Preventing an American Fukushima

Limited Progress Five Years after Japan's Nuclear Power Plant Disaster

March 11, 2016, marks the fifth anniversary of the massive magnitude 9.0 Great East Japan Earthquake and resultant 15-meter tsunami that triggered the catastrophic 2011 nuclear accident at the Fukushima Dai-ichi Nuclear Power Plant in northern Japan. The severity of the natural disaster—which far exceeded the design basis of the nuclear plant and caused the cores of three reactors to melt down and release substantial quantities of highly radioactive material into the environment—stunned the world.

In response to the accident, the US Nuclear Regulatory Commission (NRC), which regulates the US nuclear power industry, established a task force to recommend actions that the NRC should take in the near term to improve the safety of US nuclear power plants against flooding or other extreme events that may exceed their design basis—important because many US nuclear plants are in flood-prone or seismically active locales. The Near-Term Task Force—which consisted of a group of senior NRC staff—issued a 96-page report in July 2011 with 12 detailed multi-part recommendations (Task Force 2011). The task force then binned the recommendations into three tiers, with Tier 1 being the highest priority. While not exhaustive, the task force recommendations provided a strong first

Taken January 25, 2016, nearly five years after the disaster, this photo shows the damage at Fukushima Dai-ichi Nuclear Power Plant's Unit 3 reactor. Unit 3 was the site of a core meltdown and a hydrogen explosion that released radioactivity into the surrounding environment.

Union of Concerned Scientists

step for reducing the likelihood of a beyond-design-basis, Fukushima-scale accident in the United States.

The fifth anniversary of the Fukushima accident provides a good opportunity to take stock of the progress—or lack thereof—made by the NRC and the nuclear industry in carrying out the report's recommendations and in addressing the safety problems identified by the task force, other NRC staff, and independent groups, including the Union of Concerned Scientists (UCS) (Lochbaum and Lyman 2012). (See Table 1, p. 5, and Table 2, p. 6.)

Rejecting, Weakening, and Leaving the Public at Risk

Both the NRC and the nuclear industry have devoted several billion dollars and much time and labor to addressing the task force recommendations to improve nuclear plant safety. However, it is difficult to assess to what extent that considerable effort will reduce the risk to the public from severe nuclear accidents. Moreover, the NRC *has rejected or significantly weakened* many of the commonsense recommendations made by the task force despite the insights and clear lessons from the Fukushima disaster.

One reason that progress is difficult to measure is that the NRC has not established clear metrics for success. The NRC continues to cloak its decisions in highly subjective terms such as "adequate protection of public health and safety," "reasonable staging and protection" of emergency safety equipment, and "substantial safety enhancements." Ambiguity about the actual meaning of such descriptors as "adequate," "reasonable," and "substantial" provides the NRC with enormous discretion that it can—and sometimes does—abuse.

Four major examples of areas where we believe the NRC has failed to learn the lessons of Fukushima are: the NRC's decisions to limit the scope and effectiveness of the FLEX (diverse and flexible coping capability) program to protect against electrical power failures; its narrow interpretation of the terms of the "backfit" rule (a rule that allows the NRC to consider the cost of a modification that would increase safety beyond "adequate protection"); its discounting of the concept of defense-in-depth (the act of putting in additional safety measures as backups in case the primary safety measures fail); and its continued reliance on voluntary industry initiatives in lieu of enforceable regulatory requirements. All four examples are detailed below.

THE FLEX PROGRAM

The foundation of the NRC and industry response to the Fukushima accident is the "diverse and flexible coping capability" program (or FLEX for short). Launched within months after the Fukushima crisis began, FLEX was intended to be "a major step in addressing the critical problems encountered at Fukushima Dai-ichi: loss of power and reactor cooling capability" (NEI n.d.). The principal issue at Fukushima was an extended loss of all alternating current (ac) power and most direct current (dc) battery power, resulting in a loss of normal cooling capability. Even when a reactor is shut down, it requires electrical power to cool the reactor core and the spent fuel pool.

At Fukushima Dai-ichi, the prolonged power loss meant workers had to scramble to establish emergency means of injecting cooling water into the reactor cores and spent fuel pools without having the right procedures or equipment to do so. Despite heroic efforts, they were unable to provide sufficient cooling water in time to prevent the melting of the cores of three reactors; the consequences included three hydrogen explosions and massive releases of radioactivity into the air and the Pacific Ocean.

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Under FLEX, the US nuclear industry has purchased portable emergency equipment, such as portable electrical turbine generators and diesel-powered pumps, to be used in the event of a severe natural disaster. However, it is not clear how effective the FLEX program actually would be in achieving its primary purpose: mitigating a total loss of ac power at a US reactor. Indeed, over the last five years, we have observed the nuclear industry's efforts to ensure that the NRC's standards for the FLEX program are relatively cheap to meet, and to oppose the inclusion of detailed and objective criteria that would allow the NRC's inspectors to identify clear violations and the agency to effectively enforce its safety requirements.

Moreover, the FLEX program is being invoked as a broad rationale by the NRC to avoid taking further action to improve safety: see, for example, the vote by NRC Chairman Stephen Burns rejecting a staff proposal to strengthen requirements for accident management plans (Vietti-Cook

2015a). As we predicted in our book, *Fukushima: The Story of a Nuclear Disaster*, the NRC and the industry are arguing that the FLEX program can mitigate a host of other long-standing safety gaps that got renewed attention after Fukushima because it will reduce the likelihood of severe accidents overall (Lochbaum, Lyman, and Stranahan 2014). For instance, the NRC has decided that it is unnecessary to require reactor owners to reduce the density of highly radioactive spent fuel in reactor pools to decrease the amount of radioactivity that could be released in a fire (discussed in greater detail near the end of this report). Similarly, despite the fact that high concentrations of radioactive material from Fukushima spread out some 25 miles from the site, the NRC has also decided it is unnecessary to require reactor owners to increase the radius of zones around reactor sites where emergency evacuation planning is required (currently a 10-mile radius) (NRC 2014a) to at least 25 miles. Furthermore, the commercial nuclear industry has argued that the additional safety that will be achieved by implementing Tier 1 activities (e.g., the FLEX program) is so substantial that the NRC does not need to pursue the other safety issues in Tiers 2 and 3 (NEI 2015a), and the NRC has largely agreed (Vietti-Cook 2016).

The NRC has decided that it is unnecessary to require reactor owners to reduce the density of highly radioactive spent fuel in reactor pools to reduce the amount of radioactivity that could be released in a fire.

