U.S. Nuclear Power after Fukushima

Common Sense Recommendations for Safety and Security

Union of Concerned Scientists

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THE RECENT EVENTS IN Japan remind us that while the likelihood of a nuclear power plant accident is low, its potential consequences are grave. And an accident like Fukushima could happen here. An equipment malfunction, fire, human error, natural disaster, or terrorist attack could—separately or in combination—lead to a nuclear crisis.

Our nation will continue to obtain a significant portion of its electricity from nuclear power for many years to come, regardless of how rapidly energy efficiency measures and other sources of electricity are deployed. Nuclear reactors currently account for about 20 percent of U.S. electricity, and the Nuclear Regulatory Commission (NRC) has granted or is in the process of granting 20-year license extensions for most of the country's 104 operating reactors.

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Given this reality, the United States must take concrete steps now to address serious shortcomings in nuclear plant safety and security that have been evident for years. No technology can be made perfectly safe, but the United States can and must do more to guard against accidents as well as the threat of terrorist attacks on reactors and spent fuel pools.

The Responsible Parties

Nuclear power safety and security must be given the serious attention they deserve—and have not consistently received—from the nuclear industry, the NRC (which oversees the industry), Congress (which oversees the NRC), and the president (who appoints the NRC commissioners and bears ultimate responsibility for ensuring public safety).

The industry must address *known* risks and ensure that adequate safety margins are in place to compensate for *unknown* risks. Doing so is in the industry's self-interest, because nothing would affect public acceptance of nuclear power in the United States as much as a serious accident or terrorist strike. For example, reactor owners could reduce the safety and security risks associated with spent fuel by transferring it from pools to dry casks once it is cool enough. Yet for reasons of cost, they have chosen to fill the pools to maximum capacity rather than use dry casks.

The NRC must strengthen its safety requirements. For example, it does not require U.S. reactor owners to plan for and be able to cope with severe accidents like the one that occurred at the Fukushima Daiichi plant. Nor does it require new reactors to be safer than existing ones. Because additional safety features generally entail additional costs, safer designs may lose out in the marketplace to those that reduce costs by cutting safety features.[1] If the NRC does not change its regulations, new reactors will not be significantly safer, and as the number of reactors increases so will the chances of a catastrophic event.

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The NRC must also consistently enforce its regulations. Even when the agency has imposed strong standards, serious safety problems have continued to arise because of lax enforcement. For example, following a serious fire at an Alabama plant in 1975, the NRC issued fire protection regulations in 1980 and again in 2004. Yet today, more than three dozen reactors still do not comply with either set of regulations (despite the fact that fire remains a dominant risk factor for reactor core damage).

Congress must take its oversight role seriously and ensure that the NRC does its job well. Moreover, Congress should not order the NRC to further "streamline" its regulations and processes, which could result in inadequate technical reviews of complex issues.

The president must appoint people to the Nuclear Regulatory Commission who will make public safety their top priority. This is not the case today. For example, four of the five commissioners recently voted to extend the deadline for nuclear power reactors to comply with fire protection regulations until 2016 at the earliest.

Change Is Needed Now

Since its founding in 1969, the Union of Concerned Scientists has worked to make nuclear power safer and more secure. We have consistently advocated most of the measures listed below to address the serious shortcomings in U.S. nuclear plant safety and security against terrorist attack. So although most of these recommendations are not new, the situation in Japan underscores their importance. We have also developed several new recommendations in response to the Fukushima crisis.

We strongly urge the NRC to make U.S. nuclear power safer and more secure by adopting *all* the following measures, and we urge Congress and the administration to ensure the NRC follows through on its commitments.

Key Recommendations

Below we list our top eight recommendations for changes the NRC should make in its regulations and actions to improve U.S. nuclear power safety and security. The NRC should make these changes its top priority.

A complete list of our recommendations, with additional explanation of each, follows this overview of the top eight. If the NRC does not implement these changes on its own, Congress should exercise its oversight role and require the agency to do so.

Extend Regulations to Cover Severe Accidents

The NRC should extend the scope of its regulations to include the prevention and mitigation of severe accidents.

The NRC defines "severe" accidents as those more serious than the so-called "design-basis" accidents that U.S. reactors are designed to withstand. While unlikely, severe accidents can occur—as in Fukushima—and can cause substantial damage to the reactor core and failure of the containment building, leading to large releases of radiation. However, NRC regulations are focused on design-basis accidents and are far less stringent in

Following the Fukushima accident, high contamination levels were found well beyond 10 miles from the plant (the distance used for emergency planning in the United States).

addressing severe accidents. For example, the agency does not evaluate or test the severe accident management guidelines that reactor owners have voluntarily developed, so neither the NRC nor the public can be confident these guidelines would be effective. Extending NRC requirements, inspections, and enforcement to cover a wide range of severe accident conditions would ensure that effective plans and the equipment needed to deal with such accidents are put in place. (See recommendation 1 below.)

Strengthen Emergency Planning Requirements

The NRC should ensure that everyone at significant risk from a severe accident—not just people within the arbitrary 10-mile zone currently used for emergency planning—is protected.

In the United States, emergency planning for a nuclear reactor accident is limited to a 10-mile radius around the reactor. Yet the U.S. government advised Americans within *50* miles of the Fukushima Daiichi reactors to evacuate—a decision validated by the high contamination levels recorded well beyond 10 miles from the plant. A severe accident at a U.S. reactor could similarly require the evacuation of people outside the 10-mile planning zone and other protective measures to avoid high radiation exposures. The NRC should therefore require reactor owners to develop emergency plans for a larger area, based on a scientific assessment of the populations at risk for each reactor site. (See recommendation 3 below.)

