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Lessons from Fukushima:
A New "Carrot & Stick" Approach to Nuclear Safety

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Introduction

While the Fukushima Daiichi reactor crisis was set in motion by nature, it was worsened by a history of anthropogenic technical defects. Some of these defects were the result of the well-documented cozy relationship between regulators and the Tokyo Electric Power Company (TEPCO), allowing improprieties to go unnoticed. Decades of collusion and falsification of data caused the public, in the midst of the crisis, to lose faith in both the government and TEPCO. This collusion, along with other unreported problems, biased the probabilistic risk assessments (PRA) used to estimate the risks in various design-basis events (both accidental and intentional). In particular, unknown and unreported problems led to underestimated risk and to false complacency.

A two-step process is needed to address unknown, unreported problems. First, a website should be established allowing anonymous declaration of past safety violations with a specified period of amnesty for facilities that are reported for violations. It should take into account the reported violations and then undertake inspections that are not facility-specific but that are based on reactor type. This will protect the individuals who have reported a problem, because a specific facility is not targeted. In addition, inspectors should be drawn from an international pool of experts in

order to minimize the possibility of collusion between the industry and domestic regulators. If a violation is found during inspections that was not indicated in the website database for that particular facility, serious legal action should be taken. This order to minimize the possibility of collusion between the industry and domestic regulators. If a violation is found during inspections that was not indicated in the website database for that particular facility, serious legal action should be taken. This will provide incentives for individuals to report problems during the amnesty period.

Setting the Stage: A History of Collusion

In a foundry in Kure City, hundreds of miles from Fukushima Prefecture and many decades before the devastating earthquake and tsunami, an engineer supervised the construction of the 20-meter-tall steel reactor pressure vessel for the yet-to-be-built Fukushima Daiichi reactor #4. After a painstaking manufacturing process that had lasted two and a half years and cost the company tens of millions of dollars, the final step was performed improperly and the reactor vessel was seriously damaged. Rather than disposing of the reactor vessel, in accordance with regulations, the engineer's superior requested that he "reshape the vessel so that no one would ever know that it had been damaged". The engineer was led to believe that revealing the failure would lead to the "bankruptcy" of the company. [1]

Further improprieties occurred when a nuclear inspector, working for General Electric at the Fukushima Daiichi plant, was asked by his employer to "edit out footage showing cracks in plant steam pipes in video being submitted to regulators".[2] He approached TEPCO with the information but claimed that there was no response until he went public in 2000. In 2002, there was a review of TEPCO's record by the National Industrial Safety Agency (NISA)-Japan's nuclear regulatory agency-investigating 29 instances of falsification of data in order to identify those responsible. The investigations were hampered by the "disappearance of related documents" and the apparent difficulties of employees to "recall events".[3] It became clear in the course of the investigation that occurrences such as these were not rare. Indeed, other electric power companies had admitted to falsification of data as well. [4] TEPCO's behavior in this instance is one example from years of collusion between the government, utility companies, and regulators that may have contributed signifi-

cantly to the Fukushima disaster and, one may surmise, the impotent response to it. Most importantly, since the employees who committed these acts were rewarded-through salary increases and awards-rather than reprimanded, it led to a *culture* where the interests of the public were often sacrificed in favor of company interests.

Furthermore, the need to extend the life of aging reactors, rather than replacing them with new reactors, led to significant pressure on the regulating agencies to neglect safety issues. One month before the March 11th Great Eastern Earthquake, governmental regulators approved a 10-year extension for the Fukushima Daiichi-1 reactor-the oldest of the Fukushima reactors-despite the numerous safety violations and cover-ups by the company. The regulators did flag specific areas that TEPCO must monitor, but two weeks after the approval of the life-extension, TEPCO admitted that it had "failed to inspect 33 pieces of equipment related to the cooling systems, including water pumps and diesel generators, at the power station's six reactors."[5] In addition, industry experts claim that the earthquake risk assessment for the Fukushima Daiichi reactor #1 was made in haste, and the conclusion that the reactor satisfied all required earthquake mitigation measures was reached prematurely. Given all the safety issues and the spotty record of TEPCO, how is it that the reactor actually received approval?