THE BACKFIT RULE

The NRC has repeatedly invoked a regulation called the "backfit" rule to justify rejecting many of the recommendations for post-Fukushima safety upgrades. The current backfit rule restricts the ability of the NRC to impose new safety rules on the industry if they are not needed to ensure "adequate protection," the basic safety mandate of the NRC under the Atomic Energy Act (Lochbaum, Lyman, and Stranahan 2014). Safety rules that would go beyond adequate protection must meet two backfit criteria: they must pass a cost-benefit test *and* constitute a "substantial safety enhancement." The NRC can elevate any new safety measure to adequate protection status if a majority of the commissioners so designates it. Otherwise any new safety measure must meet the backfit criteria in order for the NRC to require it.

In 2012, the NRC issued two new requirements based on Near-Term Task Force recommendations that the commissioners decided were needed for adequate protection. However, for nearly all of the task force's other post-Fukushima recommendations, they declined to take the same action. Worse, according to the NRC staff's quantitative analyses, nearly all of those other recommendations failed to meet the NRC's backfit criteria.

This outcome was not a surprise to UCS or to others familiar with the way the NRC works. In our view, the NRC's methodology for carrying out backfit analyses is overly rigid, relies too heavily on uncertain quantitative risk estimates, and uses an outdated and inappropriate litmus test for determining safety significance. Thus, the NRC's methodology systematically underestimates the benefits of new safety rules for reducing the risk to the public from severe accidents. UCS believes that many of the post-Fukushima safety proposals that the NRC has rejected are clearly justified and would easily pass a backfit test that was not effectively rigged against the public interest.

For instance, when the NRC does a cost-benefit analysis of a safety enhancement, it considers primarily the value of the human lives that would be saved and the value of the land that would not be contaminated with radioactivity (both within 50 miles of a reactor accident). It does not consider other factors not easily quantified, such as the societal benefits of avoiding the long-term displacement of people who would have to flee contaminated areas—which could be hundreds of thousands or even millions of people.

DEFENSE-IN-DEPTH

The NRC has ignored one of the main concerns of the Near-Term Task Force and refused to give more weight to the benefits of other qualitative factors, such as "defense-in-depth." In a nutshell, defense-in-depth means putting in additional safety measures as backups in case the primary safety measures fail. Having backups for the backups is important to compensate for uncertainties in the performance of the primary backup systems.

However, if the risk of failure of a primary system is calculated to be low, the NRC will assume the quantitative benefit of any supplemental backup system will also be low. But its qualitative benefit—the benefit of having additional safety assurances in case the NRC's calculations are wrong—can be substantial. For example, requiring more rigorous training programs for emergency personnel would have benefits that would be clear but difficult to quantify.

VOLUNTARY INDUSTRY INITIATIVES

Another obstacle to the adoption of some important post-Fukushima recommendations is the NRC's continuing use of "voluntary industry initiatives." For decades, the nuclear industry has been making promises to take certain actions to address severe accident risks in order to ward off imposition of new regulatory requirements by the NRC—promises the industry has not always kept. NRC regulations are enforceable by law, and violators can be slapped with fines or other penalties. Voluntary industry actions, on the other hand, are unenforceable, and the NRC has very little leverage other than shaming if a licensee does not live up to its commitment. The Near-Term Task Force cited a lack of clarity in the role of voluntary industry initiatives as a significant issue that the NRC should address, but this important part of the task force's number one recommendation ended up in the dustbin.

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The Industry Wins Out

In assessing why the NRC has rejected so many of the initial post-Fukushima safety proposals and has watered down the ones it has adopted, the role of industry influence cannot be underestimated. The nuclear industry was extensively involved in developing the post-Fukushima regulatory regime. For example, the industry started buying and deploying FLEX equipment before the NRC had a chance to define its own specifications for what that equipment should be able to do and how it should perform. The industry wrote the guidance documents for implementation of all the post-Fukushima requirements imposed by the NRC and let the NRC comment on them, when the process should have occurred the other way around. And on nearly every major policy question related to Fukushima lessons learned, a majority of the NRC commissioners voted for the industry's position. (Several examples are detailed later.)

Despite its victories in staving off much-needed regulatory actions, as documented below, the industry is not resting on its laurels. In December 2015, the US nuclear industry announced the launch of a "Nuclear Promise Initiative," a program to examine ways for nuclear power plants to significantly reduce their operating expenses by 2018, in part by increasing "efficiency" (USA 2015). In a January 2016 meeting with the NRC's staff, a representative from the Nuclear Energy Institute (NEI)—the nuclear industry's trade association and lobbying group—cited the preventive maintenance program for FLEX equipment as an example of an area where the initiative would be looking to improve efficiency (for example, through cutting costs) (NRC 2016a). Thus, the NRC should probably expect to receive industry requests to modify the industry's FLEX maintenance plans—plans the NRC is in the process of reviewing now—before the ink on those plans has even dried.

In summary, in responding to the Fukushima disaster, the NRC has narrowed a few gaps in the regulatory patchwork that compromise safety, but has left far too many other safety gaps wide open. As a result, the American people will continue to be at an unacceptably high risk of Fukushima-scale nuclear accidents that could damage their health, property, and way of life.

Discussion of Selected Task Force Recommendations

A comprehensive discussion of all 12 post-Fukushima recommendations made by the NRC's Near-Term Task Force is beyond the scope of this five-year report. Below we discuss five of the most important recommendations:

- Recommendation 1 to establish a new regulatory framework that would do away with the current "patchwork" of regulatory requirements and voluntary industry actions that evolved over decades, and include clear regulations for safety measures to cope with accidents more severe than those the reactors are designed to withstand
- Recommendation 4 specifically to address how to handle prolonged station blackouts (extended loss of ac power) as a result of such beyond-design-basis natural disasters
- Recommendation 2 specifically to update and address realistic-scale seismic and flooding hazards at operating nuclear plants
- Recommendation 5 to ensure reliable venting of Mark I and Mark II boiling water reactor containments during a station blackout

TABLE 1: **Status of Selected Near-Term Task Force Recommendations for NRC Actions**

