VIEWPOINT: ADDRESSING THE IMPLICATIONS OF THE JAPANESE FUEL CYCLE THROUGH TRANSPARENCY

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The Japanese civil nuclear fuel cycle has a comprehensive scope and ambitious goals. From uranium enrichment and fuel fabrication facilities to nuclear power plants, reprocessing facilities, and fast breeder reactors, Japan has developed at no small cost a nuclear program whose sophistication equals that of any in the world and, indeed, surpasses most.[2] As with any nuclear endeavor, this program poses risks and challenges in many areas, most importantly in matters of security.

Of particular concern are Japan's accumulating stocks of civil plutonium, both in spent fuel and in separated form.[3] Although it had been hoped that it would be possible to *prevent* the accumulation of large stocks by Japan, these hopes now appear to be increasingly unrealistic. The focus of current attention is shifting towards the development of technical and institutional methods to *manage* the large-scale civil use of plutonium.

Japan occupies a central role in this debate because it is currently the only non-weapon state party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) that has large-scale reprocessing facilities in operation and under construction, and because it will be the first state to face the question of applying adequate international safeguards to large commercial bulk-handling facilities. The United States is also a critical actor because of its Asian security and economic interests, its long-standing security alliance with Japan, and its leading role in support of nonproliferation and international safeguards. How Japan, the International Atomic Energy Agency (IAEA), the United States, and the international community address these emerging issues could critically affect future perceptions of safeguards and their security value, as well as the prospects for the civil use of plutonium.

One concept that may be promising in this regard is that of *transparency*. The purpose of this essay is to outline how this idea may be applied to the Japanese case. To this end, it begins with a brief sketch of Japan's civil nuclear program and policies, then discusses the safeguards issues that these policies raise, and describes how enhanced transparency could contribute to addressing these issues. It next examines some transparency options that may be applicable in the near future to the Japanese fuel cycle, and considers the main criteria by which these options will be judged. It then briefly describes two recent and well-publicized nuclear incidents—a sodium leak at the Monju reactor and a fire at the Tokai Reprocessing Plant—that may prove to have a strong impact on Japanese attitudes towards transparency and concludes by offering some reflections on the potential benefits and limitations of transparency in the nuclear sphere.

JAPAN'S NUCLEAR PROGRAM AND POLICIES

To understand the complications of the safeguards endeavor in Japan, it is useful to analyze briefly the main elements of Japan's nuclear capabilities and policies. Among Japan's nuclear facilities are the following:

- two uranium enrichment plants;
- five low-enriched uranium (LEU) fuel fabrication plants;
- 46 light water reactor power plants (LWRs);
- a reprocessing plant at Tokai with an annual throughput of 90 metric tons (MT) uranium;
- a reprocessing plant under construction at Rokkasho that will have an annual throughput of 800 MT uranium;
- an operating plutonium fuel production facility (PFPF) at Tokai; and

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• the Monju and Joyo fast breeder reactors (FBRs).[4]

In line with Japan's basic policy of plutonium recycling, the spent fuel discharged from the LWR power plants is scheduled to be reprocessed domestically at Tokai and eventually at Rokkasho, as well as at European reprocessing plants (mainly the THORP plant in the United Kingdom and the La Hague facility in France). Once reprocessed, it will be converted mostly into mixed-oxide (MOX) fuel for use in both light water and advanced reactors.

Japan's heavy investment in nuclear power has led to the accumulation of large quantities of plutonium in various forms. One analysis estimates that by the end of 1990, Japanese power reactors had discharged just under 60 MT of plutonium in the form of spent fuel.[5] It concludes that this figure will have risen to approximately 140 MT by the year 2000, of which some 3.6 MT of plutonium will have been separated at the Tokai plant alone.[6] Many more tons of plutonium are contracted to be separated in France and the United Kingdom. Even allowing for large uncertainties in these numbers, it is clear that Japan possesses large and growing stocks of plutonium, both separated and in spent fuel, at home and abroad. These stocks will far exceed the quantity of plutonium that can be burned in the foreseeable future.

