakage, and a leak had actually occurred after a reactor shutdown in April 2008. However, the owner had taken few steps to correct this serious safety problem.

In 2010, SIT/AIT reports identified 40 violations of NRC safety regulations. Figure 1 classifies these violations by the seven cornerstones of the reactor oversight process (ROP).²

² For more information on the cornerstones and related NRC inspections, see Table 1 and <http://www.nrc.gov/NRR/OVERSIGHT/ASSESS/cornerstone.html>.

Figure 1: Near-Misses in 2010 by Cornerstones of the Reactor Oversight Process



Source: NRC (top half of figure).

Two of the NRC's regulatory cornerstones accounted for most of the near-misses in 2010. And most near-misses drew a Green finding—the weakest color-coded sanction—from the agency. NCV = Non-Cited Violations.

The most significant near-miss occurred on March 28, 2010—coincidentally, the 31st anniversary of the Three Mile Island accident—at the HB Robinson nuclear plant in South Carolina. The most costly event forced the owner of the Crystal River 3 reactor in Florida to shut it down for the entire year.

Arkansas Nuclear One, AR

The Near-Miss

The NRC sent an SIT to the plant in response to security-related problems. Reflecting the NRC's post-9/11 procedures for withholding information, the SIT report on the problem(s) and their remedies is not publicly available. However, the cover letter sent to the plant owner with the SIT report is publicly available, and indicates that the agency uncovered no violations (NRC 2010k).

Braidwood, IL

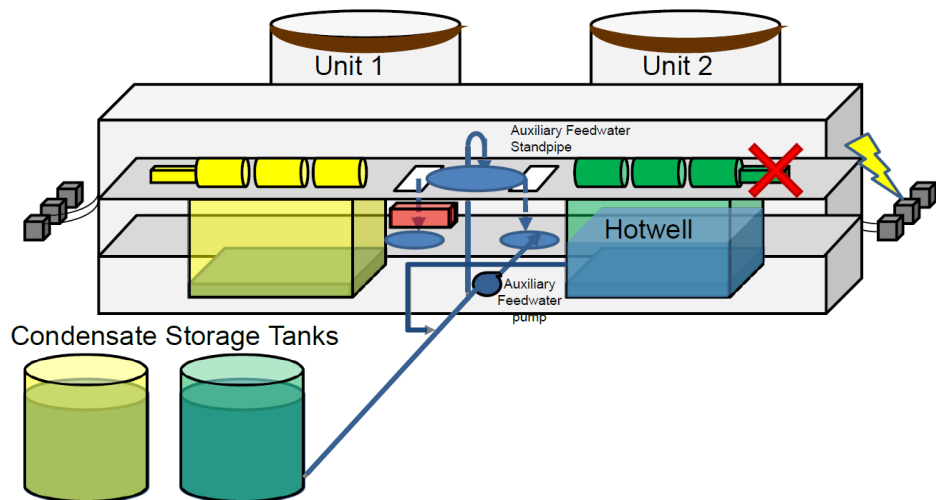
The Near-Miss

The NRC sent an SIT to the site after an unplanned shutdown of both reactors on August 16, 2010—complicated by problems with an emergency pump for Unit 2 and the steam pressure control valve for Unit 1 (NRC 2010d).

The SIT found that these complicating factors had all occurred individually at least once before, and that they combined this time to create serious risks. The NRC sanctioned the owner for having known about these problems but not correcting them. Yet the NRC also knew or should have known about them, but did nothing to compel their resolution until after this near-miss.

How the Event Unfolded

On August 16, 2010, both reactors at the Braidwood nuclear plant in Illinois were operating at full power. The Unit 2 reactor automatically shut down at 2:16 am, when an electrical ground caused the main generator to turn off. The pumps of the auxiliary feedwater (AFW) system started automatically after the reactor shutdown, to transfer water from the condensate storage tank to the steam generators.

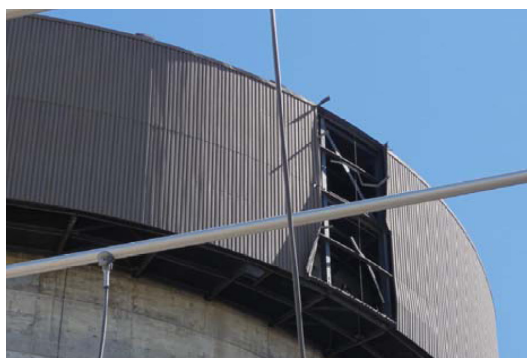


NRC drawing of the key components involved in the Braidwood near-miss. The red “X” indicates where the event started, when the main generator shut down.

However, the flow-control valve for one AFW pump failed in the open position, and the water level in the main condenser hotwell rose until valves opened to send some of this water back to the condensate tank. Nearly 12,000 gallons of water spilled onto the floor of the turbine building, from open standpipes installed on the piping between the outdoor tank and the AFW pumps (NRC 2010j).

Some of the spilled water flowed through holes in the floor and rained down on equipment on lower floors. Water leaked into an electrical panel housing controls for Unit 1 equipment. Two large pumps that circulate water between a nearby river and the main condenser stopped running because of electrical shorts. The reduction in cooling water flow through the main condenser impaired the condensation of steam inside the condenser. This impairment degraded the condenser's vacuum, triggering an automatic shut-down of the Unit 1 reactor about 15 minutes after the Unit 2 reactor shut down.

After the Unit 1 reactor shut down, the main steam safety valves (MSSVs) automatically opened to relieve pressure in the piping carrying steam from the steam generators to the main turbine. One MSSV stuck open after pressure dropped back below the opening set points. The operators did not realize that the MSSV was open until a worker arriving at the site 40 minutes later told them. Meanwhile steam passing through this open valve dislodged sheet-metal siding around the top of the Unit 1 containment building. Some of the siding landed on power lines for the Unit 1 off-site power transformer.



NRC photo of the metal siding torn from the containment building at the Braidwood nuclear power plant in Illinois.

Although two large circulating water pumps for Unit 1 had shut down because of electrical shorts, other pumps continued to run. These pumps sit in a concrete structure on the banks of the nearby river. The piping on the discharge of each pump contains a valve that closes when the pump is not running, to prevent backflow. However, the loss of electrical power that shut down the pumps also prevented their motor-operated valves from closing. Water flowing back through the idle pumps stirred up organic growth and debris. The pumps carried this material into the piping of the service water system, which supplies cooling water to essential plant equipment. The debris impaired but did not disable the system and the equipment it supported.

A second spill then complicated the Unit 1 reactor shutdown. The seal on a condensate booster pump failed, allowing water to spray onto another electrical panel. Operators stopped the pump and closed its valves to isolate the leak.

NRC Sanctions

The SIT identified two violations of regulatory requirements of the ROP's *initiating events* cornerstone. The first violation involved the failure to correct the condition that allowed water to spill onto the turbine building floor. Operators had observed such spills several times before, but had evaluated them only from a worker safety perspective.

The second violation involved failure to properly evaluate operating experience. Workers had evaluated an event at another nuclear plant where steam had dislodged metal siding, and had concluded that it did not apply to Braidwood. They failed to evaluate a previous event at Braidwood in which steam had dislodged metal siding. The NRC classified both violations as Green—the least serious of the color-coded violations.

The SIT identified two other violations of requirements associated with the *mitigating systems* cornerstone. The first involved a failure to properly inspect and clean the pump intake structure, to prevent fouling that could disable the essential service water system.

The second violation involved inadequate corrective actions. In 2008, workers had found that they needed to replace 1.5-amp fuses in safety-related electrical panels with 3.0-amp fuses. However, the workers did not do so, and the fuses failed in 2009. After the failures, workers replaced the blown fuses with 1.5-amp fuses, and these failed again during the August 2010 event. The NRC classified both violations as Green.

Brunswick, NC

The Near-Miss

The NRC sent an SIT to the site after the inadvertent discharge of Halon gas—a fire suppression agent—on June 6, 2010, into the basement of the building housing the emergency diesel generator. The release of the toxic gas into a vital area prompted control room operators to declare an Alert—the third-most-serious of four emergency classifications. The SIT investigated delayed responses to the emergency declaration.

The SIT found that workers did not know how to activate the computer systems that automatically notified emergency responders, so the responders took longer than required to staff emergency facilities. Luckily, this event was not an actual emergency, or the delay could have put people in harm's way.

How the Event Unfolded

On June 6, operators declared an Alert at 11:37 am, after Halon discharged into the building housing the plant's emergency diesel generator. Halon extinguishes fires by reducing the concentration of oxygen in the air. In this case, no fire had occurred, and the Halon discharge was spurious. While the Halon discharge was inadvertent, it prevented ready access to the diesel generator building. This restriction prompted the Alert declaration.

The Alert should have prompted operators to activate three onsite emergency response facilities within 75 minutes: the Technical Support Center, the Operations Support Center, and the Emergency Operations Facility. Specialists at the Technical Support Center help control room operators diagnose problems and take steps to mitigate them.

Specialists at the Operations Support Center help repair broken or malfunctioning safety equipment. Specialists at the Emergency Operations Facility liaise with local, state, and federal officials responding to the emergency. The Alert is also supposed to activate an emergency response data system (ERDS) within 60 minutes, which provides continuous, real-time information

on conditions at the plant to local, state, and federal authorities. These activations all occurred late.

Twenty-five minutes after the Alert declaration, the control room site emergency coordinator (CR-SEC) notified the plant's security department to initiate the emergency callout system, which notifies off-duty personnel to report to their assigned emergency response facilities promptly. Security personnel made five unsuccessful attempts to initiate the callout system, and then informed the CR-SEC that they were unable to do so. The CR-SEC then directed the control room emergency communicator to initiate the callout, who made three unsuccessful attempts.

An hour after workers declared the Alert, an emergency preparedness supervisor initiated the callout from home on the first attempt, and off-duty personnel began receiving notification to report to the plant because of an emergency. Two hours and thirty minutes after operators declared the Alert, onsite emergency response facilities were fully staffed and activated. That response time was twice as long as specified in the plant's emergency response procedures.

The CR-SEC directed the shift technical advisor (STA) to activate the ERDS 28 minutes after the Alert declaration. After several unsuccessful attempts, the STA contacted the on-call nuclear information technologist (NIT) for help in activating the ERDS. The NIT did not know how to do so, but contacted another NIT who did. The second NIT initiated the ERDS from home on the first attempt—80 minutes after operators had declared the Alert. That was 20 minutes longer than specified in the plant's emergency response procedures (NRC 2010g).