Move Spent Fuel to Dry Casks

The NRC should require plant owners to transfer fuel from storage pools to dry casks when the fuel has cooled enough to do so.

The Fukushima crisis illustrated the dangers of keeping spent fuel in storage pools when the plant lost power needed to cool its pools. It is still unclear whether cooling was resumed in time to prevent the spent fuel from overheating and melting, and releasing radiation. However, the spent fuel pools at U.S. reactors could have fared worse, since they are far more densely packed than those at Fukushima and pose even greater hazards.

The safety and security risks associated with spent fuel would be reduced by transferring the fuel from pools to dry casks once it is cool enough.

The safety and security risks associated with spent fuel would be reduced by transferring the fuel from pools to dry casks once it is cool enough (i.e., five years after removal from the reactor). With less fuel in the pools, the remaining fuel would be easier to keep cool if power is lost, and less radiation would be released in the event of an accident or terrorist attack. However, because dry casks are expensive, reactor owners have chosen to fill their pools to maximum capacity, and the NRC has not required owners to transfer their spent fuel to dry casks. (See recommendation 4 below.)

Enforce Fire Protection Regulations

The NRC should compel the owners of more than three dozen reactors to comply with fire protection regulations they currently violate.

Because a fire can disable both primary and backup emergency systems, it is a leading risk factor for reactor core damage. Following a 1975 fire at the Browns Ferry nuclear plant in Alabama, the NRC issued regulations in 1980 intended to reduce the fire hazard at all reactors, and it amended those regulations in 2004 to provide an alternative option for compliance. However, more than three dozen reactors still do not comply with these fire protection regulations, and their owners have made no firm commitments to comply anytime soon. (See recommendation 7 below.)

Set Timeliness Goals for Safety Issues

The NRC should apply the same type of timeliness goals to nuclear plant safety that it does for business-related requests from reactor owners.

The NRC has established goals for completing business dealings in a timely manner, but has not done so for resolving outstanding safety issues. By treating safety with the same urgency it gives to business dealings, the agency can provide the robust, timely oversight that is needed. (See recommendation 8 below.)

Improve Protection against Terrorist Attacks

The NRC should make more realistic assumptions about the capabilities of terrorists who might attack a nuclear power plant, and these assumptions should be reviewed by U.S. intelligence agencies.

Current assumptions about potential attackers are unrealistically modest and do not reflect real-world threats. For example, they may ignore the possibility that terrorist groups could use rocket-propelled grenades—a weapon widely used by insurgents around the world. New assumptions developed by the NRC should be reviewed by an interagency body that includes the intelligence community, the National Nuclear Security Administration, and the Department of Homeland Security. (See recommendation 15 below.)

Strengthen Safety Standards for New Reactor Designs

The NRC should require any new reactors to be safer than existing reactors.

Current policy only requires advanced reactors to provide the same level of protection as existing reactors—most of which were built at least 30 years ago. To ensure that any new nuclear plant is significantly safer than existing ones, the NRC should require features designed to prevent severe accidents and to mitigate such an accident if one occurs. (See recommendation 18 below.)

Assign an Appropriate Value to Human Life in Cost-Benefit Analyses

The NRC should increase the value of human life in its analyses so it is consistent with other government agencies. The NRC currently uses a dollar value for a human life that is only one-half to one-third the value used by other agencies. Bringing that value in line would have a major effect on nuclear plant license renewals and new reactor approvals: plant owners would have to add safety features that the NRC now considers too expensive (because it underestimates the value of the lives that could be saved). (See recommendation 20 below.)

All Recommendations in Detail

Preventing and Mitigating the Effects of Severe Accidents

The NRC considers some accidents likely enough that a nuclear reactor cannot be licensed unless it has been designed to withstand them; these are termed "design-basis" accidents. The worst such accident—as defined by the NRC—involves the partial melting of the fuel in the reactor core, but not the rupture of the reactor vessel or large releases of radiation from the containment building. Yet reactors that can withstand design-basis accidents are still vulnerable to "beyond-design-basis" or "severe" accidents, which the NRC considers so unlikely that reactors need not be able to withstand them.

While severe accidents are less likely than design-basis accidents, they are still feasible and could result from a wide variety of events, including an extended loss of power, fire, or natural disaster. A severe accident (such as that at Fukushima) will result in substantial damage to the reactor core fuel and could result in failure of the containment building, leading to large releases of radiation.

Because the NRC has addressed severe accident issues on an ad hoc basis, most measures designed to prevent and mitigate them are voluntary. The accident at Fukushima has shown that the NRC must give a higher priority to such measures. Specifically:

1. The NRC should extend the scope of regulations to include the prevention and mitigation of severe accidents. NRC regulations are focused on design-basis accidents and for the most part do not address severe accidents. For example, because NRC regulations do not require reactor owners to develop severe accident management guidelines, the agency does not evaluate or test guidelines that owners have developed voluntarily. As a consequence, neither the NRC nor the public can be confident such guidelines would be effective.