The makeup of the committee that overlooked the assessment is telling. Most of the committee members were from academia, which is heavily funded by the nuclear power industry,[6] and the committee members rarely challenge the agencies that have hired them. NISA is overseen by the Ministry of Economy, Trade and Industry, whose role is to encourage the development of nuclear energy, putting it at odds with the regulatory mandate of NISA. These lax regulatory conditions allowed Fukushima Daiichi reactor #1 to receive its extension of operations, setting the stage for its role in the nuclear crisis.

The lies and ambiguities by TEPCO continued after the tsunami struck, unnecessarily traumatizing the public and infuriating the Prime Minister, Nato Kan. After the hydrogen explosion in reactor #1, TEPCO officials gave an "opaque, and understated explanation", "a big sound and white smoke" were observed, and the "matter was under investigation".[7] TEPCO's subsequent behavior was punctuated with press statements and measurements lacking sufficient detail to interpret their meaning

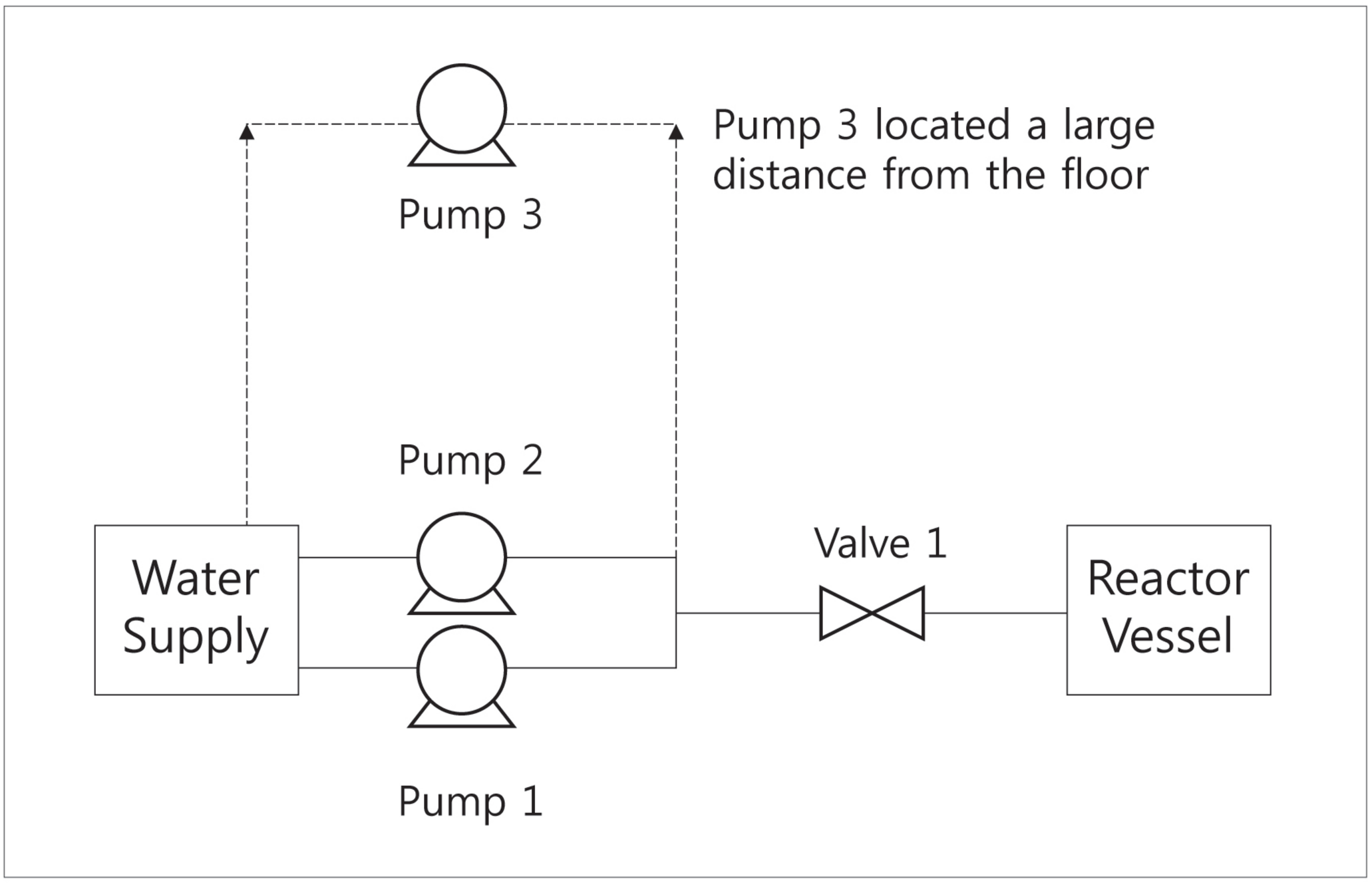
without significant scientific prowess.[8] When these press statements proved to be controversial, they were often retracted.[9] TEPCO carried out the measurements alone, excluding both independent experts and those within the government.[10] The government then based its decisions on TEPCO's measurements, inextricably linking government action (e.g., evacuation, decisions on radiation levels, etc.) to misleading statements, delays in delivering information, and incomplete measurements by the utility company.