Recommendation		Tier	Status	Expected Completion Date
No.	Description			
1	Establish a logical, systematic, and coherent regulatory framework	---	Rejected by the NRC	N/A (being addressed outside of Fukushima activities)
2.1 Phase 1	Require reactor owners to reevaluate seismic and flooding hazards	1	Accepted by the NRC	Seismic: December 2019 Flooding: December 2018
2.1 Phase 2	Update NRC design-basis safety requirements to include reevaluated seismic and flooding hazards	1	Partially accepted by the NRC but significantly weakened	TBD
2.2	Undertake rule making to require seismic and flooding hazard reevaluations and update of safety requirements every ten years	3	Staff recommends partial acceptance but with significant weakening	
2.3	Require owners to inspect reactors to assess seismic and flooding protections	1	Accepted by the NRC	December 2015 (completed)
3	Evaluate need to address risk of seismically induced fires and floods	3	Rejected by the NRC	N/A
4.1	Undertake rule making to require operating and new reactors to strengthen their capability to respond to a station blackout*	1	Partially accepted by the NRC but significantly weakened	Final rule to commission: December 2016; implementation in 2019
4.2	Issue an order requiring owners to upgrade and augment existing emergency equipment	1	Partially accepted by the NRC but significantly weakened; combined with 4.1 and reorganized	December 2016 for most plants; June 2019 for some boiling water reactors; Undetermined for plants with reevaluated hazards "far beyond the design basis."
5.1	Require owners to install reliable hardened containment vents for Mark I and Mark II boiling water reactors	1	Accepted and strengthened by the NRC	June 2019
5.2	Require owners to install reliable hardened vents for other containment designs	3	Staff recommends rejection	N/A
6	Require owners to install hydrogen control and mitigation equipment in-side containment and other buildings	3	Staff recommends rejection	N/A
7.1	Require owners to install safety-related instrumentation to measure spent fuel pool water level, temperature, and radiation level	1	Partially accepted by the NRC	December 2016
7.2-7.5	Require owners to strengthen spent fuel pool water makeup capability	2	Partially accepted by the NRC and incorporated into 4.1 and 4.2	See 4.1. and 4.2
8.1-8.4	Require owners to strengthen and integrate onsite emergency response capabilities	1	Incorporated into 4.1 and significantly weakened by the NRC	See 4.1
9.1-9.2	Require owners to enhance emergency plans to address multiunit events and prolonged station blackouts*	3	Incorporated into 4.1	

*A station blackout occurs when there is no ac power available, thus preventing normal cooling of the reactor core and the spent fuel pool.

TABLE 2: Additional Proposals Generated by NRC staff and the NRC's Advisory Committee on Reactor Safeguards

Description	Tier	Status
Require owners to add filters to containment vents or implement alternate release reduction strategies	1	Rejected
Require owners to expand emergency planning zone size beyond 10 miles	3	Rejected
Pre-stage potassium iodide to residents beyond 10 miles	3	Rejected
Require owners to expedite transfer of spent fuel to dry storage	3	Rejected
Require owners to mitigate loss of ultimate heat sink	3	Combined with 4.1 and 4.2
Require owners to install enhanced instrumentation for beyond-design-basis conditions	3	Staff recommends rejection

- Recommendation 8 to require, in part, formal guidelines for procedures for managing a severe core-melt accident, removing such grave concerns from their current status as voluntary industry initiatives out of the NRC's purview.

THE SAD TALE OF RECOMMENDATION 1: ESTABLISHING A NEW REGULATORY FRAMEWORK

The NRC requires that reactors be designed to withstand certain types of accidents—termed "design-basis accidents"—without releasing a large amount of radioactivity into the environment. However, as the Near-Term Task Force noted, the agency's treatment of more severe accidents that it presumes are less likely to occur—so-called "beyond-design-basis accidents"—is inconsistent. The current regulations require some level of protection against certain beyond-design-basis accidents but not against others. According to the task force, this inconsistency is a result of a "patchwork" of regulatory requirements and voluntary industry actions that had evolved over decades (Task Force 2011).

Recommendation 1 was meant to address this problem; it calls for the NRC to get rid of the inconsistent patchwork by establishing a "logical, systematic, and coherent regulatory framework for adequate protection that appropriately balances defense-in-depth and risk considerations" (Task Force 2011). As mentioned above, under the principle of defense-in-depth, nuclear reactors incorporate a variety of safety systems so that if one or more fail in the event of an accident, others will protect against the release of radiation.

UCS interprets the task force's call for a balancing of defense-in-depth and risk considerations as an implication that the NRC has relied too much on quantitative calculations of low risk (defined as probability times consequences) of beyond-design-basis accidents to justify reductions in defense-in-depth, even when those risk calculations have large uncertainties. Fukushima was a clear demonstration of the peril the public can face when regulators make safety decisions based on overconfidence in assessments of low risk.

As UCS discussed in its report on the first anniversary of the Fukushima nuclear accident, the task force designated Recommendation 1 as the first recommendation because it believed a systematic, effective regulatory framework was fundamental for addressing all the other recommendations on a consistent basis (Lochbaum and Lyman 2012). However, the NRC thought differently. Rather than holding up new safety requirements until it could revise and unify the overall regulatory framework, in August 2011 the commission decided to put Recommendation 1 on a track all its own and directed the staff to develop options for moving forward with the recommendation in 18 months (Bates 2011).

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The NRC staff then proceeded to pick apart Recommendation 1 until it was a mere shadow of its former self. In a paper to the Commission in December 2013 (missing the 18-month deadline by nearly a year), the staff had reduced the task force's sweeping recommendation into three limited "potential regulatory improvement activities" (Satorius 2013a).

The first "improvement activity" would establish a new category of "design-basis extension" events—meaning a special category of potential nuclear accidents in between design-basis and beyond-design-basis accidents. The proposal was intended to create a framework for strengthening the NRC's protection requirements for certain worrisome events that it currently classified as beyond design basis, such as a Fukushima-scale flood, without reclassifying them as design-basis events. The new category of design-basis extension events would be regulated less stringently than design-basis accidents but more stringently than beyond-design-basis accidents. However, the staff proposal did not include one of the key elements of Recommendation 1: a comprehensive review of beyond-design-basis accident scenarios at operating plants to see if they should be reclassified as design-basis extension events, which could lead to more stringent regulatory requirements and better protection.

The second "improvement activity" would develop guidance to better define the concept of defense-in-depth and direct how the NRC should use it in decision making. While better guidance for defining this subjective concept is badly needed, this particular proposal did not require the NRC to *strengthen* the use of defense-in-depth, as the task force had recommended.

The third activity would "clarify" the role of voluntary industry initiatives in the regulatory process—essentially, how the NRC should give credit to unenforceable industry promises to do the right thing. The staff proposal suggested merely revising the guidance for voluntary initiatives, but did not, however, include the simplest and safest alternative: eliminating credit for voluntary initiatives entirely.