The NRC requires reactor owners to have plans to cope with the loss of large areas of a plant due to explosion and fire, such as would result from an aircraft attack. However, these plans would not generally protect reactors against *any* severe accident—since the equipment or the area in which it is stored may not be designed to withstand an earthquake or other natural disaster.

Plant owners and the NRC need to re-evaluate these plans in light of Fukushima to judge whether they are realistic. In particular, high levels of radioactive contamination may make it impossible for workers to access key equipment or vital areas of the plant. Both parties must also determine how to safely manage any contaminated water if normal cooling is lost and the reactor cores and spent fuel pools need to be manually cooled with outside water.

Extending NRC requirements, inspections, and enforcement to cover a wide range of severe accident conditions would ensure that effective plans and the equipment needed to deal with such accidents are put in place.

2. The NRC should require reactor owners to develop and test emergency procedures for situations when no AC or DC power is available for an extended period. While the Fukushima accident was precipitated by an earthquake and tsunami, the direct cause was the loss of both off-site and on-site AC power—a situation known as a station blackout—leaving only DC power from batteries available. The Atomic Energy Commission (the NRC's predecessor) proposed regulations to address station blackouts as early as 1974 but the nuclear industry opposed those requirements, contending that a station blackout simply could not happen. The NRC finally issued a regulation in 1988 aimed at minimizing this risk; nevertheless, the Vogtle nuclear plant in Georgia experienced a station blackout less than two years later.

Most measures designed to prevent and mitigate severe accidents are voluntary. The accident at Fukushima has shown that the NRC must give a higher priority to such measures.

The NRC requires U.S. plants to have a strategy for coping with a station blackout of up to 16 hours, assuming that workers will be able to restore reliable AC power within this time. In developing this requirement, the NRC ignored the possibility of events—such as severe earthquakes—that could disrupt a plant's surrounding infrastructure for an extended period, as was the case at Fukushima. Reactor owners should instead be required to handle events in which AC power remains unavailable for a longer period of time, and in which both AC and DC power are unavailable.

3. The NRC should modify emergency planning requirements to ensure that everyone at significant risk from a severe accident—not just people within the arbitrary 10-mile planning zone—is protected.

In the United States, emergency planning to protect the public from direct exposure to radioactive fallout during a severe nuclear accident is limited to the area within 10 miles of each reactor. People within this zone could be evacuated and receive potassium iodide tablets to help prevent thyroid cancer (to which children are especially vulnerable). Following the Japanese earthquake, however, the U.S. government advised Americans within a 50-mile radius of the Fukushima Daiichi reactors to evacuate—a decision later validated by the high contamination levels found well beyond 10 miles from the plant.

If a severe accident occurred in which radiation was released from the containment structure, some people inside the 10-mile zone could be exposed to immediately life-threatening levels of radiation, while people well outside the zone could be exposed to levels high enough to cause a significant increase in cancer risk. This risk could be minimized by expanding the emergency planning zone so that more people could be evacuated and have access to potassium iodide, which could be important to children more than 100 miles downwind. The NRC should conduct a science-based assessment of every reactor site to determine the populations most at risk from a severe nuclear accident, then revise its emergency planning requirements accordingly.

Also, emergency response plans assume that a reactor accident would not be accompanied by another disaster or emergency that would tax emergency response resources, but the scale of the overlapping disasters in Japan overwhelmed those resources. An interagency committee including the NRC and the Department of Homeland Security should therefore revisit federal, state, and local emergency response plans to ensure they account for the possibility of overlapping disasters.

Improving the Safety and Security of Spent Fuel

While concerns about nuclear power safety are often focused on the fuel in the reactor, spent fuel stored in pools can also be a major source of radiation during an accident. If the pool is drained for even a few hours, or the cooling system is interrupted for several days, the spent fuel could overheat and its cladding could break open, leading to the release of radiation.

Moreover, spent fuel pools are located outside the robust primary containment structure that surrounds the reactor vessel, so any radiation released from the