The Implications of Collusion and a Lack of Transparency

A nuclear power plant is a complex system. Predicting the probability of the most likely range of failure possibilities falls under the rubric of PRA,[11] but these analyses are only as good as the input data used for the calculations. Ultimately, the value of the PRA depends on the data being complete and up-to-date. Therefore, if data is missing because of intentional shortcuts taken in the construction or design, leading to incomplete or fraudulent "as-built" information and unreported damage to components, the consequences can be very serious. Unreported problems pose an unknown risk, which can influence events in an unknown way. It is of great concern that it is not known what role unreported safety violations played in the conditions at the Fukushima Daiichi reactors following the tsunami and the partial meltdown. This gap in knowledge limits our understanding of their possible future implications.

Unfortunately, TEPCO did not incorporate the possibility of a tsunami exceeding six meters into its risk analysis and emergency preparedness plans and, as a consequence of the close relationship between the utility and the regulator, those decisions were left entirely to the utility.[12] The design-basis event sets the range of possibilities that spans the assessment of a PRA. Lowering the range of possibilities-such as excluding the probability of a tsunami with a height greater than six meters-not only leads to a false, lower perceived risk of an accident but also to a more serious "overconfidence of those designing and operating reactors".[13] Figure 1 illustrates how a PRA can be affected by incorrect input data.

Figure 1



A simplified reactor cooling schema to illustrate how a PRA could be influenced by input data. A probability of failure for each pump and valve are assigned based upon known component behavior. The two pumps are redundant, so if one fails, the other can be activated, decreasing the overall probability of failure of the cooling supply. However, if one of the pumps has an unreported flaw, the probability of failure could be underestimated and give false confidence in the system. In addition, the valve is a weak point in this simplified design. If it cannot open, no cooling water can reach the reactor. Furthermore, the PRA can only be as good as the design-basis event it is addressing. For example, the height of the pumps should be included in the analysis if flooding after an earthquake is considered to be a plausible design-basis event.

Consequences of Growing Mistrust

The lack of transparency on the part of the government and TEPCO downplaying the incident appear to have taken a toll on the goodwill of the international community. Initially, the international community was sympathetic towards the plight of TEPCO and the government. However, as unfortunate incidences of both deliber-

ate and unintentional releases of radioactive water into the sea occurred without notifying the international community, the sense was that the government and TEPCO should have been more open regarding the situation. Most importantly, a request for aid and advice should have been made early in the crisis. The consequences of the lack of transparency, failed attempts at mitigating the crisis, the lack of trust, and the disinterest in outside advice has evolved into a steady drumbeat of criticism from various sources. As the *Nihon Keizai Shimbun* stated, "The way TEPCO releases information utterly lacks any sense of crisis. Two months after the accident happened, it admitted a meltdown at reactor 1. They do not mention bad news until it is confirmed. Such an attitude has led to mistrust." [14]

There are lessons to be learned from Three Mile Island with regards to risk communication that were not heeded by TEPCO or the government.[15] One of the primary lessons drawn from Three Mile Island is that when communicating risks to the public it is important to first present the most serious aspects of the scenario. TEPCO repeatedly violated this lesson by presenting the situation optimistically and then changing the story as the situation worsened. As a consequence, TEPCO lost credibility and gave the public a sense that TEPCO, and by extension the government, had lost control of the situation. Other lessons from Three Mile Island were to not fear public interpretation of the information, to be as transparent as possible, and to explain the situation as simply as possible. The lesson is that technical experts are needed to act as middlemen between those managing the crisis and those explaining it to the public. The government's motivation for withholding information is to avoid panic, but studies have shown that panic is more likely to be generated when authorities are less than candid in an attempt to avert panic. Withholding information to avoid panic never seems to be the correct form of action because sooner or later the truth will come out, and when it does the government loses credibility.