The staff presented these proposals to the commission in December 2013 with a decided lack of enthusiasm, stating that it "believes that the public would continue to be adequately protected if the Commission took no action at this time on these recommendations" (Satorius 2013a, 4). Accordingly, in May 2014 the commission almost entirely rejected all three "improvement activities," relegating further consideration of such matters stemming from Recommendation 1 to a separate effort that was taking place outside of the NRC's post-Fukushima actions called the "Risk Management Regulatory Framework." Moreover, a majority of the five commissioners opined that there was nothing wrong with the NRC's current regulatory framework (NRC 2014b).

Finally, in December 2015, the staff presented the commission with a recommendation to essentially end consideration of a Risk Management Regulatory Framework, including the remnants of the task force's Recommendation 1 (McCree 2015). Such an action would mean a complete rejection of the Near-Term Task Force's number one priority for increasing the safety of commercial nuclear reactors in the United States. Indeed, some of the NRC staff did not concur with the December 2015 proposal, and the NRC's Office of General Counsel expressed concerns about it. The commission has not yet made a final decision, but the writing is on the wall.

> ***The NRC required most US reactors to be able to cope with a blackout for only four to eight hours; Fukushima Dai-ichi suffered without ac power for more than a week.***

THE STILL-EVOLVING STORY OF RECOMMENDATION 4: AVOIDING AN AMERICAN FUKUSHIMA

Recommendation 4 of the Near-Term Task Force was a direct response to the specific disaster that befell Fukushima Dai-ichi, at which five of the six reactors experienced a prolonged station blackout. In a station blackout, all ac power sources needed to cool the reactor cores and spent fuel pools are lost. While the NRC already required most US reactors to be able to cope with a station blackout for a short period of time—typically four to eight hours—Fukushima Dai-ichi suffered without ac power for more than a week, far longer than US reactors were prepared to endure. Therefore, Recommendation 4 read:

> *The Task Force recommends that the NRC strengthen station blackout mitigation capability at all operating and new reactors for design-basis and beyond-design-basis external events.*

Specifically, Recommendation 4.1 called for the NRC to initiate a rule making for a three-stage process, to require all operating and new reactor licensees to

> *(1) establish a minimum coping time of 8 hours for a loss of all AC power, (2) establish the equipment, procedures, and training necessary to implement an "extended loss of all ac" coping time of 72 hours for core and spent fuel pool cooling and for reactor coolant system and primary containment integrity as needed, and (3) preplan and prestage offsite resources to support uninterrupted core and spent fuel pool cooling, and reactor coolant system and containment integrity as needed, including the ability to deliver the equipment to the site in the time period allowed for extended coping, under conditions involving significant degradation of offsite transportation infrastructure associated with significant natural disasters.*

Since the task force recognized that such a rule making would take a long time to implement, Recommendation 4.2 called for the NRC to order reactor owners to strengthen the protection of the emergency equipment already on site for responding to a terrorist aircraft attack so that it could also survive and be usable during unexpectedly severe natural disasters.

The NRC, to its credit, decided not to wait for a rule making to require reactor owners to develop capabilities to withstand an extended station blackout along the lines of recommendation 4.1. Instead, in March 2012, it issued orders to amend reactor licenses, which were immediately effective (although owners were given more than four years to fully implement them), while continuing to pursue a change to the regulations in the longer term (Leeds and Johnson 2012).

However, the orders the NRC issued were far weaker in important respects than the requirements envisioned by the task force—due in part to significant pressure from the nuclear industry. This influence is clear from the language that the NRC included in the interim safety evaluation reports it issued after owners submitted their compliance plans: "Stakeholder input influenced the NRC staff to pursue a more performance-based approach [e.g., FLEX] to improve the safety of operating power reactors than envisioned in . . . Recommendation 4.2" (JLD 2012).

Performance-based regulation, as distinguished from "compliance-based" regulation, is focused on meeting high-level objectives without detailed requirements as to how they should be met. "Stakeholders" in this context clearly refers to the reactor owners and the industry writ large, as few, if any, public interest "stakeholders" such as UCS advocated a weakening of the task force recommendations.

a) Margins of time are insufficient

One significant weakening of the task force recommendations is related to its proposal for a three-phase strategy for coping with an extended station blackout. At Fukushima Dai-ichi, plant workers attempted to jury-rig equipment to provide cooling water to three overheating reactor cores in time to prevent them from melting, but were unsuccessful. In light of that inadequacy, the task force recommended that in the first phase "installed" plant systems—that is, the fixed equipment that is fully connected and operable under normal conditions—should be capable of providing adequate cooling for eight hours in the absence of all ac power. The task force judged that eight hours would provide sufficient time for workers to fully set up the second phase: on-site portable emergency equipment capable of providing adequate cooling for the next 72 hours. The second phase in turn would provide sufficient time for off-site resources to be delivered to the site, when the third phase would begin.

UCS commented in 2012 that the three-phase concept was a good one, but that the timelines were too short (Lyman and Lochbaum 2012). At Fukushima Dai-ichi, it took more than 17 hours before workers were able to begin continuous injection of emergency water into the Unit 1 reactor core, by which time the core had already substantially melted. Thus, UCS judged that the first stage should be required to provide cooling for 24 rather than eight hours. UCS also recommended that stage two should last for a week rather than 72 hours. The NRC already requires on-site emergency diesel generators to store a week's worth of fuel; one week therefore seems a good benchmark for the period of time that a nuclear site should be self-reliant.

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The availability of a sufficient margin of time is essential, given all the uncertainties in the timing of the many complex events unfolding during a natural-disaster-induced severe accident that must be addressed in a FLEX strategy. One example that only recently emerged is related to the time available for workers at certain pressurized water reactors to set up FLEX pumps to provide makeup cooling water. In a station blackout, seals on the primary coolant pumps that force water through the reactor core overheat and start to leak, causing an event called a "pump seal loss-of-coolant accident," which could cause a significant loss of primary coolant water in a matter of hours. The rate of leakage through the seals is a critical parameter in determining the time available for workers to supply makeup water to the primary coolant system. However, the pump seal leakage phenomenon is not well understood. In January 2016, the NRC disclosed at a public meeting that proprietary tests on a class of pump seals revealed higher-than-expected leakage rates due to a type of corrosion that had not been taken into account previously (NRC 2016a). Thus, plant owners using pressurized water reactors with that type of seal (including the two Indian Point reactors near New York City) may be overestimating the time actually available for setting up the Phase 2 pumps and may have to revise their FLEX plans. The NRC needs to require sufficient margin in the FLEX plans to accommodate emerging issues that—unlike the pump seal corrosion problem—may not be caught before the plans are approved and implemented.