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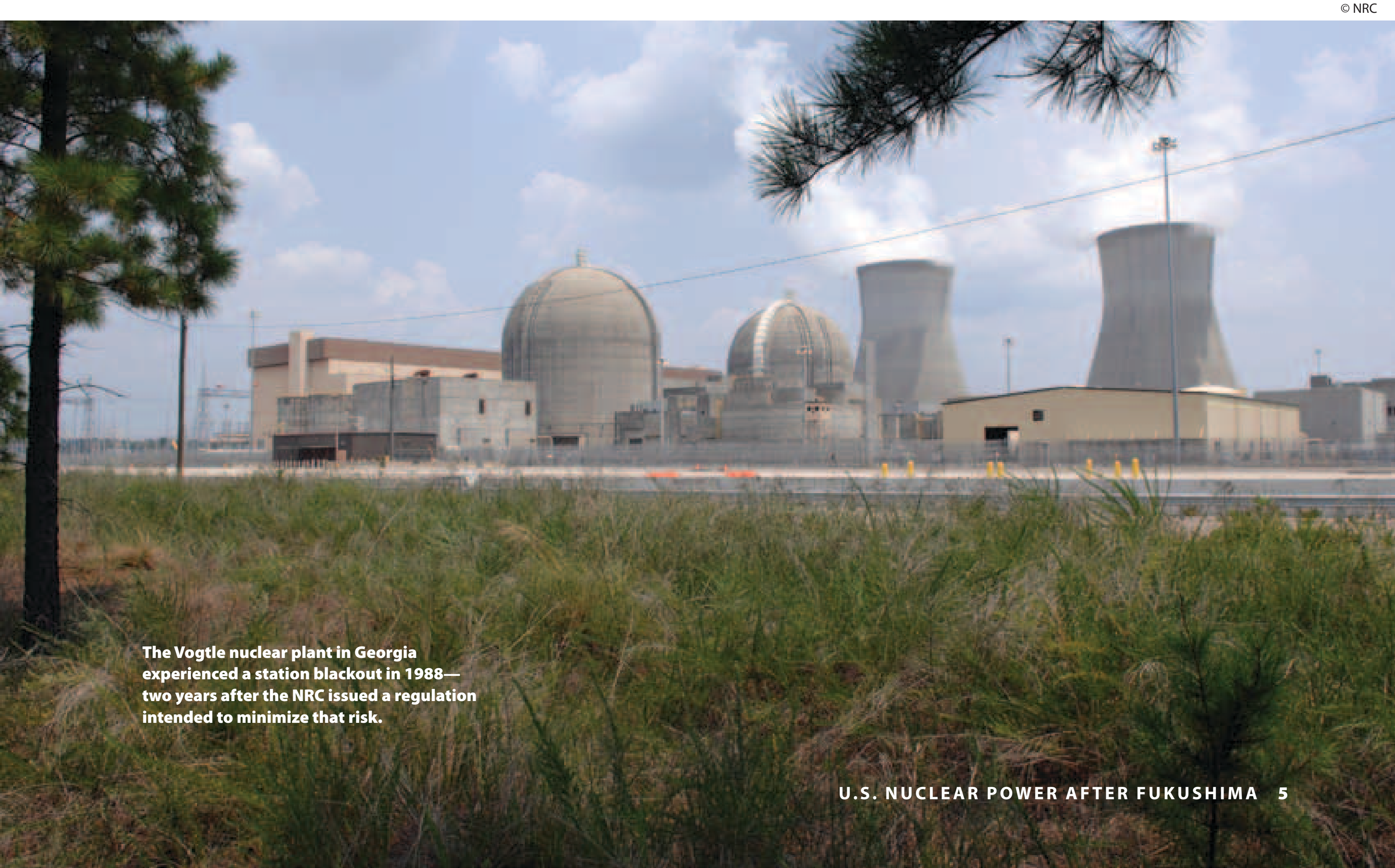


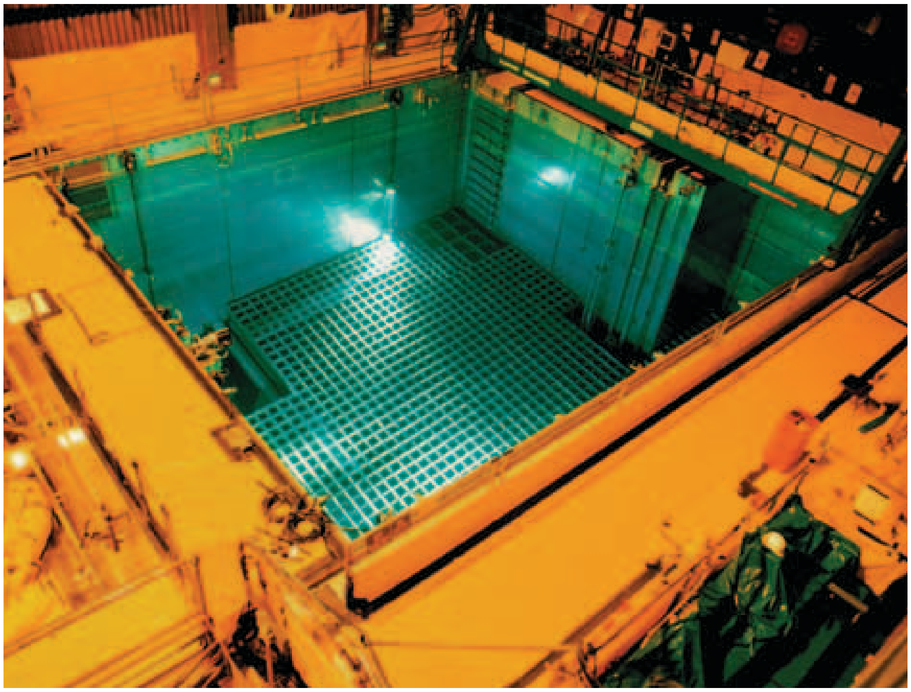
The Vogtle nuclear plant in Georgia experienced a station blackout in 1988—two years after the NRC issued a regulation intended to minimize that risk.

spent fuel pool is more likely to reach the outside environment than radiation released from the reactor core. Spent fuel pools are also more vulnerable than the reactor core to a terrorist attack.

4. The NRC should require plant owners to move spent fuel at reactor sites from storage pools to dry casks when it has cooled enough to do so.

The risks associated with spent fuel pools can be reduced by placing some of the fuel in dry casks, which are made of steel and concrete and cooled by natural convection. Spent fuel is usually cool enough to be transferred to casks after about five years, but U.S. reactor operators generally leave the fuel in pools until the pools are full. As a result, most pools contain five times as much fuel as the reactors themselves.

The less fuel that remains in the pool, the longer it would take for the water to heat up and boil away if cooling is lost, thus giving workers more time to solve the problem and restore cooling. And if an accident did occur that led to the release of radiation, less would be emitted than if the pool was full.