NRC Sanctions

The SIT identified two violations of regulatory requirements associated with the ROP's *emergency preparedness* cornerstone. The first violation involved the failure to activate the onsite emergency response facilities within 75 minutes, as specified in the plant's emergency response procedures. The NRC classified that violation as White—one step up from Green (NRC 2010a).

The second violation involved the failure to activate the emergency response data system within 60 minutes, as specified in the plant's emergency response procedures. The NRC classified that violation as Green.

Calvert Cliffs, MD

The Near-Miss

The NRC sent an SIT to the site after an unplanned shutdown of both reactors on February 18, 2010 (NRC 2010s). The SIT determined that two factors had complicated this event. One was the longstanding flow of rainwater through a leaky roof. The second was a problem created by the plant's replacement program for safety equipment.

The plant owner had originally replaced devices on safety equipment before they reached the end of their service life. To save money, the company decided to test the performance of the devices rather than replacing them au-

tomatically. However, the company stopped the routine replacement program before instituting the new regime for testing actual conditions. As a result, a worn-out device failed to prevent electrical problems caused by rainwater from propagating throughout the plant.

How the Event Unfolded

This event began when water leaking through the roof of Unit 1's auxiliary building caused an electrical short that shut down one of the four large pumps circulating water through the reactor core. The reduced flow of cooling water triggered the Unit 1 reactor to shut down automatically.

The failure of an electrical protection device on Unit 1 then created an overcurrent condition in Unit 2's power distribution system. In response, an electrical protection device on Unit 2 shut down all four pumps circulating water through the reactor core, and the loss of cooling water triggered the automatic shutdown of the Unit 2 reactor.

The problems with the power distribution system prompted emergency diesel generators for both reactors to start automatically. However, an emergency generator for Unit 2 shut down after only 15 seconds, because of a signal indicating low lubricating oil pressure. Loss of that emergency diesel generator de-energized equipment needed by the operators to control the water level in the pressurizers.

The pressurizers are large tanks partially filled with water that are connected to the pipes running between the reactor vessel and the steam generators. By heating or cooling the water inside the pressurizer, the operators can control the pressure of the water flowing through the reactor core. The pressurizer also accommodates the swelling and shrinking of water caused by temperature changes during changes in reactor power.

To supplement the pressurizer's ability to handle the expansion of water during temperature increases, water can be removed from the system via drain pipes called letdown paths. The SIT discovered that procedural problems prevented the operators from restoring the letdown paths in time to prevent water levels in the pressurizers from exceeding their safety limits.

The power distribution problems at Unit 2 eliminated the normal means of removing decay heat from the reactor core after shutdown. Operators relied instead on the turbine-driven auxiliary feedwater pump, and atmospheric steam dump valves, to remove decay heat.

The SIT found that roof leakage had been a recurring problem since 2002, and that the company knowingly tolerated it. For example, in 2005 plant workers noted 33 roof leaks. When rainfall leaked through the roof in July 2008, workers notified control room operators and mopped up the puddle. In August 2009, workers responded to water leaking through the roof onto an electrical panel by covering the panel with a plastic sheet and catching the leakage in a bucket. The plant owner discussed corrective actions but never took them.

The SIT reported that the company attributed the failure of the electrical protection device to premature aging of its coil. The device had a 40-year service lifetime but failed after 39 years, because high temperatures aged it more rapidly. The SIT discovered that 68 devices at Calvert Cliffs had a 10 percent failure rate between 1999 and 2005, and that the owner's calibration

and inspection procedures lacked common industry practices specified in a manual from the Electric Power Research Institute.

The SIT determined that Unit 2's emergency diesel generator did not run because of a failed time-delay relay. The relay prevents a shutdown stemming from low oil pressure until the pressure has first risen to the normal operating range after the emergency generator has started.

On February 18 the relay timed out too soon, shutting down the emergency generator. The SIT found that the failed relay had been in service for 3.5 years longer than the 10-year service lifetime recommended by the vendor. In 2001, the company had discontinued the practice of replacing the relays after 10 years of service. The owner substituted a performance-monitoring program for about 100 relays with safety functions, and more than 500 relays with non-safety functions. However, the owner had never developed the monitoring program, much less implemented it.

NRC Sanctions

The SIT documented two violations of regulatory requirements associated with the ROP's *initiating events* cornerstone. The first involved the company's failure to respond to recurring roof leakage with timely and effective corrective action. The second violation involved failure to properly evaluate and correct degraded electrical protection devices. The NRC classified both violations as Green.

The SIT also identified three violations of regulatory requirements associated with the *mitigating systems* cornerstone. The first violation involved failure to implement a preventive maintenance program for electrical relays with safety functions. The second violation involved failure to properly evaluate and correct recurring binding and sticking problems with electrical protective devices.

The third violation involved failure to establish procedures for restoring the primary system's letdown flow function. The NRC classified the first violation as White, and the remaining two violations as Green.

Catawba, SC

The Near-Miss

The NRC sent an SIT to the site in response to security-related problems. Reflecting post-9/11 procedures, the SIT report explaining the problems and their remedies is not publicly available. However, the cover letter sent to the plant owner with the SIT report is publicly available, and indicates that the NRC identified one Green violation (NRC 2010r).

Crystal River Unit 3, FL

The Near-Miss

The NRC sent an SIT to the site after discovery of a gap in the concrete containment walls on October 2, 2009, near an opening cut to allow workers to replace the steam generators (NRC 2010h).

The SIT found that the method used to cut through the thick concrete walls created so much pressure that thick metal reinforcing bars in the walls acted like the San Andreas fault. The SIT's computer simulations showed that the outer half of the walls had separated from the inner half along the reinforcing bars.

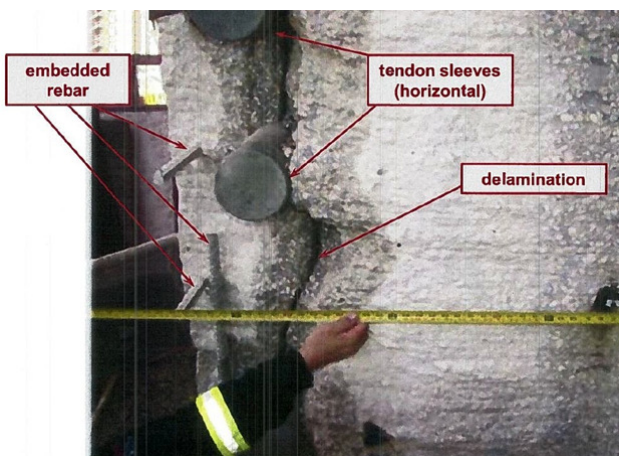
This finding raises several questions: Why didn't the company do such homework before embarking on this ill-fated experiment, and why did the NRC allow it to happen? Even more fundamentally, why did the owner design and build a massive structure with doors smaller than the equipment it houses, given the potential need to replace the equipment?

How the Event Unfolded

The pressurized water reactor (PWR) at Crystal River Unit 3 (CR3) has large heat exchangers, called steam generators. Water heated to nearly 600° F in the reactor core flows through thousands of thin metal tubes in the steam generators. This water is maintained at high pressure to keep it from boiling. Heat conducted through the walls of the tubes boils water at lower pressure outside the tubes. The resulting steam is piped to the turbine to generate electricity.

When originally installed inside the reactor containment structure in the 1970s, the steam generators were expected to last the plant's entire operating lifetime. However, corrosion, vibration-induced wear, and stress cracking degraded the generators' thin metal tubes. Thus, work performed during a scheduled refueling outage in September 2009 included replacing the steam generators. Because they were larger than the equipment hatch for the reactor containment building, workers had to cut a 25-by-27-foot opening through the 42-inch-thick containment wall to get the old steam generators out and the new ones in.

CR3's dome-shaped reactor containment structure is lined with a 3/8-inch layer of steel, reinforced with 282 horizontal 5-inch-thick metal cables, called tendons, and 144 ver-



NRC picture of the crack (delamination) in the concrete containment wall at Crystal River 3 caused when workers cut a square opening to replace the steam generators.

tical tendons embedded inside the concrete. The tendons are stretched, or tensioned, to strengthen the containment structure.

The SIT found that workers had loosened 10 vertical and 17 horizontal tendons where they planned to cut through the containment walls, and had then used a high-pressure jet of water to make the cut. A significant crack in the concrete running vertically between the horizontal tendons then appeared. Further investigation revealed a 60-by-82-foot hourglass-shaped delamination around the opening.

The SIT confirmed that the containment structure had been intact while the reactor operated, and concurred with the owner that seven factors had combined to produce more force than the concrete could withstand. Fortunately, the delamination occurred during an outage, when safety did not require integrity of the containment walls.

NRC Sanctions

The SIT identified no violations of NRC requirements. From a regulatory perspective, damaging the reactor's containment building is perfectly acceptable if the reactor is not operating, and it is not restarted until the building is fixed. The CR3 reactor remained shut down for more than a year—punishment enough for this miscue.

Davis-Besse, OH

The Near-Miss

The NRC sent an SIT to the site after the discovery on March 12, 2010, of cracks in nozzles on the control rod drive mechanism (CRDM) that had penetrated through the head of the reactor vessel. Borated reactor cooling water leaked through some of the cracks (NRC 2010f).

This situation was déjà vu all over again, as an SIT had visited Davis-Besse in 2002 after a cracked and leaking CRDM nozzle caused extensive damage to the reactor vessel head. After replacing the damaged head and correcting numerous other safety problems, operators had restarted the reactor in March 2004.

That episode had revealed that higher temperatures in the CRDM nozzles create more stress, allowing cracks to form and hastening their propagation. Despite that finding, the 2010 SIT learned that workers did not accurately track temperatures inside the reactor vessel, assuming instead that they were the same as the temperature of the water leaving the vessel. However, some temperatures inside the vessel were nearly 7° F higher.

Given that the water is at about 600° F, this error may seem minor. However, those seven degrees are the difference between detecting cracks in the CRDM nozzles before they leak and experiencing a déjà vu moment.

