CHAPTER 7

REVIEW OF "CAN THE IAEA SAFEGUARD FUEL-CYCLE FACILITIES? THE HISTORICAL RECORD"

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In Chapter 6, "Can the IAEA Safeguard Fuel-Cycle Facilities? The Historical Record," Alan Kuperman, David Sokolow, and Edwin Lyman provide a reminder of safeguarding challenges at fuel-cycle facilities by citing material accountancy failures at such facilities in England, France, Japan, and Iran. The known technical challenges of meeting the International Atomic Energy Agency (IAEA) safeguards objective are discussed, but many of the examples and much of the surrounding discussion reveal that limitations to safeguarding efforts are not merely technical. There are human factors that likely contributed to the material accountancy failures over months or years, as well as IAEA credibility considerations that probably delayed disclosures of material diversions. In addition, the technical challenge is greater than discussed, as nuclear weapons with sizeable yields can likely be manufactured with less material than was assumed.

Two examples of missing material that Kuperman, Sokolow, and Lyman cite are the 22 tons of uranium and 160 kilograms (kg) of plutonium found missing in 2005 at the Thermal Oxide Reprocessing Plant (THORP) in England, and the 206-kg of plutonium that was reported missing in 2003 at the Tokai reprocessing plant in Japan. It is tempting to claim that the IAEA simply lacks the capabilities to measure such diversions, but the amount of material missing in both cases suggests that either the measurement errors are much higher than claimed in the 2001 IAEA Safeguards Glossary or that no measurement or inexcusably few measurements were made until other signals alerted inspectors or operators to large amounts of missing material. It should be mentioned here that even though the IAEA was not responsible for safeguarding the THORP, there is no reason to assume that the technical capabilities of those responsible at the Euratom Safeguards Agency should have differed markedly from those at the IAEA.

The 206-kg found missing at Tokai was about 3 percent of the total plutonium processed over the plant's lifetime since 1977. The expected error for such a measurement at a reprocessing facility is about 1 percent, according to the IAEA.[1] While the percent of total throughput of the uranium and plutonium found missing at the THORP is not listed, the size of the leaks were almost certainly higher than 3 percent of total plant throughput between the roughly 8 months from the start of the leak to its discovery.

It is necessary here to mention what the IAEA says must be measured to have the required confidence that a material diversion has occurred. Any scientific measurement must have some uncertainty, so there is always some chance that a quantity is actually higher or lower than the number measured. This amount higher or lower divided by the measured value is called the measurement error, and the IAEA expresses this as a percentage. The IAEA also wants to be about 90-95 percent confident that, in fact, a measured material diversion has occurred, and this translates into needing measurements to differ from the original amount by 3.3 multiplied by the measurement error to claim this level of confidence. This rule is derived from basic statistics to reflect the IAEA's stated 90-95 percent confidence standard.

Knowing this, 3.3 times the expected error of 1 percent is 3.3 percent, which translates into an amount that is a bit higher than the 206-kg missing at Tokai when considering the total plant throughput. It is tempting to think that 206-kg of plutonium missing from a reprocessing facility could go undetected if it is only 3 percent of the total; it would not signal the 90-95 percent confidence needed for the IAEA to claim a diversion. However, if measurements with uncertainties of 1 percent were taken on multiple occasions over the life of the plant and if material equal to 3 percent of the throughput was indeed missing, statistics indicates that diversions over 3.3 percent of the throughput would still occasionally be measured and signal the necessary confidence to claim a diversion. The Tokai example suggests that either the measurement errors were not accurate to 1 percent or that measurements were not taken frequently enough to discover that material was missing.

Another way of thinking about such an idea is to consider counting out 100 pennies to make one dollar. If the measurement error here is 1 percent, it is expected that the total number of pennies counted would be between 99 and 101 most of the time. Now if a child entered the room and took three of the pennies without your knowledge, recounting them after the child's theft would most often give counts between 96 and 98. A count of 96 reflects a diversion equal to 4 percent of 100 and would exceed the minimum 3.3 percent difference needed to be confident that there has been a diversion. The important fact is that measurements with 1 percent error would sometimes create the appearance that four of the pennies are missing when only three have been stolen. This applies analogously to the missing 3 percent of plutonium from Tokai; frequent measurements would occasionally result in diversions appearing to exceed 3.3 percent. The statistics of 1 percent measurements demand such outcomes.