However, the NRC has gone in a different direction. It has required owners to adopt the three-stage strategy, but did not specify required minimum lengths for the first two stages. Licensees can determine their own schedules (Leeds and Johnson 2012). Inspections of the FLEX plans on the NRC website reveal that some plants have coping times for Phase 1 far shorter than the eight hours that the Near-Term Task Force recommended (NRC 2015). For example, Perry in Ohio has a coping time of six hours; Watts Bar in Tennessee has a coping time of 5.8 hours; and Three Mile Island in Pennsylvania has a coping time of just four hours. Such short coping times reduce the time available for workers to set up the Stage 2 FLEX equipment before the reactor core becomes uncovered by cooling water.

To meet the Phase 3 requirement, an industry alliance was set up to establish two "National SAFER Response Centers" located in Memphis, Tennessee; and Phoenix, Arizona (SAFER stands for Strategic Alliance for FLEX Emergency Response). SAFER centers are warehouses that store five sets each of emergency safety equipment and other supplies, including portable electrical turbine generators and diesel-powered pumps. The company managing the SAFER centers claims that either center can supply emergency equipment to up to four nuclear sites in the country within 24 hours after a request for assistance, using trucks, airplanes, and helicopters if necessary (Mundy and Brush 2014). (One of the five sets of emergency equipment is assumed to be in maintenance at any time.) Therefore, the FLEX plans only have to show that the plants can be self-sufficient for 24 hours—an easier requirement for plant owners to meet than the 72-hour period recommended by the task force.

However, the SAFER centers do not have equipment and supplies for all contingencies. For instance, they do not stock pumps capable of injecting water at high flow rates at high pressure because such high-pressure equipment would be too heavy and hard to transport and deploy (ACRS 2014, 242). Since none of the individual plants are acquiring such pumps as emergency equipment, high-pressure capability won't be available at all if needed. Also, the company managing the SAFER centers has not committed to providing the diesel fuel to power the generators and pumps; individual reactors will be responsible for obtaining any extra fuel they may require from other sources—unless a major natural disaster has rendered roads impassable, in which case SAFER has said it will fly fuel in via helicopter (Davis 2014). However, SAFER is not acquiring its own helicopters, but will rely on leasing commercial helicopters or asking state or federal resources for help, which may not be immediately forthcoming given other urgent priorities during such a disaster. Thus, the SAFER centers alone will not be able to meet all the longer-term needs the plants may have during a disaster.

b) Accident scenarios are too limited and not realistic

A major flaw in the NRC's FLEX requirements for mitigating strategies is that the nominal accident that owners are required

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Pictured above is the National SAFER Response Center in Phoenix, Arizona, which warehouses that store emergency safety equipment for the nuclear industry. While the availability of safety equipment is a positive step, there is much about the SAFER centers that could be improved, including the type of equipment available and transport methods.

to mitigate is not nearly as severe as the actual Fukushima accident. At Fukushima, a massive earthquake generated a tsunami that caused flooding in excess of what the plant was designed to withstand—the so-called "design-basis" flood height. The tsunami not only disabled the ac emergency power sources for five of the six reactors on site, but also most of the dc power sources (the station batteries) as well as much of the electrical distribution system. In addition, the earthquake and flooding caused problems both on- and off-site, such as blocking roads with debris, which greatly increased the difficulty faced by workers and emergency responders trying to mitigate the accident.

> ***Plant owners have to provide the equipment only with "reasonable protection" from natural hazards, with few objective criteria specified for what "reasonable protection" means.***

The accident scenario that the NRC is requiring reactors to mitigate, however, captures only a subset of the difficulties that actually beset Fukushima. The initiating event is described as a generic "beyond-design-basis" external event that causes a loss of all ac power and a loss of the pumps that normally transfer heat from the plant to the "ultimate heat sink," (e.g., a nearby body of water), affecting all reactors on site simultaneously. However, even though the initial event is beyond the design basis of the plant, the scenario assumes that all equipment protected from design-basis natural hazards other than the emergency diesel generators (that is, the on-site ac power sources) will survive and be usable. In other words, the NRC's hypothetical accident scenario assumes that the plant would retain ready access to working station batteries, the electrical distribution system, and safety systems such as the Reactor Core Isolation Cooling turbine installed in most boiling water reactors, which plays a critical role in boiling water reactor Phase 1 coping strategies.

In a bizarre twist, certain plant owners used the assumption that dc resources would survive in their initial FLEX plans to provide themselves with some ac power as well by converting dc battery power to ac power through inverters. Thus, in their emergency planning, they were using ac power to mitigate an accident when no ac power was supposed to be available. Only recently did the NRC realize that it had to close this loophole by clarifying that plans that assumed the availability of ac power through inverters were not in compliance with the order, and therefore that owners were also required to include contingency measures when AC power through inverters would not be available (NRC 2016b).

In short, the NRC's initiating "beyond-design-basis" external event is a rather mysterious, artificial scenario that is beyond design basis only with respect to ac power sources and normal access to the ultimate heat sink, but is within design basis with respect to everything else. Thus, it is not straightforward to assess whether the FLEX strategies that owners are developing would be effective if there was a real-world beyond-design-basis external event that would potentially disable any equipment qualified only to the design basis.

In fact, because of this and other ambiguities, it isn't even straightforward to assess the adequacy of the FLEX programs to meet the requirements of the NRC's mitigating strategies order.

The NRC requires that the equipment needed to protect against design-basis accidents, called "safety-related" equipment, meet stringent and specific quality assurance criteria detailed in the NRC's regulations. However, equipment that is needed only to cope with beyond-design-basis accidents does not have to be safety-related—thus it is much less expensive because it can usually be bought right off the shelf. Needless to say, the nuclear industry greatly prefers buying cheaper, non-safety-related equipment whenever it can. But the equipment used in the FLEX strategies defies such classification, since it is required to protect against an extended station blackout, which falls between a design-basis and a beyond-design-basis event.

In the absence of a new regulatory framework along the lines of the Near-Term Task Force's Recommendation 1, there is no systematic approach to defining the required attributes of FLEX equipment, and the NRC and the industry have come up with an ad hoc solution. Owners are allowed to take credit for installed equipment that is not safety-related for use in the event of a particular beyond-design-basis natural disaster scenario if the equipment is characterized as "robust" with respect to that event. But according to the chairman of the Advisory Committee on Reactor Safeguards, the term "robust" hasn't been defined and "nobody seems to be able to tell what that means" (ACRS 2015, 50). And the requirements for the portable FLEX equipment that plants have been acquiring since Fukushima are also vague: plant owners have to provide the equipment only with "reasonable protection" from natural hazards, with few objective criteria specified for what "reasonable protection" means.