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Spent nuclear fuel stored in pools is more vulnerable to accidents, natural disasters, and attack than fuel in the reactor core, and more likely to release radiation into the atmosphere.

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Dry casks are more secure than spent fuel pools, and with a few modifications could likely be made a viable storage option for at least 50 years.

5. The NRC should require reactor owners to improve the security of existing dry cask storage facilities.

Dry casks at reactor sites are stored outdoors on concrete pads. Although they are more secure than spent fuel pools in the event of attack, dry casks remain vulnerable to some types of weapons. According to vulnerability assessments conducted by the NRC following the 9/11 attacks, certain types of explosive weapons could breach some types of casks.[2] However, dry casks can likely be made an acceptably safe and economically viable storage option for at least 50 years with a few relatively simple modifications to security plans and site infrastructure.[3]

6. The NRC should require plant owners to significantly improve emergency procedures and operator training for spent fuel pool accidents.

Inadequate cooling of spent fuel pools can result in the release of dangerous levels of radiation. The NRC and the U.S. nuclear industry have developed extensive emergency procedures to handle design-basis reactor core accidents, and provide thorough operator training on their implementation (although, as noted in recommendations 1 and 2, these procedures should be improved for severe accidents). In contrast, they have given little thought to spent fuel pool accidents, so response procedures are inadequate and there is virtually no operator training for such accidents.

Upgraded procedures and operator training for emergency events including station blackouts should include provisions for:

- Monitoring the condition of the inflatable seals that make the pool gates watertight
- Restoring power in a timely manner to the pool's cooling system and the system providing air to the inflatable seals. This could be done, for example, by connecting these systems to the emergency diesel generators or by providing temporary generators.
- Monitoring pool temperature and water level

Making Existing Reactors Safer

Although existing reactors are designed to withstand design-basis accidents, many are vulnerable to such accidents because they do not comply with certain important safety regulations. While reactor owners can be faulted for this shortsighted behavior, the NRC is too tolerant of known safety violations. Owners also need to do a better job of identifying safety problems before they occur—including the degradation of aging equipment, which will become more problematic as the NRC extends reactor licenses.

In addition, safety problems can arise when reactors use certain types of fuel: "high burn-up" fuel and plutonium-based mixed-oxide fuel. The former is more vulnerable to damage during some types of design-basis accidents, and the latter increases the risk of some types of severe accidents as well as the risk to public health from such accidents.

7. The NRC should enforce its fire protection regulations and compel the owners of more than three dozen reactors to comply with regulations they currently violate.

Because a fire can destroy a nuclear plant's main and backup emergency systems, it is one of the most likely ways in which a reactor core can be seriously damaged, resulting in a release of radioactivity. Following a fire at the Browns Ferry nuclear plant in Alabama, the NRC issued regulations in 1980 intended to reduce the fire hazard at all reactors. Twenty years later, the agency discovered that dozens of reactors failed to meet those regulations and were therefore being operated with undue risk of serious damage from fires. The NRC developed an alternative set of fire protection regulations in 2004—the "NFPA 805 option"—and required plant owners to comply with either these or the 1980 regulations. The owners of nearly 40 U.S. reactors announced their intention to comply with the NFPA 805 option, but more than three dozen reactors still do not comply with either set of regulations, and their owners have made no firm commitments to address this fire risk anytime soon.[4] Moreover, in June 2011, four of the five NRC commissioners voted to extend the deadline for compliance until 2016.

The NFPA 805 option is based on a probabilistic risk assessment (PRA) of various fire hazards and associated protection measures. As we discuss in recommendation 22, however, there are significant flaws in the NRC's PRAs, so reactor owners should not be allowed to choose the NFPA 805 option until the agency has corrected those flaws.

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A serious fire at Alabama's Browns Ferry nuclear plant spurred the NRC to issue fire protection regulations in 1980 (and again in 2004), but more than three dozen reactors still do not comply.

Because a fire can destroy a reactor's main and backup emergency systems, it is one of the most likely ways in which a reactor core can be seriously damaged, resulting in a release of radioactivity.

8. The NRC should establish timeliness goals for resolving safety issues while continuing to meet its timeliness goals for business-related requests from reactor owners.

In addition to overseeing the safety and security of U.S. reactors, the NRC is responsible for business matters such as granting construction and operating licenses for new reactors, extending the licenses of existing reactors, and amending licenses to allow for increased power output.

Unfortunately, the NRC often places business ahead of safety. In particular, the agency has established goals for completing business dealings in a timely manner, but has not done so for resolving outstanding safety issues.

The problem is evident in the periodic reports the NRC submits to Congress detailing its progress on both safety and business matters.[5] For example, its November 2010 report indicated that in 2009 and 2010 the agency met its goal of approving 90 percent of new business within one year and 100 percent within two years. Conversely, five "generic" safety issues—unresolved problems affecting numerous operating reactors—had no timetable for resolution, and one of the five—affecting nearly 20 reactors—has been unresolved since 1996.[6]

9. The NRC should treat generic and unique safety issues alike. Until a generic issue is resolved, the NRC should account for it as a potential risk factor in its safety analyses and decision making related to all affected reactors.

When a safety problem affects—or could affect—more than one nuclear plant, the NRC labels it a generic safety issue and treats it separately from problems unique to individual plants. The agency assesses the risk associated with each generic issue by assuming that all other plant systems are fully functional and reliable; it similarly assesses the risk associated with unique problems at individual reactors by assuming that generic issues do not exist. This approach prevents the NRC from accurately assessing the overall risk from a combination of unique and generic problems.