Japan has recently released its holdings of separated plutonium both in Japan and abroad.[7] These figures are reproduced in Figure I. Plutonium holdings of this magnitude are unprecedented for a non-weapon state and demonstrate that the question of preventing the accumulation of plutonium stockpiles by Japan is now effectively moot.

Figure I: Locations and Quantities of Japanese Separated Plutonium (Pu)

Location of separated Pu	Quantity (kg)
Tokai RP	836
Tokai MOX	3,018
Joyo, Fugen, R&D	498
United Kingdom	1,412
France	7,308
Total	**13,072**

Parallel to the development of these reprocessing plans has been the growth of an increasingly "strong connection…between European and Japanese fuel-cycle policies."[8] As an illustration, over 40 percent of the fuel contracted for reprocessing at THORP between 1992 and 2002 is Japanese-owned, as is some 20 percent of the fuel contracted at La Hague from 1990 to 2000.[9] Connections of this magnitude, and the financial obligations they entail, have effectively cemented Western European and Japanese civil nuclear policies together for the near future. Reprocessing of Japanese civil spent nuclear fuel is likely to continue at these facilities well into the next century.

To address the safeguards and security issues arising from Japan's nuclear program, it is important to understand clearly the bases of Japan's nuclear policies. While the short-term economics of reprocessing are currently dubious, Japanese planners have a far longer planning horizon than most. It is not uncommon for them to plan decades into the future, and they may view short-term economic losses as justifying long-term gains.[10]

Furthermore, Japan's nuclear energy decisions are not based on economics alone. Indeed, they may not even be based primarily on economic considerations. Energy independence and national security interests may have an equal or greater weight in Japanese calculations. Bereft of indigenous energy resources—including uranium—and precariously dependent on foreign oil supplies, Tokyo almost certainly views the establishment of a self-supporting and independent closed nuclear fuel cycle as a strategic goal that is in its deepest national security interests.[11] The trends discussed above—continued research and development on advanced nuclear power concepts and increasing stocks of plutonium—are consistent with a long-term view of the benefits of nuclear power for Japan.

Japan's deeply-held views on nuclear energy conflict with the nonproliferation goals of the United States. U.S. policymakers have known this for some time, and, accordingly, U.S. policy has often taken the shape of a compromise between the U.S. interest in nonproliferation, Japan's interest in energy independence, and their mutual interest in a strong and healthy alliance.

What is new, however, is that U.S. civil nuclear policies currently have a decreasing effect on Japanese nuclear policies. The United States has declined from its once-dominant position in the worldwide nuclear industry. The U.S. monopoly on civil uranium enrichment services ended long ago. The United States, alone among

the weapon states, has no plans to reprocess civil spent fuel, and is no longer a leader in research and development of advanced nuclear energy concepts. Furthermore, since the 1970s, it has become clear that the unilateral U.S. deferral of reprocessing of civil spent fuel has not been reciprocated in other advanced nuclear nations, where different industrial, energy, and national security interests have taken precedence.

In sum, then, it appears increasingly unrealistic to believe that it will be possible to prevent the development and implementation of plutonium recycling by Japan. If this is accepted, the analytical and policy focus must then shift to seeking out ways of *managing* civil plutonium use and examining the issues that such activities raise.

NEW SAFEGUARDS ISSUES

As Japan's development of bulk-handling plutonium facilities proceeds and its stocks of separated plutonium increase, international safeguards will face the increasingly difficult task of providing assurance to the international community that civil nuclear material is not being diverted to military or other unknown purposes.