The accountancy failure at Tokai is explained by human errors and not measurement limitations. Either the IAEA does not know what the standard errors are in measuring equipment used around the world, or it is claiming greater precision than the instruments have; an additional possibility is that users of the equipment do not know how to use it. It is also possible that no or very few measurements were taken, which adds another element into safeguarding efforts. Perhaps inspectors with high confidence in the operators at a particular plant or inspectors safeguarding plants located in countries deemed unlikely to divert material for use in a nuclear weapon will be more likely to skip material accountancy measurements. When so much material is found missing in the examples Kuperman, Sokolow, and Lyman cite from Tokai and THORP, the questions raised go beyond the IAEA's technical capabilities.

Additional human factors need to be considered in discussions about the IAEA's credibility related to false alarms or claims of a diversion when, in fact, none has occurred. The IAEA aims to keep this below 5 percent, which statistical calculations show is the previously mentioned standard of at least 3.3 multiplied by the measurement error. This consideration can be understood in the following way: If 20 measurements are made that meet the IAEA's threshold for diversion, one of those measurements is statistically likely to be false.

It is important to be aware of the problems the IAEA might encounter upon falsely claiming that a diversion has occurred. The agency is only able to do its work if it receives cooperation from states and if it made a claim that turned out to be false, cooperation in implementing safeguards might disappear. A state could say the IAEA was pressured by the United States so it could claim it has nuclear weapons ambitions and is interested in rallying international opinion for economic sanctions or military action against it. Future collaborative efforts between states and the IAEA could be in jeopardy, and the loss in trust from such an event could be a major setback.

Even though the chance of false alarms is a quantitatively expressed measurement, the political factors in bringing a claim of material diversion are highly relevant and add a challenging layer to safeguarding efforts. Any measure of material diversion with the required confidence will likely be repeatedly examined before a claim is brought against a state; the understandable risks of being wrong would likely demand it. This process will take time and, in the real event that material has been diverted, provide a state with additional time to build a nuclear weapon. A state could also say that the IAEA is mistaken or that it needs to check its own records to resolve the accounting discrepancy. This could delay any punitive action and buy yet more time.

Such factors could also lead states to conclude that diversions into nuclear weapons should be attempted with well-prepared excuses in preparation for the IAEA raising alarms. A state might calculate that it could divert material only to wait and see if the IAEA detects it. If the IAEA sounds an alarm, a state could attempt to creatively smooth over the discrepancy and resolve it without fear of consequence. If the IAEA misses the diversion, then a state could proceed through the remaining clandestine steps to a bomb with greater confidence. That states considering the manufacturing of nuclear weapons will almost certainly give more thought into how to build them without detection than those trying to stop them raises the possibility that the IAEA is never likely to detect a material diversion it could confidently say was made for inclusion in a nuclear weapon. At least it seems unlikely, given the IAEA's constraints.

It is not unreasonable to ask whether the human factors in safeguarding efforts will always remain considerable limitations, no matter what improvements are made in measurement precision. The upgrades that Kuperman, Sokolow, and Lyman propose for safeguards would indeed be improvements, but they are all aimed at improving measurement error. Although vitally important, one must wonder whether any claimed improvements are indeed real and whether, if real, they would significantly improve efforts at meeting the IAEA's safeguards objective, which is:

> the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection.[2]

Might timely detection always be impossible when considering a state determined to build a nuclear weapon as quickly as possible upon diversion from a fuel-cycle facility? Improved measurement accuracy might provide greater confidence that, indeed, some material is missing, but what are the limitations of such improvements? How much increased confidence is possible as a result? Should the human factors already discussed weigh more heavily—or perhaps dominantly—in considerations of safeguarding limitations?

The one quantitative definition that Kuperman, Sokolow, and Lyman did not discuss in enough detail was the definition of a significant quantity (SQ). The IAEA defines a significant quantity as "the approximate amount of nuclear material for which the possibility of manufacturing a nuclear explosive device cannot be excluded."[3] Kuperman, Sokolow, and Lyman use the IAEA's definition of 8-kg for a significant quantity of plutonium-239 (Pu-239), but this amount has been challenged as too large, given the information now publicly available about nuclear weapons design. This is an important oversight, as the effectiveness of a safeguards system depends on whether a diverted SQ can be detected, and the need to detect smaller quantities would place increased demands on safeguarding efforts. Most importantly, however, the IAEA's definitions in this regard are extraordinarily irresponsible if sizeable nuclear weapons can be built with smaller amounts of material than what the IAEA has defined as its concern. The question of whether it is possible to detect a diversion with the required confidence and raise a claim that the requisite material for a nuclear weapon is missing must meet a whole new standard. Such an error raises questions about how the IAEA views its role if it accepts the shortcomings of its own definitions.