How the Event Unfolded

The March 2001 discovery of similar cracking and leakage at the Oconee nuclear plant in South Carolina prompted the NRC to require more extensive inspections of CRDM nozzles. The nozzles are four-inch-diameter hollow metal tubes that penetrate through the six-inch-thick steel heads atop the reactor pressure vessel. The nozzles connect the control rods used to regulate

the power level of the reactor core to electric motors on a platform above the reactor vessel head.

When workers performed Oconee-inspired inspections at Davis-Besse in March 2002, they found extensive cracking in the nozzles, and that leaking borated water had significantly degraded the reactor vessel head. Workers replaced this damaged head with one from the closed Midland nuclear plant in Michigan, and restarted Davis-Besse in March 2004. Inspections of the CRDM nozzles during refueling outages in 2006 and 2008 revealed no evidence of leakage.



White-crystalline boric acid leaked through a cracked nozzle in the head of the reactor vessel at the Davis-Besse plant in Ohio. NRC photo.

However, inspections during the March 2010 refueling outage revealed that two cracked CRDM nozzles had leaked borated reactor cooling water, and that many other nozzles had apparent cracks. Although the reactor vessel head did not need repair or replacement, workers repaired 24 of the 69 CRDM nozzles.

The SIT identified three violations of regulatory requirements associated with the ROP's *initiating events* cornerstone. The first involved workers' failure to control water rinse time after applying a liquid dye penetrant to the CRDM nozzles and welds. The penetrant makes cracks more apparent during a visual inspection. The uncontrolled rinse time could have allowed the penetrant to wash away before the inspection.

The second violation cited control room operators for failing to provide specific guidance to ensure that workers examined the entire affected area on camera. The third violation involved a defective welding process used to repair one of the two leaking CRDM nozzles. The procedure failed to control temperature during the welding process. Welding temperature is important to ensuring high-quality results: too low a temperature can allow the metal to cool before strong bonds form, while too high a temperature can damage the metal. The NRC classified all three violations as Green.

Diablo Canyon Unit 2, CA

The Near-Miss

The NRC sent an SIT to the site after operators could not open valves that provide emergency cooling water to the reactor core and containment vessel during a test on October 22, 2009 (NRC 2010x).

The SIT found that a misguided fix of an earlier problem had caused this even larger problem. When the valves failed to open and close within specified time limits, workers shortened their "travel distance." The workers did

not realize that this meant that these valves no longer reached their finish lines. Interlocks prevented other safety valves from opening until the first valves were fully open. The NRC sanctioned the company for a bad “fix,” and for inadequate post-fix testing that should have identified the unintended consequences but failed to do so.

How the Event Unfolded

In July 2005, workers became aware that motors for valves that provide emergency cooling water to the reactor core could not move against pressure inside the cooling system’s pipes under certain accident conditions. In October, workers revised the emergency operating procedure to have control room operators establish cooling water flow within 30 minutes of an accident, to reduce pressure on the valves. However, operators needed to ensure that the valves would function under all credible accident conditions.

In February 2008, therefore, workers changed the gear ratios on the motors for the valves, to enable them to move against any pressures that might occur. The workers then tested the valves to verify that they could move from fully closed to fully open in 25 seconds or less, as required. However, the valves failed the test. To fix that problem, an engineer shortened the travel distance between the two positions, and both valves passed retests.

Eighteen months later, when operators tried to open the valves to allow pumps to provide flow inside the containment building, they would not open. That meant operators would be unable to provide cooling water to the reactor core and containment vessel at a key point during an accident.

The SIT found that three pairs of valves were interlocked, and that the first pair had to open fully before the other pairs could do so. The February 2008 modification to shorten the travel distance of the first pair meant that they stopped moving before they reached the fully open position. That is, the fix for the problem that some valves might not open when required meant that other valves definitely would not open.

NRC Sanctions

The SIT identified three violations of regulatory requirements associated with the ROP’s *mitigating systems* cornerstone. The first violation involved the improperly analyzed change that shortened travel distances for the valves. The second violation involved inadequate post-modification testing of the valves. The NRC classified both violations as Green. Although the February 2008 modification impaired the emergency core cooling systems, workers could have opened the valves manually, so that mitigated the severity of the violations.

A third violation involved the October 2005 revision to emergency operating procedures that introduced a manual action into an accident response. The SIT determined that workers failed to conduct a safety evaluation to determine whether this change required NRC review and approval. The NRC classified this violation as Severity Level IV, the least serious sanction.

Farley, AL

The Near-Miss

The NRC sent an SIT to the site after a vendor notified the agency about a defective coating on a pump shaft journal (a device used to maintain the shaft alignment as it rotates at high speed), which contributed to the failure of a service water pump at Unit 2 in August 2009 (NRC 2010u).

The SIT found that the company had replaced the failed pump just three years earlier. The purchase order for the replacement pump specified key parameters, including some intended to protect it from damage caused by excessive vibration. However, the installed pump did not satisfy those parameters, and it failed after excessive vibration exacerbated the defect in the journal coating.

How the Event Unfolded

The service water system provides cooling water to safety equipment, such as emergency diesel generators, during an accident. Each of two reactors at Farley has five service water pumps. Four pumps must be available to allow each reactor to operate safely, with the fifth pump acting as a spare.

In April 2006 the company issued a purchase order for 11 service water pumps to replace the originals. Workers then replaced five of the original pumps over the ensuing three years. The first one replaced was the 2E pump on Unit 2. However, the new pump failed in August 2009, and was replaced again and sent back to the vendor for evaluation. The vendor found that a defective coating on the pump shaft's bearing journal had led to bearing damage and fracture of the wear ring.

The SIT found that purchase specs for the replacement pumps required that the critical speed of the rotor be at least 25 percent above the pump's normal speed, but that the replacement pumps failed to meet that requirement. Operating the pumps contrary to this specification increased their susceptibility to vibration, contributing to the August 2009 failure.

NRC Sanctions

The SIT identified one violation of regulatory requirements associated with the ROP's *mitigating systems* cornerstone. The violation involved the failure to ensure that service water pumps conformed to purchase specifications. The NRC classified the violation as Green.

Fort Calhoun, NE

The Near-Miss

The NRC sent an SIT to the site after the turbine-driven auxiliary feed-water (AFW) pump automatically shut down shortly after operators started the pump during a monthly test. The AFW system is an emergency system. During normal plant operation, it is in standby mode.

However, although the AFW system plays a vital role in an accident, the SIT found that the pump had failed numerous times over many years. The

owner had never found the cause of the problem, and therefore had never taken steps to prevent it.

How the Event Unfolded

On February 17, 2010, workers manually started the turbine-driven AFW pump, to test whether it could deliver the required flow of water within the time frame assumed in safety studies for the plant. The pump automatically shut down shortly after it started because of high pressure in the turbine's exhaust. When pressure in the exhaust line rises to nearly 10 times normal, a piston unlatches a trip lever, which shuts down the turbine.

There were no indications that pressure in the turbine exhaust line had actually exceeded the normal range during the test. This prompted workers to check the calibration and functioning of the device that triggers the automatic shutdown. They found nothing wrong with the calibration, but they did observe that minor bumping of the equipment unlatched the trip lever. When they tried to start the AFW pump with the trip lever already unlatched, it soon shut down, just as it had during the February 17 test. The company responded by restricting access to the area around the trip device, and by requiring shift managers to brief workers needing access to that area before entry.

The SIT identified four violations of regulatory requirements associated with the ROP's *mitigating systems* cornerstone. The first violation involved five instances where workers bumped the AFW and the pressure trip lever had unlatched, preventing the pump from starting when required. The second violation involved the company's failure to develop procedures to verify that the trip device for the AFW pump was properly latched.

The third violation involved an inadequate procedure in which workers did not properly vent air from the oil system for the AFW pump control after maintenance. As a result, the AFW pump failed to start during a test on February 26, 2009.

The fourth violation involved failure to properly translate information in the plant's design into its equipment, which led to the automatic shutdown of the AFW pump during a test on April 6, 2009. The NRC classified all four violations as Green (NRC 2010n).

HB Robinson, SC

The Near-Miss

The NRC sent an SIT to the site to investigate electrical fires, which had caused an unplanned reactor shutdown and declaration of an Alert—the third-most-serious emergency classification—on March 28, 2010. The SIT found so many problems that the NRC upgraded it to an AIT after a few days (NRC 2010q).

The AIT documented numerous problems in many areas—including design and procurement of safety equipment, maintenance, operations, and training—over many years. There is simply no excuse for the fact that the company and the NRC had not detected and corrected at least some of these problems before this event.

How the Event Unfolded

The event began when a 4,160-volt electrical cable shorted out and started a fire. An electrical breaker designed to automatically open and deenergize power to the shorted cable failed to do so.

The failed electrical breaker allowed electricity to flow from a circuit through the shorted cable into the ground, reducing the circuit's voltage. This circuit powered a large motor-driven pump circulating water through the reactor core, among other components. As the circuit's power dropped, the pump's output also dropped low enough to trigger the reactor to shut down automatically.

The electrical problems damaged the main power transformer between the plant and its electrical grid. When the reactor shuts down, this transformer usually allows the electrical grid to supply power to the plant's equipment. However, the damage to this transformer meant that another transformer had to provide the sole connection to the electrical grid. Other electrical breakers opened to isolate the faulted cable. This stabilized the plant's electrical conditions, but left roughly half of its equipment without power.

The equipment without power included valves on drain lines from the main steam lines. Although these valves normally close when a reactor shuts down, they opened fully on loss of power, as designed. That meant that heat escaped from the reactor more rapidly than normal, exceeding the cool down safety limit of 100° F per hour. The large reactor vessel and its piping have strict limits on how fast they can heat up or cool down to prevent thermal stress from cracking the metal. The operators did not notice the open drain valves or abnormally fast cool down. Another power failure 33 minutes later closed the drain valves.

The electrical problems interrupted the supply of cooling water to the pump seals for the reactor coolant system. When seals are damaged by overheating, cooling water leaks into the containment building. Control room operators did not notice the lack of cooling for more than 30 minutes.

After the reactor shut down, the operators started two pumps that transferred water from a tank in the auxiliary building to the reactor vessel. When this tank emptied, the pumps were supposed to automatically realign to obtain water from the refueling water storage tank. This realignment failed to happen. The operators did not notice this failure for nearly an hour.