The NRC usually has 6 to 10 generic safety issues open at any given time, and often takes more than a decade to rectify these problems. In the meantime, these unresolved issues may increase the likelihood of an accident or worsen its consequences.

If the NRC required plant owners to use multiple inspection techniques, workers at South Carolina's Summer nuclear plant would have detected a crack in a pipe connected to the reactor vessel earlier.

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One example is related to the emergency pumps of the 69 U.S. pressurized-water reactors (PWRs). In 1979 the NRC determined that steam and water jetting from a broken pipe during an accident could dislodge pipe insulation and equipment coatings, which could clog the emergency pumps needed to cool the reactor core. Yet the agency assigned a very low probability to emergency pump failure because it ignored the possibility of an accident involving a broken pipe. Having understated this risk, the agency did not require reactor owners to address the problem until the end of 2007, but even now some 20 reactors are still not in compliance.[7]

10. The NRC should require plant owners to use multiple inspection techniques to ensure detection of any degradation in aging, high-risk equipment.

The periodic inspections and safety equipment tests required by NRC regulations do not use techniques varied enough to detect problems with high confidence, which is especially important for aging equipment that is slowly deteriorating. For example, when one of the largest pipes connected to the reactor vessel at South Carolina's Summer nuclear plant began leaking in 2000, workers discovered a crack in the pipe. Past inspections had missed the crack because the sonar-like probe being used lifted off the outer surface of the pipe as it moved onto a nozzle with a larger diameter. The resulting air gap masked signs of the crack. Other inspection methods that are not vulnerable to this problem would have detected the crack earlier.

11. The NRC should require plant owners to periodically inspect equipment outside the scope of normal inspections, both to determine whether that scope is appropriate and to detect problems before safety margins are compromised.

Because monitoring every square inch of a nuclear plant would be impractical, inspections target equipment and structures considered most vulnerable to degradation. When workers discover degradation outside the scope of their inspections, the scope is enlarged to include the suspect equipment or plant areas in all future inspections. However, the NRC does not require plant owners to periodically inspect equipment and structures considered less vulnerable.[8]

For example, in 2002 operators shut down Unit 1 at Illinois' Quad Cities nuclear plant when the beam holding down a pump inside the reactor vessel broke apart and pieces of the beam damaged one of the other pumps. Workers had frequently inspected the beam at its two ends, where it was believed cracks were most likely to form, but the beam cracked in its middle. Had the scope of these inspections occasionally extended to the entire beam, the crack would likely have been discovered before the beam broke apart.

12. The NRC should revise its regulations for the licensing of "high burn-up" fuel to ensure public safety, and restrict how this fuel is used until the revisions are complete.

Over the last couple of decades, reactor owners have increasingly used high burn-up fuels that can be left in the reactor for a longer period of time, allowing fuel to be replaced every other year rather than once a year. However, the NRC approved these fuels without fully understanding the problems that can occur by irradiating them for an extended period of time. For example, high burn-up fuels are more vulnerable to damage during certain types of design-basis accidents, including those where coolant is lost or control rods are ejected.[9] The NRC has now known about these problems for more than a decade but is responding slowly due to industry resistance. As a result, a significant quantity of fuel in U.S. reactors today may not be able to withstand design-basis accidents.

The use of mixed-oxide fuel increases the probability of certain types of severe accidents and the magnitude of the environmental and health impacts of such a severe accident.

13. The U.S. government should prohibit the use of plutonium-bearing mixed-oxide (MOX) fuel in reactors, and end the program to produce MOX fuel from excess weapons plutonium.

The United States is currently constructing a facility that would produce MOX fuel for commercial reactors using the plutonium from dismantled nuclear weapons, and the French company Areva has proposed to build a U.S. facility that would reprocess spent fuel and use the resulting plutonium to make MOX fuel. However, the use of such fuel increases the probability of certain types of severe accidents (such as those in which core damage would result from the ejection of control rods) and the magnitude of the health and environmental impacts of such a severe accident.[10]

Because MOX fuel contains greater amounts of highly radiotoxic plutonium and heavier elements than standard low-enriched uranium fuel, it could increase the number of deaths resulting from a severe accident by 25 to 100 percent, depending on whether the plutonium comes from weapons or spent reactor fuel.[11] MOX fuel should therefore be banned, and excess plutonium from weapons should be blended with radioactive waste, encased in glass or a ceramic material, and disposed of in a long-term repository.

Ensuring the Continued Safety of Reactors with Renewed Licenses

When the NRC revises regulations or adopts new ones (as when a generic safety issue has been resolved), it sometimes "grandfathers" (or exempts) existing reactors from these regulations. For example, in 1985 the NRC required new reactors to incorporate design features that would make their sump screens less likely to become clogged with debris during an accident, but exempted existing reactors. Such exemptions continue to apply even when a reactor receives a 20-year license extension, despite the fact that aging

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By requiring workers to periodically inspect equipment outside the scope of normal inspections, more problems will be detected before safety margins are compromised.

reactors are more likely to develop some types of safety problems.

14. Before granting a license renewal, the NRC should review all differences between current regulations and any past decisions specific to the aging reactor, to confirm that these differences will not compromise public safety going forward.