One example of where "reasonable protection" may not be so reasonable can be found in the list of acceptable measures for protecting FLEX equipment at reactors from flooding in the NRC-approved guidance document prepared by the Nuclear Energy Institute, the industry's trade association. The guidance allows FLEX equipment to be stored below the maximum design-basis flood level "if time is available and plant procedures/guidance address the needed actions to relocate the equipment" (NEI 2015b). In other words, the emergency equipment that is supposed to be readily available to keep the reactor from melting down in the event of a flood could itself be stored in a place vulnerable to flooding, provided that the owner has a plan to move the equipment in time to save it from the flood. Such an allowance is a complete retreat from the Near-Term Task Force report, which recommended that such equipment be stored five or six meters *above* the estimated maximum flood level or in watertight enclosures (Task Force 2011). One would think that in the event of a massive flood, the last thing that reactor workers would want to have to worry about was moving the FLEX equipment out of harm's way.

[***Emerging evidence indicates that most US nuclear plants could face natural hazards more severe than those they were originally built to withstand.***]

Unsurprisingly, the lack of specificity in defining the level of protection of emergency equipment has led to a wide variation in the "robustness" of the FLEX plans that the NRC has required each nuclear plant to prepare. Some plants, such as the Tennessee Valley Authority's Watts Bar station in Tennessee, have built hardened storage buildings for FLEX equipment that meet or in some cases exceed design-basis standards. Some other plants, such as Perry in Ohio, originally planned to build such a building but decided instead to store equipment in existing safety-related structures. And Three Mile Island Unit 1 in Pennsylvania has proposed to use non-safety-related structures—such as the turbine building—that have not been qualified to resist design-basis hazards such as earthquakes or floods, to store some FLEX equipment and to protect other safety systems and equipment that it credits in its FLEX plan. All nuclear plant FLEX plans can be found on the NRC's web site (NRC 2015).

It is far from clear that the FLEX plans will even protect against all design-basis natural disasters because the NRC has not required that the FLEX equipment be able to survive such disasters with high assurance. And the situation is even more confusing if beyond-design-basis accidents are considered, since the mitigating strategies order does not require the FLEX plans to consider all the damage that could be caused by such accidents (other than their ability to cause a loss of all ac power and normal access to the ultimate heat sink, as discussed earlier).

THE PERPLEXING STORY OF RECOMMENDATION 2: ADDRESSING REALISTIC SEISMIC AND FLOODING HAZARDS

We turn now to the Near-Term Task Force's Recommendation 2. Emerging evidence indicates that most US nuclear plants could face natural hazards more severe than those they were originally built to withstand (Lyman 2014). The NRC was aware of such a higher actual vulnerability well before Fukushima with regard to earthquakes and some types of flooding events, such as upstream dam breaches. More recently, the higher actual vulnerability of nuclear plants is becoming even more apparent as the result of the reevaluation of seismic and flooding hazards that the NRC ordered in response to the task force recommendation 2.1a. For instance, the NRC has required owners to consider such phenomena as "local intense precipitation" that may occur simultaneously with other sources of flooding and were not considered in the original design-basis flooding evaluations. For many reactors, the reevaluated maximum flood heights are greater than the design-basis flood levels they are prepared to endure, as was the case at Fukushima.

Despite the clearly higher vulnerability and risk, however, the NRC has so far refused to issue a simple requirement that nuclear plants must be able to withstand the *actual* natural hazards that they could face, as determined by the reevaluation process, rather than merely the out-of-date hazards that they were designed to withstand decades ago.

This situation has caused a great deal of confusion. The key issue is whether the design basis for a nuclear plant should be changed to incorporate the reevaluated hazards it may actually face. Such a change would have the most costly impact since it could require major upgrades to the safety-related equipment needed to protect against the hazards. Alternatively, the plant's design basis could remain the same and the reevaluated hazards would be considered "beyond design basis." Such reclassification is more than mere semantics: under this alternative approach, the plant's protections against the reevaluated hazards would not have to be as robust as they would be if the reevaluated hazards were used to establish a new design basis. The commercial nuclear industry heavily favors this less costly and burdensome approach.

In late 2014, the NRC staff sent the commission a proposal for addressing the reevaluated flooding hazards (Satorius 2014) along the lines of an approach being pushed by industry. For the vast majority of plants, the proposal required that only the FLEX equipment, but not the design-basis safety equipment, be upgraded to address the reevaluated flooding hazards. (In other words, if the reevaluated flood level was one meter higher than the design basis, the owner simply could raise the storage platform for the FLEX equipment by one meter to comply with the revised requirements.) Indeed, the proposal put all the emphasis on measures to mitigate flood damage to reactor safety equipment, rather than on measures to prevent the flood from damaging the reactor in the first place. This 2014 staff proposal led to significant dissension within the NRC staff, including an unusual objection filed by senior managers (Satorius 2014).

UCS called on the commission to reject the proposal (Lyman 2015a). A few weeks later, the commission voted down the most egregious part of the staff proposal in a 3–1 vote. The course of action that emerged from that vote, however, may in the end produce results that differ little from those had the commission approved the entire staff proposal. Under the revised plan, most plants will probably be able to satisfy the requirements to acknowledge higher risk by upgrading protection of their FLEX equipment alone. They may also have the option to meet them by making new voluntary "regulatory commitments" to address certain scenarios such as local intense precipitation. (For instance, they could promise to send workers to clean out clogged storm drains—not necessarily an easy task during a torrential rainstorm-of-the-century.) It is important to note, however, that such voluntary regulatory commitments are not requirements that the NRC can enforce.

Only a few plants may have to proceed with comprehensive flooding assessments. Even those plants may not be subject to new regulatory requirements if owners can show that the cancer risk to the public from meltdowns caused by superfloods would still be "acceptable." Such an outcome would be a prime example of how the industry has successfully used FLEX to deflect additional regulatory requirements.

THE DILEMMA OF RECOMMENDATION 5.1: TO RELEASE RADIATION . . . OR NOT TO RELEASE RADIATION?

As the reactor cores overheated in the initial stages of the accident at Fukushima Dai-ichi, plant personnel needed to reduce the reactor pressures in three of the reactors in order to inject emergency cooling water. Although the boiling water reactors were equipped with containment vents that could be used to reduce pressure, operators were unable to open the vents quickly from the control rooms because ac power was unavailable. As a result, workers could not get enough cooling water into the cores of three reactors to prevent them from melting down. Also, the overpressurized containments leaked both hydrogen and fission products, resulting in three hydrogen explosions and significant radiological releases into the environment.