About four hours into the event, the operators attempted to restore power to the de-energized circuit, but they did not check first to ensure that workers had fixed the original fault—and they had not. When the operators closed the electrical breaker to repower the circuit, they reenergized the shorted cable, and it caused another fire. The electrical disturbance also triggered alarms on



Conduit for electrical cables damaged by the fire at the HB Robinson plant. NRC photo.

both sets of station batteries, prompting the operators to declare an emergency Alert.

The AIT documented an incredibly long series of mistakes that first caused this event and then made it more severe. For example, the cable that started the first fire, installed in 1986, did not meet several parameters specified in the plant design. The design called for providing coated copper conductors for the cable, but it had uncoated conductors. The design also called for an outer jacket on the cable, but it did not have one. And finally, the design called for insulating the cable with self-extinguishing and non-propagating material. However, rather than extinguishing when the cable was de-energized, the fire actually spread along its length.

The non-conforming cable was connected to an electrical breaker that was supposed to open if the cable failed to isolate the problem. But with the breaker closed, a light bulb thought to indicate that the breaker was closed would not illuminate. Workers had replaced the bad light bulb in November 2008, but the new bulb also failed to illuminate. These workers thought that meant the bulb was good but the socket was bad, so they requested that other workers repair it. The second group of workers never made the trip, thinking it merely concerned an annoying problem with an unnecessary light bulb. But that bulb, when lit, actually indicated that control power was available to automatically open the electrical breaker. With the bulb not lit, the electrical breaker did not open.

Control room operators joined this error-fest with errors of omission and commission. First, they failed to stay aware of key plant parameters. For example, they did not note that the cool down rate of the reactor coolant exceeded the safety limit of 100° F per hour. Second, as noted, they failed to ensure that workers had corrected the original electrical fault before reenergizing the electrical circuits. Because the problem remained uncorrected, their misguided actions started another fire.

NRC Sanctions

The AIT identified 14 unresolved problems (NRC 2010e; NRC 2010i). Follow-up reports documented resolution of these problems. The NRC also identified six violations associated with the ROP's *initiating events* cornerstone:

- One violation involved a deficiency in the systems approach to training. This training weakness manifested itself in the operators' failure to mitigate a loss of cooling water to the seals on reactor coolant pumps during this event.
- A related violation involved the company's failure to develop emergency procedures to guide operators in ensuring cooling of the seals of the reactor coolant pump.
- One violation involved inadequate work and post-maintenance testing that prevented the charging pump from automatically switching from the volume-control tank to the refueling water storage tank.

- One violation involved inadequate design control that enabled installation of an out-of-specification electrical cable. Failure of this cable initiated the March 2010 fire.
- One violation involved inadequate configuration of the control room simulator. Some valves modeled in the simulator behaved exactly opposite to those in the actual plant after a loss of electrical power. Operators received misleading training in how to handle this scenario.
- One violation involved inadequate corrective actions for a degraded control power condition for an electrical breaker, which prevented it from opening when required to isolate an electrical fault during the March 2010 event.

The NRC classified four violations as Green, and deferred classification of the other two.

The NRC also identified two violations of regulatory requirements associated with the ROP's *mitigating systems* cornerstone. The first involved inadequate corrective actions for a degraded condition on the output breaker for emergency diesel generator B. A stuck control relay link caused the emergency diesel generator to fail in October 2008, and again in April 2009, before workers identified and corrected the problem.

The second violation involved the failure to provide the NRC with complete and accurate information on the problem with the breaker for the emergency diesel generator. The plant owner informed the NRC, in writing, that certain diagnostic and testing activities had been performed when in fact they had not. The NRC classified the first violation as being preliminarily White, and deferred classification of the second violation.

HB Robinson, SC

The Near-Miss

The NRC sent an SIT to the site after an automatic shutdown of the reactor on October 7, 2010, followed by equipment failures and operator miscues (NRC 2010b). This was the second near-miss at Robinson in six months (see the preceding case).

The SIT found many of the same shortcomings that had played a role in the earlier near-miss: bad design, nonconforming parts, inadequate operator performance, and poor training. The SIT should not have been surprised: an owner cannot correct years of programmatic deficiencies overnight.

How the Event Unfolded

The problems began shortly after midnight, when one of four pumps that supply cooling water to the reactor vessel experienced a motor failure and automatically shut down. That shutdown, in turn, triggered an automatic shutdown of the reactor and main turbine, per the plant design. One of the two feedwater pumps normally supplying makeup water to the steam generators also shut down automatically.

About a minute after the reactor shut down, relief valves opened in the steam system to protect piping and components from damage caused by excessive pressure. The shutdown of the turbine stopped steam from entering it. The steam vented directly into the turbine building, where its high temperature triggered the fire protection system for the main turbine's lubricating oil system. Water began spraying inside the turbine building to extinguish a nonexistent fire. About a minute later, two-inch piping in the fire protection system ruptured, adding to the flooding. Workers dispatched to the turbine building manually closed valves within 10 minutes, stopping the water flow.

About 11 minutes after the reactor shutdown, the second feedwater pump supplying makeup water to the steam generators automatically shut down because of high water level in the steam generators. The auxiliary feedwater (AFW) system—a backup to the normal system—had started after the trip of the first feedwater pump, and continued to provide makeup water.

Concerned that continued reliance on the AFW system rather than the normal feedwater system might prompt the NRC to issue a Red violation, the operators attempted to restart one of the normal feedwater pumps about four hours after the reactor shut down. Although they restarted the pump, it automatically shut down right away because they had improperly reset the parameters that had caused it to shut down in the first place. Not understanding the normal feedwater system, the operators gave up trying to restore it.

About 10 hours after the reactor shut down, day-shift operators tried to restart one of the normal feedwater pumps. They succeeded in doing so, but only because they improperly defeated safety interlocks. That meant they operated without required safety protection for the next 3 hours and 11 minutes. After realizing this mistake, the operators restarted the AFW system and re-inserted the safety interlocks. About 30 minutes later, the operators successfully restarted the normal feedwater pump with safety interlocks.

NRC Sanctions

The SIT determined that the motor failure that initiated this event had stemmed from age-related degradation of the insulation on the motor winding. The reactor owner had been aware of this problem, and developed a plan in 2003 to deal with it. However, the motor that failed on October 7 had not yet been fixed.

The SIT determined that operators' procedures and training did not allow them to recover from the automatic reactor shutdown. They had encountered similar problems in trying to recover from the automatic shutdown six months earlier.

The SIT also determined that the fire protection system for the lubricating oil system for the main turbine had started up because steam vented into the turbine building after the turbine shut down falsely simulated a fire condition. Events at the plant on May 15, 2007, and November 6, 2009, had shown that this would occur, but the company had done nothing to correct the problem. In response to this event, workers installed piping to carry steam vented from the relief valves outside the turbine building.

The SIT determined that the pipe in the fire protection system ruptured because workers had improperly welded two different types of metal together. This failure reinforced the large inventory of information showing that welding two different materials together simply does not work.

The SIT identified two violations of regulatory requirements associated with the ROP's *mitigating systems* cornerstone. The first involved the violation of safety requirements when day-shift operators improperly bypassed safety interlocks to restart a pump in the normal feedwater system.

The second violation involved regulations requiring owners to correct known deficiencies in equipment in a timely manner. Specifically, the owner knew that steam vented after turbine shutdowns inadvertently initiated the fire protection system in the turbine building, but had done nothing to correct it. The NRC classified both violations as Green.

Surry, VA

The Near-Miss

The NRC sent a SIT to the site after a loss of power to instrumentation caused the Unit 1 reactor to shut down automatically on June 8, 2010, with ensuing complications (NRC 2010I).

The SIT found that an overheated electrical device had started a fire in the Unit 1 control room about 90 minutes after the reactor shut down. A similar device had overheated and started a fire in the Unit 2 control room the previous November. The NRC sanctioned the company for not taking steps to prevent a fire at Unit 1 that it had taken to prevent another fire at Unit 2.

How the Event Unfolded

The event began when workers removed one of two power supplies to an electrical bus service—an electrical connection—for planned maintenance. The electrical bus powered circuits controlling plant equipment, as well as devices for monitoring them.

During the maintenance, a worker dropped a tool, causing an electrical short that disabled the remaining power supply to the electrical bus. That, in turn, caused various valves in the feedwater system to either lock up or fully open. The result was an imbalance between the amount of steam flowing from the steam generators and the amount of water supplied to the steam generators by the feedwater system. Less than 90 seconds later, low water level in one steam generator triggered the automatic shutdown of the reactor and the turbine.

The imbalance also triggered two standby emergency pumps to begin supplying makeup water to the reactor vessel. This measure was precautionary, as no piping had ruptured, and the reactor vessel was not losing water. About 20 minutes later, the unnecessary makeup water increased pressure in the reactor vessel to the point where a relief valve opened automatically, to protect the system. That relief valve opened and closed 14 times during the next 20 minutes. A similar relief valve, which stuck open the first time it opened, contributed to the partial meltdown of the Unit 2 reactor core at Three Mile Island in March 1979.

About 90 minutes after the reactor shut down, overheated electrical resistor/capacitor (RC) filters inside a control room cabinet caught fire. The operators put out the fire within three minutes. Shortly afterward, electrical fuses blew to de-energize some instrumentation monitoring key plant parameters. The operators restored power within minutes.

NRC Sanctions

The SIT learned that overheated RC filters had caused a fire in a control room cabinet at Unit 2 in November 2009. After putting out the fire and replacing the scorched filter, workers wrote a condition report asking technicians to investigate why the RC filter had overheated. However, the company closed the condition report without any investigation or evaluation. After the similar fire in Unit 1, workers tested all the RC filters in cabinets in both control rooms. They found many in a degraded condition, including some that produced visible electrical sparks during testing. Workers replaced all RC filters in all applicable cabinets.

The SIT identified one violation of regulatory requirements associated with the ROP's *initiating events* cornerstone. The violation involved failure to correct degraded RC filters in Unit 1 instrumentation cabinets after discovery of the same situation at Unit 2. The NRC classified the violation as Green.

Wolf Creek, KS

The Near-Miss

The NRC sent an SIT to the site after a nearby lightning strike on August 19, 2009, disconnected the plant from the electrical grid. The reactor and turbine automatically shut down in response, as designed. Onsite emergency diesel generators started automatically, to provide electrical power to essential safety equipment. Essential service water (ESW) pumps also started automatically. However, a pressure spike in the ESW system after the pumps started created a 3/8-inch-diameter hole in the piping. The SIT investigated the loss of offsite power and the ensuing damage to the ESW system (NRC 2010y).