A New Culture of Transparency for Sustainability of the Industry

All nations must come to terms with the possibility of improprieties at all levels in high-risk industries such as the nuclear, oil, gas, and chemical sectors. The present manifestation of safety in high-risk industries is not adequate, as the Fukushima disaster and the Deepwater Horizon oil disaster have illustrated. The loss of trust by

the public has not only resulted in a muted, often confused, emergency response by TEPCO and the government for the Fukushima disaster, but the loss of the public's trust has led to low acceptance of spent-nuclear-fuel management solutions as well. The public, especially those who live within the local jurisdictions in which the nuclear reactors, power plants, oil fields, and the like reside, must have a window into the activities of the industry. Building trust with the local population and the government is key for the industry to be sustainable. Therefore, a dialog should be initiated between members of the informed public, regulators, and the industry to look at practical solutions for increasing the acceptance of the industry. Public trust is like a currency; once lost it needs to be rebuilt before any new initiatives will be accepted.

Another way of building trust is to institute a stricter relationship between the regulator and the industry. In Japan, there is a history of a revolving door between industry personnel and governmental regulators. Of course, Japan is not alone in this, and this is not unexpected. High-risk industries tend to be very complicated, and regulators must understand as much about the industry as the engineers and technical experts from the industry itself. Therein lays the conundrum that all high-risk industries face-in a small pool of experts it is difficult to garner the expertise needed to regulate the industry without having worked in the industry. What is needed is an international team of experts who are not tied to the industry. Their specific duty would be to perform safety inspections of nuclear plants, just as nuclear facilities are inspected in order to determine compliance with the Nuclear Non-Proliferation Treaty (NPT). This is particularly important for newcomers to the club of nuclear nations where the industry and regulatory system are not well developed.

Suggestions to Address Unknown "As-Built" Problems: A "Carrot and Stick" Approach

To address the implications of *unknown* problems excluded from "as-built" drawings or hidden from regulators, an international whistleblower website should be established, allowing technical professionals (retired or current) from the industry to reveal safety problems without repercussions. After a specified amnesty period has elapsed, an independent, international team of experts would assess the database and design a set of inspections that addresses the problems specific to each reactor type.[16]

The details of the inspections must be carefully planned to ensure that the inspections are detailed enough to catch the worst offenses, yet general enough that the whistleblower is protected from consequences inflicted by past or present employers. It is known that similar kinds of safety violations occur across sites, therefore a database of common problems may catch unreported problems at other reactor sites as well. The consequences of violations must be swift. If a reactor is found to have a serious safety violation, as defined in a detailed legal document specific to reactor type, the reactor must be shut down without delay. Furthermore, legal action must be taken unless the problem was already revealed on the website for that particular facility. This "carrot and stick" approach will provide an incentive for companies and employees to reveal unreported problems during the amnesty period.

A question that remains unanswered is what fraction of reactors worldwide should be inspected via this special inspection regime. Random inspection, as proposed by International Atomic Energy Agency (IAEA) Director General Yukiya Amano,[17] is a possibility. However, it should be done often enough[18] to create real incentives for individuals to reveal problems during the amnesty period. Legal instruments to develop such an inspection regime will be difficult to attain. However, I believe a solution such as the one presented here is in the interest of all nations that have a developed nuclear power system, to all nuclear newcomers, and to all their neighbors.

Conclusion

It is encouraging that Japan has engaged its neighbors and the IAEA to discuss the first chapter of "lessons learned" from the Fukushima crisis. Undoubtedly, there will be many more chapters to write because the crisis is far from over. Japan still faces a difficult test. However, I hope that Japan learns from lessons of the past: it cannot sacrifice transparency in an effort to mitigate panic. Secrecy was born in the age when the military nuclear complex was intertwined with the civilian one. Fortunately, these two entities have been successfully decoupled. There is no longer any role for secrecy.