When the NRC reviews an application to renew a reactor's operating license, it never revisits its past decisions. Thus, it never considers whether an exemption granted in the past should remain in effect for an additional 20 years of operation. The agency should determine whether requirements that apply to a specific reactor could compromise public health and safety during the next 20 years compared with current regulations, and if that is the case, apply the current regulations instead.

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Even though plant owners are given advance notice of mock attacks, their security forces too often fail to repel the unrealistically modest threats envisioned by the NRC.

Making Existing Reactors More Secure against Terrorist Attacks

Existing reactors are not as secure as they could—and should—be. NRC assumptions about potential attackers are unrealistically modest, so reactor owners are not required to defend against real-world threats. Moreover, in recent "force-on-force" tests the NRC conducts to determine whether security personnel can defend a plant against a mock attack, more than 10 percent of plants failed the NRC's modest scenarios—even though plant owners are given advance notice of the tests.

15. The NRC should revise its assumptions about terrorists' capabilities to ensure nuclear plants are adequately protected against credible threats, and these assumptions should be reviewed by U.S. intelligence agencies.

The NRC's "design-basis threat" (DBT) defines the size and abilities of a terrorist group that a nuclear facility must be able to repel. Before 9/11 the DBT consisted of three attackers armed with nothing more sophisticated than handheld automatic rifles, working with a single insider whose role was limited to providing information about the facility and its defenses. The DBT was upgraded post-9/11, but still does not reflect real-world threats. For example, it may ignore the possibility that terrorists would use rocket-propelled grenades—a weapon used by insurgents around the world.

The assumptions underlying the DBT should be reviewed by an interagency body that includes the intelligence community, the National Nuclear Security Administration, and the Department of Homeland Security.

16. The NRC should modify the way it judges force-on-force security exercises by assessing a plant's "margin to failure," rather than whether the plant merely passes or fails.

The NRC's current approach only recognizes whether or not a plant owner's security force is able to prevent the destruction of an entire "target set" that would result in core damage. No distinction is made between good and barely adequate performance. Several years ago, the NRC proposed to enhance its evaluation system by incorporating margin to failure (i.e., how close the plant came to suffering core damage), but the proposal was opposed by the industry and has not been adopted.

17. The U.S. government should establish a program for licensing private security guards that would require successful completion of a federally supervised training course and periodic recertification.

Given the poor performance demonstrated in force-on-force exercises, there is currently no assurance that reactor owners can defend their reactors against DBT-level attacks. By establishing a rigorous training and licensing program for reactor guards, the federal government would help ensure that adequate security standards are met.

Making New Reactors Safer and More Secure against Terrorist Attacks

Any expansion of nuclear power in the United States would provide an opportunity to build safer, more secure reactors—if mandated by the NRC. In the absence of stronger safety and security standards, the industry will keep its costs down by meeting but not exceeding the current standards.

18. The NRC should require new reactor designs to be safer than existing reactors.
In 1986, the NRC issued a policy requiring advanced reactors to provide merely the same level of protection as existing reactors. Instead, any new reactors should have additional features designed to prevent severe accidents, to mitigate a severe accident if one should occur, and to reduce reliance on operator interventions during an accident (which are inherently less dependable than built-in measures).

For example, a containment building designed to withstand the high pressures that can occur in a severe accident decreases the risk of radiation escaping into the environment. Yet some reactor types do not have such containment buildings and therefore require electrically powered systems such as hydrogen igniters to maintain the building's structural integrity. Moreover, the trend in new reactor designs is to reduce the size and strength of containment buildings.

19. The NRC should require new reactor designs to be more secure against land- and water-based terrorist attacks.
Nine years after 9/11, the NRC required new reactor designs to incorporate features that would enhance the reactor's ability to withstand an airplane attack, either by maintaining the structural integrity of the containment building and spent fuel pool or by maintaining cooling of the core and spent fuel pool if structural integrity is lost. But the NRC rejected a proposal that would also require features designed to reduce vulnerability to land- and water-based attacks. All potential modes of attack need to be addressed.

Improving the NRC's Cost-Benefit and Risk-Informed Analyses

In deciding whether to require reactor owners to undertake a safety retrofit, the NRC often conducts a cost-benefit analysis that compares the costs of the retrofit with the dollar value of the lives that would potentially be saved. However, the results of these analyses are skewed because the NRC uses a much lower figure for the value of a human life than the rest of the U.S. government. Moreover, these analyses only account for potential damage to fuel in the reactor, not in spent fuel pools.

In the absence of stronger safety and security standards, the industry will keep its costs down by meeting but not exceeding the current standards.

There are also serious problems with the way the NRC uses probabilistic analyses to assess the risks of different types of accidents, which may have the effect of underestimating the actual risks. For example, the agency's analyses do not fully account for the risks of earthquakes and extreme weather.

20. The NRC should increase the value it assigns to a human life in its cost-benefit analyses so the value is consistent with other government agencies.
U.S. agencies other than the NRC place a value on a human life of between $5 million and $9 million. The NRC—despite the Office of Management and Budget's recent warning that it would be difficult to justify a value below $5 million—has continued to value a human life at $3 million since 1995.[12]

Bringing the NRC's calculations in line with other agencies would have a major effect on nuclear plant license renewals and new reactor approvals: plant owners would have to add safety features that the NRC now considers too expensive (because it underestimates the value of the lives that could be saved).