The SIT found that a 2007 internal study had forecast leakage in the ESW piping, and that leakage had actually occurred in April 2008 in an event similar to that in August 2009. The NRC sanctioned the company for having identified this safety problem but having failed to correct it.

How the Event Unfolded

The SIT found that Wolf Creek personnel had little responsibility for the plant's electrical switchyard. Most responsibility rested with Westar Energy, an independent electricity provider. This division of responsibility meant that workers at Wolf Creek did not enter all switchyard-related problems into the plant's corrective action program, which determines the root causes of equipment failures and proper fixes.

For example, one or more transmission lines between the plant and the electrical grid had failed 31 times since 2004, but workers had not entered 20 percent of those failures into the corrective action program. The SIT also learned that when Wolf Creek workers received accounts of switchyard problems at other nuclear facilities, they did not effectively communicate that information to Westar Energy. The plant was therefore more vulnerable to offsite power interruptions than necessary.

The loss of offsite power triggered several fire protection alarms. Plant procedures called for workers to monitor areas triggering the alarms, to com-

pensate for the disabling of automatic fire detection and suppression circuits owing to the loss of power. NRC inspectors discovered that more than a dozen areas lacked the required fire watches.

The plant's response to the loss of offsite power, and the resulting rupture in the ESW piping, led to a sizable leak in the auxiliary building—discovered by an NRC inspector seven hours later. During an accident or a loss of offsite power, this plant's ESW system draws water from a nearby lake for numerous cooling systems, including one used to remove heat from the reactor core and containment.

The SIT found that similar leakage in ESW system piping had occurred after another loss of offsite power in April 2008. The SIT concluded that the company's evaluations after these two events were too narrow to determine the causes and consequences of the problem. Specifically, the SIT found that the company had not adequately evaluated the damage caused by internal corrosion of ESW system piping and components.

The SIT also found that a 2007 assessment of the ESW system found that lake water was causing pitting and other corrosion. The study recommended better chemistry control and monitoring measures to prevent damage. However, managers opted to delay "repairs until such degradations (pitting) had become through-wall leaks" (NRC 2010y).

NRC Sanctions

The SIT documented two violations of regulatory requirements associated with the ROP's *initiating events* cornerstone. One violation involved the failure to enter electrical switchyard problems into the corrective action program. The second violation involved failure by the operators to control the water level in the steam generator after the reactor shut down. The NRC classified both violations as Green.

The SIT identified five other violations of regulatory requirements associated with the ROP's *mitigating systems* cornerstone. The first involved the failure to assess the impact of the through-wall leaks caused by internal corrosion of ESW piping on the system's operability.

The second violation involved inadequate corrective action following damage to ESW piping after the loss of offsite power in April 2008. The third violation involved inadequate corrective action related to the corrosion problems identified by the ESW assessment in 2007.

The fourth violation involved failure to develop and implement needed procedures. Wolf Creek required operators to visually examine systems subject to water-hammer forces during electrical events for structural damage. However, the company did not include the ESW system in such inspections, despite the fact that a water hammer after the loss of offsite power in April 2008 damaged ESW piping and components.

The fifth violation involved a violation of the plant's operating license reflected in the inadequate response to fire protection alarms. The NRC classified all five violations as Green.

Observations on Near-Misses in 2010

Nearly all 14 near-misses in 2010 resulted from known safety problems that went uncorrected. With luck, such impairments do not interact to turn a bad day into a catastrophe. However, Three Mile Island and countless other

nuclear and non-nuclear technological catastrophes show what can happen when luck runs out.

Many excuses underlie owners' failures to correct these safety problems. For example, each time the roof at Calvert Cliffs leaked without serious consequences, that outcome encouraged the owner to continue to tolerate the problem rather than fixing it before luck ran out. At Surry, operators considered the electrical component that overheated and caused a fire in the Unit 2 control room an isolated failure—until the same component overheated and caused a fire in the Unit 1 control room.

At Wolf Creek, an internal 2007 study predicted through-wall corrosion of piping in the emergency cooling system, and an event when the piping actually leaked validated that prediction in April 2008. Yet the owner took inadequate steps to correct the safety problem until the piping leaked again in August 2009. None of these excuses are defensible, particularly in an industry that so often claims to place safety first.

Shortcomings in NRC Oversight

A majority of the SIT and AIT findings in 2010 fell into two of the ROP's seven cornerstones: initiating events and mitigating systems. The NRC already devotes considerable resources to these cornerstones through the efforts of its onsite inspectors. These near-misses therefore do not suggest that the agency needs to reallocate resources from other cornerstones.

However, NRC inspectors—full-time personnel at each nuclear plant, supplemented by employees from regional offices and headquarters—conduct about 6,300 person-hours of oversight at each plant each year. Why didn't this NRC inspection army identify all, some, or at least one of the problems contributing to these 14 near-misses?

Agency inspectors audit only about 5 percent of the activities at each plant each year. That means each device examined, each test result reviewed, and each maintenance activity witnessed represents 19 unaudited devices, tests, and activities.

Limiting audits to only 5 percent makes sense if and only if the NRC views the findings as insights into the bigger picture. Instead, the agency treats them as if they stem from 100 percent, full-scope audits. When inspectors find a broken device, an erroneous test result, or a maintenance activity that does not reflect procedure, they simply require companies to fix the device, correct the problem and rerun the test, or perform the maintenance activity correctly.

The NRC simply cannot be an effective regulator if it continues to treat limited-scope audits as full-scope audits. Instead, every NRC finding should trigger a formal evaluation of why an owner failed to fix a problem before NRC inspectors found it. Such an evaluation would answer questions such as:

- Did plant workers identify the device as broken?
 - If so, did they attempt to repair it?
 - If so, why wasn't the repair successful?
 - If not, was the reason for the deferral justified?

- If workers did not identify the device as broken, why didn't the plant's tests and inspections work?
 - Are tests and inspections adequate to detect this kind of failure?
 - Do workers conduct tests and inspections often enough?
- What other devices might also be broken but undetected?
- What assurances can the owner give that uninspected devices will work?

Owners of the top-performing nuclear plants do not wait for the NRC to ask such questions: they already ask and answer them. For example, workers at the South Texas Project discovered that reactor cooling water had leaked from instrumentation lines on the bottom of a reactor in spring 2003.

To prepare for public meetings between the NRC and the owner, UCS reviewed the agency's inspection reports as well as company documents. This owner answered all our questions—plus dozens more we had not considered asking—during its own presentations at the meetings. Unfortunately, not all reactor owners back up their safety-first assertions with such solid homework. The NRC must ask the questions that the underperformers are not asking.

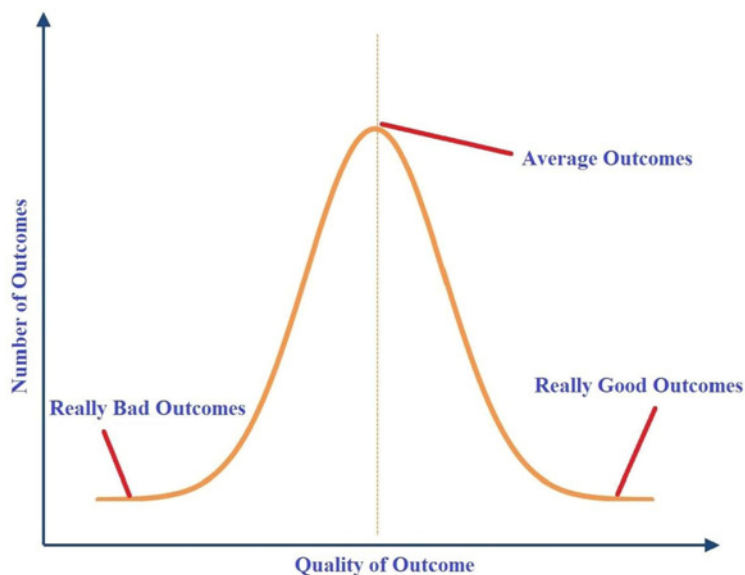
This is especially important because 4 of the 14 near-misses in 2010 occurred at reactors owned by Progress Energy. Progress owns less than 5 percent of the U.S. nuclear fleet, yet experienced more than 28 percent of the significant events that year. These near-misses occurred at three different Progress-owned sites—Robinson, Crystal River 3, and Brunswick: only one Progress site did not have a near-miss.

While these events may have nothing in common other than the same owner, the corporate hand may have played a role. Companies with multiple reactors at various sites develop fleet-wide standards and procedures intended to improve performance through the sharing of best practices. However, even good intentions can contribute to bad outcomes in the face of insufficient resources, or resistance to change among employees. The NRC should take formal, documented steps to confirm that four near-misses at three Progress Energy sites in the same year is coincidence, or identify common causes and ensure that the company eliminates them.

CHAPTER 3

**POSITIVE OUTCOMES FROM
NRC OVERSIGHT**

This chapter describes situations where resident NRC investigators acted to bolster the safety of nuclear plants before problems spiraled into significant events that prompted the agency to send in an outside team to provide more in-depth analysis. These positive outcomes are not necessarily the best the NRC achieved last year—we would have had to review and rate all NRC safety-related actions to make that claim. Nor are these outcomes the only positive ones the NRC achieved last year—far from it.



UCS's review focused on really good and really bad outcomes from the larger population of average NRC outcomes.

Instead, in choosing these situations, we focused on especially good outcomes. We also found two important instances in which the NRC expanded public access to agency officials and information on reactor safety. These results show that the NRC can be an effective and accessible regulator, and provide insights into how onsite investigators can emulate these results in other situations.

Oconee Letdown Flow

On October 9, 2009, workers shut down the Oconee nuclear plant in South Carolina for scheduled refueling. On October 11, they conducted a routine test to verify that the letdown line of the reactor coolant system for Unit 1 had adequate flow. The letdown line prevents the pressurizer from overfilling during an accident. If it does, the system can leak more water than the emergency makeup pump can compensate for.

No water flowed through the letdown line during the test. Workers found that gasket material from a valve had broken apart and completely clogged a filter in the line. Workers replaced the valve and cleaned the filter, and completed a successful test of the letdown flow rate before restarting Unit 1 in December (NRC 2010t).