Some of the emerging difficulties are illustrated by the Rokkasho reprocessing plant. With an annual throughput of about 8,000 kg plutonium,[12] Rokkasho rivals the reprocessing plants heretofore found only in the weapon states. For comparison, the UP3 plant at La Hague (to which Rokkasho is related) also processes about 8,000 kg plutonium per year, while THORP has a throughput of some 7,000 kg of plutonium per year. Due to their nature, however, bulk-handling facilities, such as enrichment or reprocessing plants, impose inherent limits on the accuracy with which the material flows within them can be measured. As the throughputs of these plants increase, these errors unavoidably involve greater amounts of material.[13] Recent research indicates that meeting the IAEA's detection goals in large-scale bulk-handling facilities is likely to be a challenge, a conclusion supported by recent safeguards studies at the PUREX plant at Hanford.[14]

The difficulties posed by such throughputs are inherent in the nature of NPT safeguards (which is laid out in IAEA document INFCIRC/153 and its associated revisions). This document—the result of lengthy negotiations after the conclusion of the NPT—sets the goal in paragraph 28 of "the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons…or for purposes unknown."[15] It further defines the two basic measures by which the IAEA attempts to achieve this goal. Paragraph 29 specifies that "material accountancy [is the] safeguards measure of fundamental importance, with containment and surveillance [C/S] as important complementary measures."[16]

The notion of a significant quantity (SQ) of nuclear material mentioned in paragraph 28 needs explanation. The IAEA defines a SQ to be "the approximate quantity of nuclear material in respect of which, taking into account any conversion process involved, the possibility of manufacturing a nuclear explosive device cannot be excluded."[17] Numerically, a SQ of plutonium (Pu^{238} < 80 percent) or U^{233} is defined to be 8 kg, while a significant quantity of highly-enriched uranium (HEU, U^{235} >= 20 percent) is defined to be 25 kg.[18] For a reprocessing plant with the plutonium throughput of the scale of those mentioned above (i.e., on the order of tons of plutonium each year), meeting the above goals with traditional material accountancy techniques alone would require measurement errors substantially less than one percent of the annual throughput.[19] This goal is quite difficult to attain, and, as a result, the use of enhanced C/S techniques to complement materials accountancy in bulk-handling facilities is also under examination by the international safeguards community. Similar considerations apply to the problems that arise in safeguarding large stocks of separated and/or unseparated plutonium.

Due to these and other difficulties, there has recently been renewed international interest in other ways of ensuring nondiversion in sophisticated nuclear fuel cycles.[20] The thrust of these efforts can be seen most clearly in the extended IAEA review of NPT safeguards known as "Programme 93+2."

This program, though implemented in response to the discoveries in Iraq after the Gulf War,[21] has developed into a thorough review of IAEA safeguards practices, and could have a significant effect on the manner in which safeguards are implemented across the board. Among its many recommendations for strengthening international safeguards are:

- increased information access by the IAEA, including timely provision of design information on the construction and modification of nuclear facilities;
- increased transparency with respect to transfers of nuclear material;

- expanded declarations of states' nuclear programs;
- the use of environmental sampling;
- improved information analysis capabilities; and
- greater use of advanced technologies to collect, transmit, and analyze safeguards data. [22]

Although Japan is a member in good standing of the NPT and the international nonproliferation regime, it can be argued that Japan has a certain responsibility to the international community to go beyond the letter of its safeguards obligations. Its ambitious nuclear policies have simultaneously pushed the limits of current safeguards technologies and have aroused fears and concerns among its neighbors and other states, some of which harbor intense historical grievances against Japan. Japan has a rigorous and modern material accountancy system in place (and under active development) and has been an international leader in safeguards research and development, but the scope of its nuclear program suggests that additional measures would be valuable.

ADDRESSING THESE ISSUES THROUGH TRANSPARENCY

Many of the methods that might be employed in Japan come under the general rubric of *transparency*. As used here, transparency refers to the unilateral implementation by Japan of additional measures—complementary to the full-scope safeguards already in place at Japanese nuclear facilities—aimed at selectively releasing information regarding Japan's nuclear activities to either the IAEA, national governments, or the public at large. The purpose of such measures would be to aid existing safeguards in fulfilling their fundamental security objective: to assure and demonstrate to the international community that civil nuclear facilities and materials are not being used for undeclared purposes.