The U.S. Department of Energy (DOE) has confirmed that 4-kg is sufficient for building a nuclear device in the case of Pu-239 and uranium-233 (U-233),[4] and others have suggested that only 1-kg can be used for these isotopes.[5] This shows that 8-kg should be considered too large. The relevant assumption here is that materials for neutron reflecting and compression techniques are accessible by non-nuclear weapons states for making sizeable bombs with less material.

Leaving aside the omission about significant quantities, Kuperman, Sokolow, and Lyman do lay out the technical challenges in safeguarding these facilities, challenges that guarantee many kinds of diversions by determined proliferators would go undetected. Nowhere, however, might the technical capabilities of the IAEA prove less relevant than in the case of Iran and the current state of its nuclear program. The danger Iran presents is the advancement of its program under IAEA safeguards, thereby shortening the time needed for acquiring the requisite material for a nuclear weapon. With recent hopes for diplomatic progress in curtailing the program notwithstanding, Iran's program reveals a limitation to safeguards no matter the current capabilities or prospective improvements in them. Although analysts differ slightly in how much time Iran might need to acquire the material for one bomb (usually assumed to be 20- to 25-kg of U-235), continued enrichment of uranium to 3.5 percent and acquisition of additional centrifuge capacity could very shortly, if it has not already, make the time needed for assembly of a nuclear weapon so short that detection of a material diversion for bomb assembly could not prevent one from being built. This judgment holds important implications for the future of nuclear proliferation, as states learn they are able to come so close under IAEA safeguards to a nuclear weapon that the world has no choice but to act as if they have one.

This raises the question of whether it will become increasingly futile to focus on improving the ability to detect a material diversion from a fuel-cycle facility. The lower political and economic costs of pursuing nuclear weapons under the guise of a safeguarded civilian nuclear power program, where a state can be assisted in the effort from international suppliers or may be increasingly able to build the needed fuel-cycle technologies indigenously, suggest that the United States needs to define what it considers unacceptable along the spectrum of nuclear capability with regard to the fuel cycle. To draw the line at proscribing an Iranian nuclear weapon—as the United States may argue—would prove unmanageable. Once the requisite amount of material is produced, constructing and equipping a warhead is a relatively short and technologically straightforward process, almost certainly impossible to detect in a timely fashion. Not until a more effectual standard—and the credibility to enforce it—has emerged should improvement in the IAEA's abilities be regarded as helpful in preventing the manufacture of a bomb.

Kuperman, Sokolow, and Lyman have certainly provided a message that the nonproliferation community needs to hear more often, that the current technical capabilities of the IAEA make safeguarding fuel-cycle facilities very challenging. The bad news is that human factors and their interaction with these capabilities, as well as the inability of the United States to define what is unacceptable nuclear capability, make success in safeguarding less likely than even they suggest.

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1. *IAEA Safeguards Glossary*, 2001 Ed., Vienna, Austria: International Atomic Energy Agency (IAEA), p. 53, available from *www-pub.iaea.org/MTCD/publications/PDF/nvs-3-cd/PDF/NVS3_scr.pdf*.

2. The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, IAEA Information Circular (INFCIRC) 153, Vienna, Austria: IAEA, June 1972, available from *www.iaea.org/Publications/Documents/Infcircs/Others/infcirc153.pdf*.

3. *IAEA Safeguards Glossary*, p. 23.

4. Classification Bulletin WNP-86, Washington, DC: U.S. Department of Energy, February 8, 1994, states, "Hypothetically, a mass of 4 kilograms of Plutonium or Uranium-233 is sufficient for one nuclear device." (Although this sentence is unclassified, the full text of the bulletin is classified.) No such statement has been issued with respect to Uranium-235.

5. Thomas B. Cochran and Christopher E. Paine, *The Amount of Plutonium and Highly Enriched Uranium Needed for Pure Fission Nuclear Weapons*, Washington, DC: Natural Resources Defense Council, revised April 13, 1995.