Workers installed the same type of valves in Units 2 and 3 around the same time. However, they did not test their letdown flow rates, citing two primary reasons: (1) the degradation of the Unit 1 valve was an isolated occurrence unlikely to happen in Units 2 and 3; and (2) even if the filters in those units were blocked, control room operators could bypass them to establish a flow path. In the face of these lame excuses, resident NRC inspectors could have easily asked a few questions about the Unit 1 test results and moved on to other concerns. Instead, they peeled away the claims and found serious problems.

First, the inspectors found that the manufacturer of the failed valve had informed the plant owner in November 2009 that valves in other units were equally vulnerable to degradation. Second, the inspectors found that the alternate flow path would not be available during an accident. To create that path, workers would have had to open closed valves within the reactor containment buildings—which they could not do in the dangerous conditions existing in the wake of an accident.

On February 20, 2010, spurred by NRC inspectors, workers reduced the power level of Unit 2 to test the letdown flow rate—and found that debris from a degraded valve had indeed clogged the filter. Three days later they found the same problem in Unit 3.

The NRC issued a Yellow finding to the plant owner in August 2010—not for the failure at Unit 1, but for allowing the same degraded conditions to impair Units 2 and 3 for nearly three months after discovery of the first clogged filter (NRC 2010m). If the NRC inspectors had not taken the hard route and persisted with their questioning, Oconee Units 2 and 3 would have operated with a key safety system significantly impaired.

NRC managers supported these inspectors by issuing the Yellow finding. Had the plant owner reacted when workers first revealed the problem, the agency would not have needed to issue any sanction. And had the owner reacted sooner to pointed questioning by the inspectors, the NRC would probably have levied a lighter Green or White sanction. The Yellow finding deservedly called attention to the unsafe condition sustained for three months because of the owner's recalcitrance.

Browns Ferry Oil Leak

On July 24, 2009, workers conducted a routine test to verify the performance of the high pressure coolant injection (HPCI) system for the Unit 1 reactor at the Browns Ferry plant in Alabama. The HPCI system is an emer-

gency system that is normally in standby mode. If an accident drains cooling water from the metal vessel housing the reactor core, the system provides makeup water to protect the core from damage caused by overheating.

During the test, an oil leak of 0.25 to 0.50 gallons per minute developed. The HPCI system uses oil pressure to regulate the position of valves that control the flow of makeup water to the reactor vessel. The plant owner initially reported this condition to the NRC as degradation that could prevent the HPCI system from fulfilling its safety function during an accident. However, the owner later retracted this report, claiming that further evaluation had revealed that the oil leak was too small to impair valve control.

However, the NRC resident inspectors at Browns Ferry asked an important question. The HPCI system operates for just minutes during a test, but might have to operate for hours during an accident. Would the oil reservoir have enough capacity to sustain the valves during that entire time? After reevaluating the situation, the owner answered no, and formally reported the problem with the HPCI system to the NRC.

The inspectors' efforts produced much more than a mea culpa from the plant owner. They refocused the company's workers on all the potential consequences of a degraded condition. The inspectors' efforts also produced another significant outcome. HPCI systems at other U.S. nuclear reactors also contained the part that broke at Browns Ferry, and the vendor recalled it. The ripple effect from the actions of these NRC inspectors yielded safety dividends at nuclear plants across the country.

In contrast to the Oconee case, the NRC did not issue a Yellow finding (or any finding) for the problem with the HPCI system at Browns Ferry. That is because the owner fixed the HPCI problem within hours—although the “what-if” analysis required NRC intervention and took much longer. At Oconee, the flawed what-if analysis delayed correction of safety hazards at Units 2 and 3 for months.

Kewaunee Emergency Pumps

When the reactor at the Kewaunee nuclear plant in Wisconsin is operating normally, two emergency safety injection (SI) pumps are in standby mode. If cooling water drains out of the reactor vessel because of a pipe break or other accident, these pumps automatically start to transfer cooling water from the refueling water storage tank to the reactor vessel.

However, under some conditions, the pressure inside the reactor vessel is initially higher than that created by the SI pumps, which prevents them from supplying water to the vessel. In that situation, if the pumps operate but water does not flow through them, the water would heat up and could damage the pumps. To protect them, a small pipe recirculates water back to the refueling water safety tank, until the pressure inside the reactor vessel drops low enough to allow the pumps to deliver the cooling water.

At Kewaunee, NRC resident inspectors found that workers were routinely closing valves in the recirculation pipes while testing the safety injection system—despite the fact that the reactor was still operating (Dominion 2010). The inspectors noted that this practice disabled both SI pumps because they share a common recirculation line. In response, the company changed the testing procedure to avoid disabling the key emergency pumps while the reactor was operating.

This was a good catch by NRC inspectors for several reasons:

- The problem occurred only during infrequent tests. The inspectors might have focused just on practices during normal operation or accidents.
- The problem reflected an atypical plant design at Kewaunee. At most plants, SI pumps have separate recirculation lines back to the refueling water safety tank. The inspectors caught a problem that they probably had not encountered in their training or other experience.
- Closing the valves during testing had been standard practice since the reactor began operating in 1973. That the problem existed for nearly 40 years testifies to its subtlety. Numerous plant workers and NRC inspectors who had reviewed the safety injection system had overlooked it.
- The SI pumps would not need the recirculation line during most accidents. If a pipe ruptures, the SI pumps automatically start when pressure inside the reactor vessel drops from about 2,235 pounds per square inch (psi) to 1,815 psi. The discharge pressure of the SI pumps is nearly 2,195 psi. Thus the pumps would typically supply makeup water immediately to the reactor vessel, without the need for the recirculation lines.

However, operators may manually start the SI pumps in response to events such as a rupture in a steam generator tube. Depending on the size of the tube, the pressure in the reactor vessel could remain close to normal long enough for SI pumps to sustain damage.

How Top NRC Officials Served the Public Interest

The NRC chair and commissioners visit several nuclear plants each year. These visits typically involve a tour of the facility and a brief presentation by the owner on plant safety. The visits also often feature updates by resident NRC inspectors on the plant's performance. The agenda may even include a press conference or a meeting with local elected officials.

Although not unprecedented, an NRC chair or commissioner rarely meets face to face with residents who live near nuclear plants, to listen to their concerns and explain what the agency is doing about them. In 2010, the NRC chair and a commissioner took the time to do just that.

NRC Chair Gregory B. Jaczko visited the Vermont Yankee nuclear plant on July 4. His visit included a 90-minute roundtable meeting with several members of the public, at which Jaczko heard their concerns and offered his views (NRC 2010p). The NRC arranged a telephone call-in so stakeholders from around the country could listen to the discussion.

Similarly, when NRC Commissioner William D. Magwood IV visited the Braidwood nuclear plant in Illinois on November 16, he met with local citizens to hear their concerns about the more than 6 million gallons of radio-

actively contaminated water that had leaked from the plant. One attendee told UCS that it was the most meaningful dialogue the community had had with the NRC since the leaks were first reported in late 2005.

These officials impressed members of the public by telling them exactly what they most wanted to hear—the truth. For example, Chair Jaczko shared concerns that senior NRC managers expressed to him about Vermont Yankee, and the measures they planned to address those concerns. When those senior NRC managers spoke at public meetings in Vermont weeks and months earlier, they remained silent about those concerns, instead conveying only rosy assurances. Chair Jackzo and Commissioner Magwood provided spin-free commentary on conditions at these plants.

Expanding Public Access to NRC Records

Members of the public can gain access to NRC records in several ways. For example, they can search the Agencywide Documents Access and Management System (ADAMS), which includes hundreds of thousands of records.³ They can also submit requests for information to the NRC under the Freedom of Information Act (FOIA). The NRC significantly improved public access to its records via both these avenues in 2010.

The agency introduced Web-Based ADAMS (WBA), a new interface that greatly enhances public access to NRC records.⁴ WBA lacks the firewall barriers of earlier interfaces, and allows users to find, view, and download records more easily. The system also allows NRC staff to make changes to it more quickly. For example, after some users told the NRC that the interface had made some routine searches more difficult, employees revised WBA within days to allow the requested searches.

The NRC also recently added a search tool to its website that greatly facilitates public access to licensee event reports (LERs).⁵ Federal regulations require plant owners to submit LERs on the causes of problems with safety equipment and corrective actions taken. The new search tool allows users to find LERs for a specific cause at a specific reactor during a specific time frame, and provides many other search options. The LER database also extends back decades—long before records stored in ADAMS.

The NRC also significantly improved its response time to FOIA requests. UCS has often waited months and sometimes more than a year for NRC responses to FOIA requests. In 2010, UCS received complete responses to FOIA requests of comparable scope within weeks.

Unlike the Oconee, Browns Ferry and Kewaunee catches, these gains in public access to information do not immediately affect plant safety. However, they deserve equal recognition. The NRC prides itself on being transparent. When it backs up good intentions with action, everyone wins.

Observations on Effective NRC Oversight

At Oconee, Browns Ferry, and Kewaunee, some information suggested that the status quo was acceptable, but onsite NRC inspectors probed deeper.

³ See <http://www.nrc.gov/reading-rm/adams.html>.

⁴ See <http://www.nrc.gov/reading-rm/adams/web-based.html>.

⁵ See <https://lersearch.inl.gov/Entry.aspx>.

Resident inspectors at other plants can improve plant safety by asking similar kinds of questions:

- Could workers actually perform critical but dangerous safety-related actions inside a reactor containment vessel during an accident?
- Could a degraded safety system work reliably for the entire essential period if an accident occurs?
- Even if problems with a safety system might not limit its performance during many accidents, could the system perform as required during *all* such events?

In all three of these cases, plant owners were initially satisfied that reactor safety was adequate, but NRC inspectors revealed that the owners were wrong. These owners should have ensured plant safety without NRC assistance—and in fact were legally required to do so. Given this record, the NRC must insist that plant owners find out why their own testing, inspection, and evaluation methods fail to uncover safety-related problems.

CHAPTER 4

NEGATIVE OUTCOMES FROM NRC OVERSIGHT

This chapter describes situations where lack of effective oversight by on-site NRC inspectors led to negative outcomes. As Chapter 3 noted, these outcomes are not necessarily the worst the NRC achieved last year. Rather, they provide insights into practices and patterns that prevent the NRC from achieving the return it should from its investment in oversight.