1. J. Clenfield, "Fukushima Engineer Says He Helped Cover Up Flaw at Dai-Ichi Reactor No. 4", *Bloomberg*, March 23, 2011. See: http://www.bloomberg.com/news/2011-03-23/fukushima-engineer-says-he-covered-up-flaw-at-shut-reactor.html.
2. Y. Kageyama, "Bungling, Cover-ups Define Japanese Nuclear Power", Boston Globe (AP), March 17, 2011.
3. "N-Watchdog Has Few Teeth, Digs Up Even Fewer Bones", *The Daily Yomiuri*, October 3, 2002. Loaded to Lexis-Nexis October 2, 2002.
4. "Japanese Revelations: A Japanese Government Demand That Utilities Come Clean About Past Safety Problems Has Resulted in Many Incidents Coming to Light", *Nuclear Engineering International*, loaded to Lexis-Nexis May 22, 2007. Also available at: business.highbeam.com/5474/article-1G1-165167805/japanese-revelations-japanese-government-demand-utilities.
5. H. Tabuchi, N. Onishi, and K. Belson, "Japan Extended Reactor's Life, Despite Warning", *New York Times*, March 21, 2011.
6. C. Digges, "Fukushima Daiichi's Reactor No 1 Was Granted 10-Year Operational Extension Despite Warnings of Its Frailties: 120,000 Imperiled by Radiation Poisoning", Bellona Foundation Website, March 3, 2011. Available online at: www.bellona.org/articles/articles_2011/fukushima_reactorext.
7. Tetsuya Endo (former Vice Chairman of the Atomic Energy Commission of Japan) has written commentary on the AJISS website (May 25, 2011) stating: "Because of preconceptions that the Japanese suppress 'inconvenient' information, that they are disturbingly opaque, and that they intentionally underestimate the impact of disasters, there was a propensity among overseas observers to filter information from Japan through these biases." I want to take issue with this statement, which I find to be unhelpful. However, it should be noted that this brief is entirely based on my perceptions.
8. See comment at: F. Dalnoki-Veress, "What Caused the High Cl-38 Radioactivity in Fukushima Daiichi Reactor #1", published on the Japan Focus website at http://www.japanfocus.org/-Ferenc-Dalnoki_Veress/3509.
9. TEPCO press release, "Improvement Plan for the Exact Nuclide Analysis at the Site of Fukushima Daiichi Nuclear Power Station under Instruction of NISA (Continued Report 1)", April 20, 2011. Available online at http://www.tepco.co.jp/en/press/corp-com/release/11042008-e.html.
10. This was despite the call from the domestic and foreign experts for independent measurements and analysis and offers of technical advice.
11. See the following website for how the PRA is used in the nuclear industry: www.nrc.gov/reading-rm/doc-collections/fact-sheets/probabilistic-risk-asses.html.
12. K. Krolicki, S. Disavino, and T. Fuse (Reuters), "Wave Predicted; Engineers Knew in 2007 Fukushima Plant Likely to Be Hit by Tsunami", *National Post*, April 2, 2011.
13. M. V. Ramana, "Beyond Our Imagination: Fukushima and the Problem of Assessing Risk", Bulletin of the Atomic Scientists, April 19, 2011. Available online at www.thebulletin.org/web-edition/features/beyond-our-imagination-fukushima-and-the-problem-of-assessing-risk.
14. C. Johnson, "Japanese Refuse to Bow to Authority; Furious Public Demands Truth About Meltdown", Washington Times, May 26, 2011.

15. P. Sandman, "Tell It Like It Is: Lessons from Three Mile Island", *IAEE Bulletin* 47, no. 2, 2006.
16. In the interest of protecting the whistleblower, the nature of the inspections are applied specific to the reactor type not specific to the site, which could lead to the identity of the individual being revealed.
17. S. Guy, "IAEA Nuclear Head Wants Random Inspections to Ensure Safety", UN Multimedia Radio, June 20, 2011. Available online at: www.unmultimedia.org/radio/english/2011/06/iaea-nuclear-head-wants-random-inspections-to-insure-safety/.
18. To optimize the frequency of random inspections in this case, we should learn from the inspection regime for nuclear arms reductions and from the IAEA inspection regime to support the NPT. For further discussion of optimizing the frequency of inspections for arms control, see Committee on International Security and Arms Control, National Research Council, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials: An Assessment of Methods and Capabilities*, National Academy of Sciences Report, 2005.

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