There are 30 operating boiling water reactors in the United States of the same containment designs (called Mark I and Mark II) as the Fukushima Dai-ichi reactors. Thus, the task force recommended that owners of all such reactors install reliable hardened containment vents that could be opened even during a prolonged station blackout.

> ***The industry claimed that the quantitative benefits of the filters (that is, the number of cancer deaths that would be avoided) would not be worth their cost.***

The NRC's implementation of this recommendation came close to being a success story. Instead, as is the case with so many of the task force's other recommendations, the NRC's half-a-loaf approach leaves significant gaps in the safety framework that the task force had hoped to mend.

In 2012, the NRC ordered Mark I and Mark II owners to install reliable hardened containment vents that could be used in the early stages of a station blackout (that is, before core damage began). However, soon after the commission issued its order, the NRC staff realized that it was important to ensure that the vents remained operable even after the reactor core started to melt and temperature and pressure greatly increased. The staff then recommended that the NRC augment its requirement so that the hardened vents would be reliable not only during a station blackout but also be "severe accident capable." But that new recommendation raised another issue: if the vents were opened after the core had started to melt, that would release radioactivity into the environment. Thus, venting decisions would be more difficult for plant operators because the action could result in the deliberate release of radiation and extensive land contamination.

The clear solution would be to add filters to the vents, as countries such as Sweden and Switzerland did many years ago. Consequently, the NRC staff recommended that the commission also require filters.

In response, the industry cried foul. In a January 2013 letter, it claimed among other things that the quantitative benefits of the filters (that is, the number of cancer deaths that would be avoided) would not be worth their cost, and that the NRC staff inappropriately gave credit to defense-in-depth, a "qualitative" benefit. The industry argued that actions plant personnel could take using FLEX equipment would be as effective as or even more effective than filters for reducing radioactive releases during a core melt accident. (For example, the industry suggested using the FLEX pumps to flood the containments with water to trap radioactivity.) In a letter to the NRC, the industry argued that instead of requiring filters from the outset, the NRC should conduct a rule making that would evaluate and compare all "performance-based filtering strategies" (Pietrangelo 2013). However, all the alternatives to filters identified by the industry shared one major disadvantage: they depended on the ability of plant workers to carry out complex operations and the reliability of FLEX equipment to function in the midst of a core melt accident. In contrast, filters are simple passive systems requiring no staff action and hence would be more reliable.

Soon after the NRC received the letter, the commission voted to initiate a rule making along lines similar to the industry proposal comparing "performance-based filtering strategies." The staff was directed to assess the technical basis for the different alternatives within one year, and to complete the rule making within four years. This effort became known as the "containment protection and release reduction" rule making. ("Containment protection" refers to actions taken to prevent containment failure after a core melt accident; "release reduction" refers to actions taken to reduce the amount of radiation released through the vents while taking actions to protect containment.)

More than two years later, the NRC staff came back with their analysis of the technical basis for the rule making. Their conclusion: Not only were vent filters *not* justified—reversing the staff's own initial position—but also none of the alternatives for release reduction that the industry had proposed was justified either (Satorius 2015a). In other words, the staff advised the commission that a rule making for release reduction strategies was not even needed (although it still argued for a "containment protection" rule making that would codify the order on severe-accident-capable hardened vents).

In response, on August 19, 2015, the commission voted 3–1 not to proceed with *any* rule making (Vietti-Cook 2015b), thus depriving the public of any opportunity to provide comments on the need for filters or for filtering strategies. As a result, in the event of a severe accident, the NRC is leaving plant

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Pressure in the Fukushima Dai-ichi reactors led to three hydrogen explosions, releasing significant radiation into the surrounding environment. Here, on Februrary 24, 2015, contaminated soil is seen collected and bagged, awaiting transfer to the sites where interim storage facilities will be constructed.

operators with a horrible dilemma: to open the vents and deliberately release radioactivity into the environment, or to allow the reactor containment to overpressurize and potentially rupture, resulting in an even greater release of radiation.

THE LIFE AND DEATH OF RECOMMENDATION 8: COPING WITH SEVERE ACCIDENTS

The previous discussion makes clear that the NRC's regulatory framework is particularly weak when it comes to addressing severe accidents *after* the reactor core starts to melt. In Recommendation 8, the Near-Term Task Force highlighted the fact that the NRC does not require owners to develop plans to help operators cope with core melt accidents. Instead, such plans, called Severe Accident Management Guidelines (SAMGs), are maintained as voluntary industry initiatives. As voluntary initiatives, the plans are not subject to NRC enforcement, unlike the detailed Emergency Operating Procedures that plants maintain to deal with accidents *before* the core starts to melt.

[*The commission's bad decision leaves yet another gaping hole in the regulatory patchwork, leaving the public at risk in the event of an American Fukushima.*]

The 1979 Three Mile Island core meltdown, like Fukushima, revealed problems in the training of operators to deal with core damage accidents. In its aftermath, the NRC sought to require plant owners to develop procedures for managing severe accidents. Instead, the industry promised to develop SAMGs as a voluntary initiative. After Fukushima, the NRC inspected the voluntary guidelines and found many deficiencies—but it could not compel owners to fix them because they were voluntary.

To address this serious issue, the task force recommended that the NRC take three key steps: convert the SAMGs to regulatory requirements, integrate them with the existing Emergency Operating Procedures, and require better training on the integrated procedures. Such steps are long overdue. It makes no sense for the NRC to have regulatory oversight over the procedures that would apply *before* core damage occurs but to lose that oversight *after* core damage occurs. After all, it wasn't even clear to the operators at Fukushima when core damage began at the three affected reactors.

The NRC folded the task force's Recommendation 8 into the consolidated "mitigation of beyond-design-basis events" rule making that it initiated in response to the task force's Recommendation 4.1. Then it expanded the scope of that consolidated rule making to include most of the elements of the various task force recommendations related to mitigation of beyond-design-basis external events, ranging from hazard reevaluations to equipment to procedures to training to emergency response.

The NRC staff sent the commissioners a proposed draft rule in April 2015, which included a regulatory requirement for SAMGs (Satorius 2015b). However, the staff said that this proposed regulatory requirement for SAMGs would not meet the backfit rule *quantitative* standard of a "cost-justified substantial safety enhancement," referring to the overly rigid, flawed methodology described earlier (see page 3). Instead, as justification for the new regulatory requirement for severe accident guidelines, the staff cited the *qualitative* benefits of the provision for increasing defense-in-depth (see page 3).