Peach Bottom's Slow Control Rods

The NRC was aware of a serious safety problem at the Peach Bottom nuclear plant in Pennsylvania in 2010, and an even more troubling response by the plant owner, yet did nothing except watch.⁶

The Peach Bottom plant includes two boiling water reactors (BWRs), both with 185 control rods. The power level in these reactors can spike under certain conditions. If that occurs, all control rods can be fully inserted within seconds to stop the nuclear chain reaction—a vital response. Fatal accidents at the Chernobyl nuclear plant in Ukraine in April 1986, and the SL-1 nuclear plant in Idaho in January 1961, occurred when unchecked increases in reactor power caused massive steam explosions.

The operating licenses for the Peach Bottom BWRs require the owner to test the control rods periodically, to verify that their insertion times are within required safety margins. Each control rod travels 12 feet from the fully withdrawn to the fully inserted position. The licenses require that each control rod begin moving within 0.44 second, and finish moving within 3.35 seconds, after operators initiate this response. Because each BWR features 185 control rods, some can be “slow” if their neighbors are “fast.” The operating licenses and associated safety studies limit the share of slow control rods to 7 percent of tested control rods.

On January 29, Peach Bottom workers tested the insertion times of 19 control rods at Unit 2, and found that three took longer than 0.44 second to begin moving. The workers then tested other control rods, to try to reduce the share of slow ones to less than 7 percent of those tested. However, they in-

⁶ For more information on this Peach Bottom event, see Union of Concerned Scientists. 2010. Artful dodgers at Peach Bottom. Cambridge, MA. Online at http://www.ucsusa.org/nuclear_power/nuclear_power_risk/safety/brief-on-slow-control-rods-at.html.

stead found more slow ones. Workers ultimately tested all 185 control rods and found that 21 were slow.

The operating license for Unit 2 requires workers to shut down the reactor within 12 hours if more than 13 control rods are slow. However, workers did not shut down Unit 2. Instead, the team testing the control rods slowed its pace to match that of the team repairing the slow ones. That meant the plant never officially had more than 13 slow control rods. However, because of the foot-dragging, tests of all 185 control rods took longer than two days—a task I have performed in a single 12-hour shift at similar reactors.

The control rods were slow because of a part found to be faulty in the 1990s. The vendor offered free replacement kits at the time, and other BWR owners fixed the problem. However, 39 of the 185 control rods at Peach Bottom Unit 2—including the 21 slow ones—still had the defective part.

As soon as workers traced the cause to the defective part, the safe and legal move would have been to shut down the reactor. Instead, the workers conspired to keep the reactor operating despite known safety flaws. Had Unit 2 encountered an event that required rapid insertion of the control rods before employees finished playing their games, the results could have resembled those at Chernobyl and SL-1.

Onsite NRC inspectors were fully aware of the shenanigans at Peach Bottom but simply stood by. The NRC later issued a Green citation to the plant owner for replacing the defective parts only belatedly (NRC 2010w). However, the agency could and should have examined earlier tests of the control rods to show that testing all 185 does not take two days, and then asked the owner to justify the foot-dragging. The NRC also should have forced the plant owner to comply with federal safety requirements rather than scoff at them.

The NRC's reaction contrasts sharply with that in 1987, when the agency fined both individual Peach Bottom operators and the company after finding that operators routinely slept on duty. The NRC did so because they demonstrated "a total disregard for performing licensed duties and a lack of appreciation for what those duties entail," and because supervisors and senior plant managers knew or should have known about the rampant sleeping (NRC 1987). In so doing, the NRC noted:

The NRC expects licensees to maintain high standards of control room professionalism. NRC licensed operators in the control room at nuclear power plants are responsible for assuring that the facility is operated safely and within the requirements of the facility's license, technical specifications, regulations and orders of the NRC.

Because both operators and managers deliberately circumvented safety requirements again in 2010, the NRC should have levied similar sanctions. When the agency condones egregiously poor performance, it is being unfair on many levels. First and foremost, that response is unfair to the people living around Peach Bottom, who deserve protection. A lax response is also unfair to the owners of other plants, who sometimes pay a price for doing the right thing.

For example, the owner of the North Anna nuclear plant in Virginia voluntarily shut down the Unit 2 reactor in September 2010. The owner took this step after workers at Unit 1—which had shut down on September 12 for refueling—discovered 58 cubic feet of Microtherm insulation and 8 cubic feet of calcium-silicate insulation inside the containment building.

In 2007, to resolve a safety problem, workers had removed Microtherm and calcium-silicate insulation from the containment buildings for North Anna Units 1 and 2. During an accident, such insulation could block the flow of water to emergency pumps used to cool the reactor core and the containment building. The owner replaced the Microtherm and calcium silicate with another type of insulation less likely to impair the performance of emergency pumps.

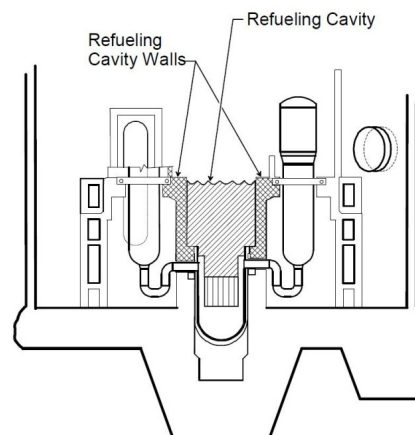
In 2010, rather than arguing that unlike Unit 1, Unit 2 did not contain leftover Microtherm and calcium-silicate insulation, or that Unit 2 could operate safely until its next scheduled refueling outage, the owner voluntarily shut down Unit 2 and fixed the problem (NRC 2010c). The owner did the right thing despite the fact it carried a price tag reflecting lost revenue from electricity sales and the higher cost of replacing insulation on short notice. North Anna's owner clearly placed safety ahead of production.

This owner took a financial hit for doing the right thing—only to watch as the NRC allowed Peach Bottom's owner to avoid a financial hit by doing the wrong thing. North Anna's owner has a long track record of putting safety first.⁷ Not all owners can match that record. The NRC must deprive owners of the option of placing safety second, third, or lower.

Indian Point's Leaking Refueling Cavity Liner

The Indian Point nuclear plant in New York features two pressurized water reactors (PWRs). To refuel a PWR, workers flood the refueling cavity with water, which allows them to remove irradiated fuel assemblies from the reactor core and replace them with fresh fuel assemblies. The water both removes decay heat from the irradiated fuel assemblies and shields the radiation they emit, protecting the workers.

The Final Safety Analysis Reports (FSARs) submitted by the plant owner with the application for an operating license for Unit 2 stated that the refueling cavity was “designed to withstand the anticipated earthquake loadings,” and that “the liner prevents



NRC drawing showing refueling cavity walls and the fuel rods located at the bottom of the cross-hatched refueling cavity volume.

⁷ In fall 2001, North Anna's owner voluntarily shut down a reactor months before a scheduled refueling outage, to inspect the nozzles on the reactor's control rod drive mechanism (CRDM). The owner of the Davis-Besse plant in Ohio, in contrast, resisted NRC pressure to conduct these inspections, and operated a reactor into 2002 with cracked and leaking CRDM nozzles. The NRC later found that this near-miss of a reactor accident was the most serious event since the Three Mile Island meltdown in 1979.

leakage in the event the reinforced concrete develops cracks.” When the NRC issued the operating license for Unit 2, the leakage prevention function of the liner for the refueling cavity became part of the licensing basis.

However, NRC inspectors at Indian Point recently found that the liner has been leaking 2 to 20 gallons per minute since at least 1993 (NRC 2010v), and that the plant owner has not yet delivered on repeated promises to fix the leak. That means the device installed to prevent leakage after an earthquake is leaking before an earthquake even occurs. The liner has no other safety function. Yet NRC managers have dismissed the longstanding problem, noting that the refueling cavity leaks only when it is filled with water (NRC 2010o).

These inspectors are repeating the very same mistakes the NRC made at the Millstone nuclear plant in Connecticut 15 to 20 years ago. In March 1996 the NRC made the cover of *Time* magazine—and not as regulator of the year. *Time* called the NRC out for failing to enforce its own rules. Workers at Millstone routinely transferred all the fuel from the reactor core to the spent fuel pool during each refueling outage, despite a regulatory requirement to do so only under abnormal conditions. Workers also nearly always violated a regulatory requirement to wait a few hours before transferring fuel out of the reactor core, to allow radiation levels to drop, thus lowering the threat to workers and the public from the movements.



After being embarrassed on the cover of *Time*, the NRC found that the Millstone reactors had been operating outside their design and licensing bases, and ordered the owner to shut them down (NRC 1996). The NRC also fined the owner a then-record \$2.1 million, for “several failures to assure that the plants were operated in accordance with design requirements in the plants’ Final Safety Analysis Report (NRC 1997a).

To prevent another Millstone, the agency also required its inspectors to review “the applicable portions of the FSAR during inspection preparation and verify that the commitments had been properly incorporated into plant practices, procedures, or design (NRC 1997b). The resident inspectors at Indian Point were expressly carrying out this prevent-another-Millstone mission when they discovered that the degraded refueling cavity liner no longer conformed to the plant’s licensing basis.

The Millstone debacle also prompted the NRC to develop specific guidance on what plant owners should do when they find degraded or nonconforming conditions (NRC 2008).

This guidance allows owners to resolve nonconforming conditions via any one of three options: (1) full restoration to the FSAR condition; (2) a change in the licensing basis to accept the new condition; or (3) some modification of the facility or licensing basis other than restoration.

That means the Indian Point owner could fix the refueling cavity liner so that it no longer leaks. Or the company could seek NRC approval for leaving

the cavity liner as is, if an evaluation shows that the plant would then maintain required safety margins. Or the owner could seek NRC's approval to modify the plant or its procedures to compensate for the leaking liner.

However, the Indian Point owner has chosen option 4: to do absolutely nothing to resolve the safety nonconformance, daring the NRC to respond. That was the very same option the Millstone owner chose in the early 1990s—which led to the reactor shutdown and the NRC's efforts to prevent such a situation from ever happening again.

The laissez-faire approach to safety at Indian Point contrasts sharply with the approach at Turkey Point Unit 3 in Florida, after a similar problem surfaced in 2010. On July 29, workers at that plant detected a through-wall crack in the drain pipe from the refueling cavity transfer canal (FPL 2010). Workers could not repair the crack until they drained the refueling cavity, but the owner committed to making the repair immediately after they did so.