It should be emphasized that the transparency measures to be discussed below are not a replacement for traditional safeguards. They are not aimed at the quantitative goal of helping to complete a materials balance more precisely. Rather, they are intended to provide additional information (both qualitative and quantitative) that can then be compared with data obtained through safeguards and other means to help form a more complete picture of Japan's nuclear activities. For most of the measures described below, it is envisioned that the information released by transparency methods would be shared with the general public, but it is also possible that some information too sensitive for general release could be selectively distributed to interested governments or international organizations. In either case, increased transparency would be aimed at achieving the fundamental security objective of safeguards by a different route.

Every technique for managing the security implications of proliferation has some drawbacks, and transparency is no exception. It is possible that additional transparency measures could be construed as legitimizing plans for reprocessing. Indeed, if Japan, for example, were able to demonstrate that it could use plutonium to provide power in a proliferation-resistant, economic, and environmentally safe manner, global views of nuclear power could improve.

Increased knowledge, however, can cut both ways. If increased transparency regarding the Japanese fuel cycle were to raise questions about the amounts of fissile materials involved, or the possible environmental impact of the Japanese nuclear program, perceptions of nuclear energy in general, and of the Japanese program in particular, could be dimmed significantly. In this as in every other case, the possible costs of transparency in legitimizing the civilian use of plutonium need to be balanced against the potential security benefits.

Although it is probable that Japan seeks such legitimization, the arguments given above suggest that it will proceed with its plans regardless.[23] The security issues thus raised will require policy answers. Maintaining and improving the quality of international safeguards and transparency are fundamental policy responses, but ones that will involve carefully considered tradeoffs.

POTENTIAL TRANSPARENCY OPTIONS

The key to transparency in the case of Japan (or in any other case) is information. Confidence that actual operations are in line with declarations is gained when a wide variety of data is gathered in different ways and under different conditions, and when these data can be cross-checked for consistency with each other and with declarations.

This section lists some specific transparency options that go beyond traditional safeguards methodologies and that may have application to the Japanese fuel cycle. Because of the difficulties that materials accountancy will encounter in safeguarding bulk-handling facilities such as Rokkasho, particular attention will be given to options that provide information complementary to that gained by materials accountancy.[24]

Some of the options may be found to be either impracticable or undesirable for various reasons. If these options are considered seriously by Japan, the United States, and the international community, several criteria will have to be used to judge the various alternatives on the basis of political and economic costs and benefits. The types of criteria that are likely to be employed either implicitly or explicitly will be discussed below.

Unilateral Declarations

The simplest (and perhaps most likely) transparency measures involve unilateral public declarations by Japan about its nuclear activities and materials. Simple though this idea seems, it is not mandated by either the NPT or IAEA safeguards agreements, nor have states customarily given out such information.

Japan has already taken a first step in this direction by releasing the quantities and locations of separated plutonium it currently holds. This first step could be easily supplemented by regularly updating this information on its material holdings and disseminating it widely.

One can envision broader declarations along these lines. In addition to material holdings, the Japanese government and its nuclear contractors could publicly declare:

- facility operating schedules, including schedules for dissolver batches at reprocessing facilities and detailed irradiation histories at reactors;
- data on dissolver batches, including the amount, burnup, and cooling time of the spent fuel being dissolved; and
- data related to the infrastructure of reprocessing or other bulk-handling facilities, e.g., electricity and water usage.