21. The NRC should require plant owners to calculate the risk of fuel damage in spent fuel pools as well as reactor cores in all safety analyses.
Reactor owners' cost-benefit analyses of safety problems do not consider the risks of damage to fuel in spent fuel pools, yet the pools' cooling systems are often coupled to other plant systems. By ignoring these risks, reactor owners underestimate the potential costs of some types of severe accidents.

22. The NRC should not make decisions about reactor safety using probabilistic risk assessments (PRAs) until it has corrected its flawed application of this tool.
PRAs, which the NRC and the nuclear industry use for a variety of purposes, can be a valuable tool when used appropriately.[13] For example, because inspecting every inch of pipe in a nuclear plant is not feasible, PRAs can determine which portions of pipe have the greatest risk of failure or would cause the most damage if a failure occurred, and should therefore receive priority during inspections. PRAs are also used to assess the possibility that multiple safety systems might fail and cause a reactor meltdown.

However, UCS, the Government Accountability Office, the NRC inspector general, the NRC Advisory Committee on Reactor Safeguards, and the NRC itself have all documented serious problems with the agency's PRAs, including omission of key data, inconsistent assumptions and methodology, and inadequate quality standards. For example, the NRC does not require that PRAs include a rigorous evaluation of seismic risks, even though earthquakes may be one of the biggest potential contributors to core damage.

To be valid, PRAs must include all internal and external events that could lead to an accident. They must address all modes of operation (including shutdown and low-power modes), incorporate rigorous uncertainty analyses, and meet strict quality assurance standards. The NRC must also account for a wider range of potential accident consequences by including more conservative assumptions about weather and other variables (e.g., by using results for the ninety-fifth percentile rather than the average).

Ensuring Public Participation

Public input has long played an important role in the NRC's process for licensing power plants, and the agency has admitted that the public's participation has improved safety on numerous occasions.[14] Nevertheless, the NRC has effectively limited such participation by eliminating the public's right to discovery and cross-examination.

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23. The NRC should fully restore the public's right to obtain information and question witnesses in hearings about changes to existing power plant licenses and applications for new licenses. When the NRC announced in 2004 that it was rejecting the public's right to discovery and cross-examination during licensing hearings, the attorneys general of five states voiced their opposition to the change, but the agency adopted it anyway. Neighbors of existing and proposed reactors deserve to play an active part in the licensing process.

Endnotes

1 A current example is the Areva EPR (Evolutionary Power Reactor), which has safety systems not required by the NRC and has attracted much less interest in the United States and abroad than the Westinghouse AP1000, which meets but does not exceed NRC requirements.

2 See, for example: Lyman, E. 2010. NRC: Taking spent fuel security in the wrong direction. 51st annual meeting of the Institute of Nuclear Materials Management. Baltimore, MD. Online at *www.ucsusa.org/assets/documents/nwgs/Lyman-INMM-2010-paper.pdf*.

3 National Research Council. 2006. *Safety and security of commercial spent nuclear fuel storage*. Washington, DC: The National Academies Press, 68. Online at *www.nap.edu/catalog.php?record_id=11263*.

4 For information on the specific reactors that do not comply with fire regulations, see the UCS Nuclear Power Information Tracker at *www.ucsusa.org/nucleartracker*.

5 The NRC began submitting these reports in 1999; they are available online at *www.nrc.gov/reading-rm/doc-collections/congress-docs/monthly-reports*.

6 For more information on these five generic safety issues, see: Beasley, B.G. 2011. Generic Issue Management Control System report (FY 2011, Q2). Nuclear Regulatory Commission memorandum, April 7. Online at *http://pbadupws.nrc.gov/docs/ML1108/ML110810919.pdf*.

7 For additional information on this problem, see: Lochbaum, D. 2003. *Regulatory malpractice: NRC's "handling" of the PWR containment sump problem.* Cambridge, MA: Union of Concerned Scientists. October 29. Online at *www.ucsusa.org/nuclear_power/nuclear_power_risk/safety/regulatory-malpractice-nrcs.html*.

8 For additional information, see Lochbaum, D. 2004. *U.S. nuclear plants in the 21st century: The risk of a lifetime.* Cambridge, MA: Union of Concerned Scientists. May. Online at *www.ucsusa.org/nuclear_power/nuclear_power_risk/safety/us-nuclear-plants-in-the.html*.

9 Barré, F., C. Grandjean, M. Petit, and F. Arreghini. 2009. *Fuel behaviour under LOCA and RIA and its implication on the current safety criteria*. Institut de Radioprotection et de Sûreté Nucléaire. Online at *www.eurosafe-forum.org/files/Presentations2009/Seminar2/Abstracts/2.5-Fuel%20behaviour%20under%20LOCA%20and%20RIA-Barre.pdf*.

10 Lyman, E. 2001. Public health consequences of substituting mixed-oxide for uranium fuel in pressurized water reactors. *Science & Global Security* 9:33–79. Online at *www.princeton.edu/sgs/publications/sgs/pdf/9_1lyman.pdf*.

11 Ibid.

12 Appelbaum, B. 2011. A life's value: It may depend on the agency. *New York Times*, February 17.

13 PRA calculations were first developed in the NRC's Reactor Safety Study of 1975 (a.k.a. the Rasmussen report).

14 For examples, see: Union of Concerned Scientists. 1985. The value of public participation. In: *Safety second: A critical evaluation of the NRC's first decade*. Cambridge, MA. February, 77.

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