The industry's Nuclear Energy Institute strongly opposed this proposal, asserting that the use of "qualitative" factors like defense-in-depth to impose backfits would set a "bad precedent" by giving the NRC staff leeway to justify "virtually any new requirement," (NEI 2015c), a position opposite to that of the Near-Term Task Force. Nevertheless, a majority of the NRC commissioners voted to support the industry position and to strike the regulatory requirement for SAMGs from the draft rule (Vietti-Cook 2015c).

The commissioners also rejected another reasonable provision that the NRC staff proposed but that the NEI industry group opposed: to require new reactors to have improved built-in features to protect against beyond-design-basis events and thereby reduce their reliance on manual mitigation actions (Vietti-Cook 2015c).

In lieu of regulatory requirements, the nuclear industry pledged to strengthen their voluntary commitment to maintain SAMGs. But apparently all such a pledge means is that the industry will promise more loudly to do the right thing. The guidelines will remain voluntary and the NRC will be able only to suggest, but not to compel, owners to fix them if they are defective. The commission's bad decision leaves yet another gaping hole in the regulatory patchwork, leaving the public at risk in the event of an American Fukushima.

AN UNREASONABLE RISK: HIGH-DENSITY SPENT FUEL STORAGE

US nuclear plants today store spent nuclear fuel in on-site pools at much higher densities than the pools of cooling water were originally designed to handle. This situation greatly increases the risk to the public in the event of an accident or terrorist attack that breaches the pool wall or floor and precipitates a rapid loss of cooling water. If the fuel is uncovered

Radioactive cooling water, continuously generated since the Fukushima disaster, is collected in tanks until a long-term storage solution is determined. The NRC's plans for dealing with an American Fukushima could result in a similar buildup of radioactive water.

by cooling water, it can catch fire and eventually melt, releasing a huge quantity of radioactivity into the air, primarily the highly radioactive and long-lived isotope cesium-137.

Many feared that a catastrophic spent fuel pool fire could occur at Fukushima. Concerns that the high density spent fuel pools at Units 3 and 4 could be losing coolant and overheating prompted panicked efforts to replenish the lost water. The US government quickly ran computer simulations to assess what would happen if the spent fuel in both pools caught fire. US officials were concerned about the safety of American Embassy personnel in Tokyo. Indeed, results of computational simulations indicated that, according to standards set by the US Environmental Protection Agency, evacuations might have been necessary as far away as Tokyo, about 120 miles (200 kilometers) from the site (Lyman 2015b).

Ultimately, workers at Fukushima were able to get sufficient cooling water into the two spent fuel pools in time to prevent fuel damage. However, their success is not cause for complacency. It is a risky proposition to count on heroic worker actions to avert such a disaster. The consequences of a spent fuel pool fire can be greatly lessened if a simple step is taken: namely, decreasing the density of the spent fuel in the pool by expeditiously transferring spent fuel from pools to safer on-site dry storage casks (Alvarez et al. 2003). But the NRC and the industry have long asserted that high density spent fuel pool storage is safe and expedited transfer is unnecessary (NEI 2014a).

After Fukushima, the task force issued a number of recommendations for improving spent fuel pool safety, but—for whatever reason—expedited transfer was not among them. Nonetheless, other NRC staff proposed that the NRC reconsider the safety of the current practice of high-density spent fuel storage, and the commissioners agreed (Satorius 2013b).

In 2013, the NRC staff produced an analysis that found that thinning out the density of the spent fuel in the cooling pools could significantly reduce the consequences to public health, property, and the economy from a spent fuel pool fire (Satorius 2013b). However, again using its faulty litmus test for safety significance, the staff claimed that it didn't matter by how great a factor the impacts would be reduced because the risk to the public was already so low in the first place. (Some staff filed non-concurrences from this conclusion, which were attached to the report, but their concerns were dismissed by senior management.) A majority of the NRC commissioners sided with the staff and voted to terminate further consideration of expedited spent fuel transfer—another bad decision heralded by the industry's NEI (NEI 2014b). In doing so, the NRC rejected a commonsense measure that would have both increased defense-in-depth and reduced the risk to the public should the spent fuel catch fire.

Conclusions and UCS Recommendations

- **The NRC urgently needs to revise its regulatory framework.** The NRC may have buried the Near-Term Task Force's highest priority Recommendation 1, but the pressing need for a new regulatory framework remains. The NRC should eliminate its faulty litmus test for safety significance, give more weight to defense-in-depth measures, and ensure generous safety margins to compensate for all the unknowns associated with severe accidents.
- **The NRC needs to develop a validation strategy for FLEX that will give clear results that the public can understand.** Many safety gaps have become apparent in the NRC's regulatory regime after Fukushima. In addressing them, the NRC and the nuclear industry are putting most of their eggs in the FLEX basket and not pursuing additional improvements that could increase defense-in-depth in the event that FLEX fails to deliver. This narrow strategy makes it essential that the FLEX program be highly reliable and capable of dealing with a wide range of potential natural disasters—including ones that exceed a nuclear plant's design basis. The industry asserts that FLEX will be able to handle virtually anything that comes its way, but because of the problems with FLEX detailed in this report, it is difficult for the public to have confidence in the program's performance. Under the current approach, the reactor owners validate their FLEX plans themselves with limited independent NRC oversight.

  To address this concern, UCS repeats our call for a rigorous NRC-run inspection program to validate FLEX strategies at every nuclear power plant in the United States. Such a validation program should be modeled after the "stress tests" that were conducted for nuclear plants in Europe and Japan after Fukushima and the performance-based inspections that the NRC employs for assessing security at nuclear plants. The NRC should choose a set of challenging severe accident scenarios and evaluate each plant's ability to respond to the accident from beginning to end. Evaluations should use a variety of different assessment tools. These tools should include computer modeling using the NRC's own computer codes (rather than the industry's), field equipment testing, and drills and exercises to model the performance of operators and other personnel. The assessments should validate timelines and should fully account for uncertainties. Only through the results of such a program can the NRC and the public obtain a clear understanding of how well US nuclear power plants will be able to protect against a Fukushima-scale accident.
- **The NRC needs to recognize that the FLEX program is not a panacea: other severe accident risks still need to be addressed.** If the NRC were to revise its regulatory framework along the lines of the task force's Recommendation 1, it is likely that the NRC would have reached different conclusions regarding many, if not all, of the safety recommendations that the NRC rejected—from filtered vents to expedited spent fuel transfer to expanded, 25-mile emergency planning zones. UCS remains hopeful that a future commission will see the merits of revising its regulatory framework and ultimately reverse the many bad decisions made over the five years since the devastating Fukushima nuclear accident.

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