In principle, all of this information could be published on the Internet on a facility-by-facility basis. If such data were available, they could be checked fairly easily for internal consistency. Depending on the exact form of the information released, there is a possibility that it may be misused by parties that might aim to disrupt facility operations in some way. Judgments must be made in each individual case as to the possible dangers of such an event, however, as long as care is taken to ensure that information on the transport schedules of materials between different facilities is kept confidential, it is unlikely that releasing the pieces of information listed above could increase the vulnerability of peaceful nuclear facilities to external action in any significant way.

As will be discussed below, legitimate proprietary or security concerns could arise in regard to the dissemination of this information. However, the degree of detail in the released data could be suitably chosen to address most of these considerations.

Independent Observations or Measurements

In addition to unilateral declarations, Japan could allow independent observations or measurements at its nuclear facilities. As part of the normal course of safeguards implementation, Japan does allow inspections by the IAEA at "strategic points" within its nuclear facilities. Moreover, as part of the Programme 93+2 initiative, the IAEA is seeking expanded physical access to safeguarded facilities.[25] But how such expanded access will actually work at Rokkasho remains unclear, as discussions between Japan and the IAEA regarding Rokkasho's "Facility Attachment"—the specific blueprint for how the IAEA will implement safeguards at Rokkasho—are ongoing.[26]

There are additional transparency options that could complement these initiatives. For example, Japan could allow air samples from the stack at the Rokkasho facility to be taken during fuel decladding and dissolution and then analyzed for their noble gas isotopics. Such samples would be fairly unintrusive, and analysis of these data could yield information on the burnup of the fuel being reprocessed.[27] Under Part I of Programme 93+2, the IAEA has some authority under current safeguards agreements to take environmental samples, but, once again, the details of how and what type of samples would be taken at Rokkasho, and what methods of analysis would be deemed acceptable, remain to be worked out.[28]

Ranging somewhat further afield, Japan could permit independent observations or measurements aimed at corroborating some of the information released in the form of unilateral declarations. Japan could provide for closed-circuit television monitoring of stored materials in various forms (e.g., reactor fuel in cooling ponds or separated plutonium in dry storage.) These images could be made available in appropriate forums, which would depend on a careful consideration of any potential risks involved.

Japan already has a nondestructive assay monitoring system to monitor material entering and leaving PFPF, as well as remote fuel flow monitors at the Monju and

Joyo FBRs that continuously determine the amounts of material moving into and out of the facility.[29] These systems are currently used to aid the IAEA in its task of accounting for nuclear materials, but similar remote radiation monitoring technologies could easily be used to collect data to check declared fuel-loading schedules at reactors, to monitor environmental emissions, or to detect batch movements in Rokkasho to authenticate previously declared dissolution and separation schedules. In particular, as Japan's stocks of plutonium grow, there will be an increasing need to extend continuous, unattended monitoring systems to storage facilities. New technologies, such as digital image processing, could find useful applications in this important arena and are currently being explored by Japan, the United States, and the IAEA. Once again, much of the data gathered by these methods could easily be distributed to appropriate audiences in a timely fashion.

In all cases of independent observations or measurements, the IAEA is the natural organization to perform the task, but it is also possible that other potential regional or international organizations concerned with Japan's nuclear activities—in particular, the notion of an Asian nuclear energy organization similar to EURATOM has been informally raised in some quarters[30]—could have an interest in using some of these technologies or methodologies.

The IAEA is bound by confidentiality provisions in its safeguards agreements to keep the results of its inspections and measurements out of the public arena, and traditionally, Japan (as well as other nations with advanced nuclear industries) has been reluctant to distribute such information to the public. However, Japan could decide independently to release to the public certain types of data collected by the methods mentioned above. Doing so would place Japan at the forefront of international transparency efforts in the nuclear arena.

Criteria for Evaluating Transparency Options

If any of the above alternatives are seriously considered by Japan, they will undoubtedly be ranked according to the political benefits they may bring versus the potential political, security, and economic prices they may exact. It is premature (and presumptuous) to give a detailed ranking of the attractiveness of the above alternatives. Nevertheless, it is possible to infer from past experience some essential considerations.