The owner also committed to “daily walkdowns for increased leakage or new leak locations while the transfer canal is filled.” In other words, workers would inspect that area each day for water leaking from the damaged drain pipe. Rather than fall back on the NRC's apparent indifference to leaks from the refueling cavity, this owner took steps to manage the risk until workers could correct the degraded condition.

The NRC's performance at Indian Point is worse than that 15 to 20 years ago at Millstone, for the simple reason that the agency has put measures in place to prevent the next such fiasco. The NRC has explicitly directed resident inspectors to determine whether nuclear plants are operating within their licensing bases, and whether they are adhering to the agency's guidance given any discrepancies.

The resident NRC inspectors at Indian Point did their job by flagging the degradation of the liner for Unit 2's refueling cavity, and the fact that the plant does not conform to its licensing basis. However, NRC managers have deviated from their own post-Millstone guidance by accepting the degraded, nonconforming condition without any analysis showing that the plant has critical safety margins. There is just no excuse for the NRC to revert back to its pre-Millstone nonchalance regarding nuclear reactors that operate outside their licensing bases.

Curbing Illegal Radioactive Effluents

NRC regulations permit owners to routinely release air and water contaminated with radioactivity from their nuclear facilities. However, owners must monitor and control the pathways for such effluents, and the total inventory must remain below federal limits. These regulations are intended to protect the public from radiation-induced health problems.

The NRC has enforced these regulations inconsistently over the past decade. Examples at two plants—one positive and one negative, both at plants owned by Entergy—illustrate this baffling inconsistency.

In September 2008, Hurricane Gustav caused considerable damage to the River Bend nuclear plant outside Baton Rouge, La. High winds tore sheet metal siding from three sides of the turbine building. The company repaired some damage and prepared to restart the reactor—planning to replace the walls of the turbine building later.



The turbine building at the River Bend plant after Hurricane Gustav removed its metal siding. NRC photo.

If the radioactivity level of air flowing through ventilation ducts in the turbine building rises too high, radiation detectors sound alarms and dampers close, to stop any release to the environment. Because the River Bend turbine building lacked walls, any radioactively contaminated air that had leaked into the building would have reached the environment via uncontrolled and unmonitored pathways.

The potential for unmonitored and uncontrolled releases spurred the NRC to take steps to prevent River Bend from restarting. Only after reinstalling the walls and complying with regulations could the owner restart the plant.

In January 2010, Entergy informed the NRC that it had detected tritium—radioactively contaminated water—in an onsite monitoring well at the Vermont Yankee nuclear plant. The company thought the tritium was coming from a leak in an underground pipe, but was uncertain about the location, size, and nature of the leak. The NRC allowed the company to continue operating Vermont Yankee while workers searched for the leak. Weeks later they found holes in two underground drain pipes that carried radioactively contaminated water to a tank inside the turbine building.

At River Bend, the mere potential for an unmonitored and uncontrolled release of radioactively contaminated air prompted the NRC to prevent the reactor from operating until the owner eliminated that potential. Yet at Vermont Yankee, an actual unmonitored and uncontrolled release of radioactively contaminated water from spurred no response from the NRC.

The agency did the right thing at River Bend by enforcing its regulations and not allowing Entergy to intentionally violate them. The agency did the wrong thing at Vermont Yankee—and at Pilgrim in Massachusetts, Oyster Creek in New Jersey, Brunswick in North Carolina, and many other plants by pretending that those same regulations did not exist.⁸

The people living in Vermont and other states expect and deserve the same protections as those the NRC provided to residents of Louisiana. By

⁸ See Lochbaum, David. 2010. *Regulatory roulette: The NRC's inconsistent oversight of radioactive releases from nuclear power plants*. Cambridge, MA: Union of Concerned Scientists.

failing to enforce regulations designed to protect public health and safety, the NRC let millions of Americans down.

Observations on Lax NRC Oversight

Unsurprisingly, the common elements in the situations that produced negative NRC outcomes are essentially mirror images of the elements responsible for positive NRC outcomes.

When workers at Oconee sought to narrow a problem to Unit 1, NRC inspectors expanded the shortcoming to two other reactors. When workers at Peach Bottom sought to narrow a problem to a handful of control rods at Unit 2, NRC inspectors passively accepted that response.

When workers at Browns Ferry justified a degraded safety system by saying that it satisfied all requirements at that moment, NRC inspectors questioned whether the system could respond throughout an emergency. When workers at Indian Point noted that a critical safety liner leaked only when filled with water, NRC managers meekly nodded.

When workers at Kewaunee explained that they had been testing a safety system a certain way for nearly four decades, NRC inspectors asked whether the system could do its job if the reactor remained in operation during testing. When workers at Indian Point explained that a safety device had been leaking for more than two decades, NRC managers simply accepted that deviance.

When River Bend's owner sought to restart a reactor without the ability to monitor and control releases of radioactively contaminated air from the turbine building, the NRC stepped in to prevent that scenario. When Vermont Yankee's owner sought to continue operating the reactor while releasing radioactively contaminated water from an uncontrolled and unmonitored pathway, the NRC stepped aside and allowed it.

NRC inspectors cannot examine every inch of piping or every foot of cabling. They cannot look over the shoulder of every worker to verify that he or she is following every procedure faithfully, and that the result of every test is valid.

NRC staff informed commissioners some 15 years ago that inspectors could audit 5–10 percent of all activities at each reactor each year. Every safety problem found during a 10 percent sample audit represents 9 safety problems in areas not sampled. Each safety problem found during a 5 percent sample audit represents 19 other safety problems in areas not sampled.

The NRC cannot be blamed for safety problems in areas it does not examine, but the agency deserves considerable blame for failing to correct safety problems it has identified. When the agency's limited-scope audits find broken devices, the failures of the plants' testing and inspection regimes to find and fix these devices are the true safety problems. By failing to insist that owners correct these true safety problems, the NRC does nothing about the 90–95 percent of conditions and activities in nuclear plants that it does not audit.

Peach Bottom, Indian Point, and Vermont Yankee are all in the NRC's Region I. All the negative outcomes in 2010 involved Region I reactors, while none of the positive outcomes involved Region I reactors. Those outcomes may simply be statistical anomalies. Or they might indicate where the

agency most needs to reform its own efforts and those of plant owners—and soon.

CHAPTER 5

SUMMARY AND RECOMMENDATIONS

In UCS's view, the 14 near-misses reported at nuclear power plants in 2010 are too many, for several reasons:

- Two of the near-misses occurred at the HB Robinson plant in South Carolina. These events shared contributing causes, including design flaws complicated by known but uncorrected equipment problems—and inadequate operator performance. Neither the plant owner nor the NRC should have allowed conditions to deteriorate so deeply and broadly that they set the stage for near-miss after near-miss.
- Four of the near-misses occurred at three plants owned by Progress Energy. This company owns only four plants. Better corporate governance and NRC oversight likely would have prevented the company's fleet from having such a bad year.
- Reactor owners could easily have avoided many of the near-misses in 2010 simply by correcting known problems. For example, one Calvert Cliffs reactor was known to have a leaking roof, with frequent reminders occurring when it rained. But the problem remained uncorrected until rainwater triggered a series of events that ultimately shut down both reactors.
- Similarly, workers at Wolf Creek predicted in 2007 that piping in a vital cooling system was vulnerable to leaking, and actual leakage in April 2008 validated that prediction. Yet the company merely patched the leak, allowing the degraded piping to leak further in August 2009.

The NRC identified 40 violations of federal safety regulations in these near-misses. Some of these violations resulted from problems arising during the event itself, but most were for safety problems known for months if not years. When known problems combine to cause near-misses, they are not surprises: these were accidents waiting to happen.

The NRC enables lax behavior to occur again and again. For example, the NRC sanctioned the Calvert Cliffs owner for not having fixed the leaky roof. When the owner finally fixed it, NRC inspectors verified the repair.

However, they let the owner off the hook by not probing whether other known safety problems remain uncorrected. Nor did the NRC ask the owner to explain why it had allowed the leaking roof to go unrepaired for so long, or to describe measures it would use to prevent future roof leaks from going uncorrected. In short, the NRC did little to prevent known safety problems from causing future near-misses at Calvert Cliffs and other sites.

The NRC must draw larger implications from narrow findings for the simple reason that it audits only about 5 percent of activities at every nuclear plant each year. The agency's limited-scope audits are designed to spot-check whether an owner's testing and inspection regimes are ensuring that a plant complies with regulations. Those regimes, if fully adequate, should find and correct any and all safety problems, leaving none for NRC inspectors to identify.

Each NRC finding therefore has two important components: identifying a broken device or impaired procedure, and revealing deficient testing and inspection regimes that prevented workers from fixing a problem before the NRC found it. The NRC's recurring shortcoming is that it focuses nearly exclusively on the first part. It is good that the NRC assured that the leaking roof at Calvert Cliffs no longer leaks even when it rains. But the NRC failed in the larger sense by not ensuring that Calvert Cliffs patched leaks in its testing and inspection regimes that allowed this known problem to languish for so long. The NRC simply has to do better in tackling this larger picture.

The NRC can do better because the NRC did do better in some cases last year. Agency inspectors uncovered safety problems at the Oconee, Browns Ferry, and Kewaunee plants that their owners initially misdiagnosed or dismissed. NRC resident inspectors kept asking questions until the true picture came into focus. Their commendable efforts meant that owners corrected safety problems, making these plants less vulnerable to near-misses. The intangible dividends from these efforts are very likely lessons learned by these plant owners about the kinds of questions they should be asking themselves. If so, the ripple effect from these NRC efforts will further reduce the risks of near-misses.

Unfortunately, the stellar performance exhibited by the NRC in the Oconee, Browns Ferry, and Kewaunee cases is not yet the rule. The NRC did not flag comparable safety problems at the Peach Bottom, Indian Point, and Vermont Yankee nuclear plants.

At Indian Point, the liner for the refueling cavity has been leaking for nearly 20 years. The only reason the liner was installed is to prevent leakage during an earthquake. That means the chances that the liner could fulfill its only safety function are nil. The NRC tolerates this longstanding safety violation. However, if an earthquake caused a near-miss at Indian Point, the NRC would sanction the company for having violated safety regulations for so long—even though the agency is essentially a co-conspirator in this crime.

By boosting its commendable performance and shrinking its poor performance, the NRC would strengthen safety levels at nuclear plants across the country, reducing the risks of near-misses—and full-blown accidents.

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