In the case of Japan, with its large civil nuclear program, a key issue will be minimizing the costs, intrusiveness, and information loss of any transparency measures. These factors were of great importance some years ago when the NPT's safeguards systems were being negotiated, and they will figure heavily in any analysis of the feasibility of future transparency measures. In particular, they argue for an emphasis on technology-intensive measures over human-intensive measures.

Political considerations will also be prominent in such deliberations. Japan will undoubtedly seek to avoid or to mitigate measures that it views as particularly burdensome, or that could single out its nuclear program for special treatment, or that could in some way overly impede its plutonium recycling program. For example, Japan may be reluctant to publish data taken on radioactive emissions at its nuclear facilities if it feels that these data could fuel unease among the population or could make Japan a target of attacks by environmental or other groups ideologically opposed to its nuclear program.

In the past, the uncertain prospect of any real benefit from, as well as a natural reluctance to, allowing outside "interference" in its nuclear activities have combined to make Japan (and other nuclear nations) hesitant to publicize its nuclear operations in the way enhanced transparency measures would require. But in recent years Japan has indicated—through its publication of its plutonium holdings and other means—that it is now more willing to entertain proposals for greater transparency consistent, of course, with legitimate proprietary and security interests.

CHANGES IN ATTITUDES?

Two recent prominent incidents at Japanese nuclear facilities—a sodium leak at the Monju FBR in 1995, and a small fire at the Tokai Reprocessing Plant in March of this year—imply that Japan may now need to make its nuclear activities more transparent to regain the public trust needed to pursue its ambitious nuclear program.

On December 8, 1995, while Monju was operating at approximately 40 percent of its design electrical output, a sodium leak developed in the reactor's secondary cooling loop.[31] This leak continued for about three hours while the reactor was being shut down and ultimately resulted in the loss of about 650 kg of liquid sodium from the loop. A fire also resulted in the vicinity of the leak.

Upon investigation, the cause of the leak was determined to be a failure of a thermocouple housing inserted perpendicularly to the sodium flow. From an engineering perspective, this is the sort of problem that commonly arises when debugging a new design as complex as Monju, and, in this particular case, one that can easily be remedied by a simple redesign of the thermocouple housing. There was no impact on the primary sodium coolant loop, and at no time was any threat ever posed to the public.[32]

The Power Reactor and Nuclear Fuel Development Corporation (PNC), the company that designed and operates Monju, reacted to the leak by attempting to cover it up. Predictably, this attempt failed, and the resulting furor has seriously impaired Monju's operations. The reactor remains shut down at present and for the near future. In essence, PNC's reaction allowed a technical problem that would have been relatively inexpensive to correct to idle a $5 billion plus reactor.

On March 11 of 1997, PNC suffered another misfortune when a small fire and subsequent explosion in the Bituminization Demonstration Facility (where low-level waste is mixed with asphalt for permanent storage) of its Tokai Reprocessing Plant resulted in exposure of 37 workers to small amounts of radioactivity.[33] As with the Monju leak, the main cause of the ensuing public reaction was not so much the technical details of the incident itself, which was fairly minor, as the difficulties PNC seems to have in reporting promptly and accurately on such incidents, which, as with all things nuclear, are subject to intense scrutiny. The company has come under a tremendous amount of criticism from both the Japanese public and government for its handling of this situation.[34] Indeed, Japan's Science and Technology Agency, which runs PNC, has called for a criminal investigation of PNC's reporting on the Tokai accident.

PNC appears to be taking steps to improve its information reporting procedures. In a recent review of the company's operations, PNC acknowledged that its "information supply activities were inappropriate"[35] after the Monju incident and that it will in the future be "working hard to realize an open PNC under the recognition that the thorough disclosure of information is necessary if the general public is to feel secure with regard to nuclear power."[36]

While it remains too early to tell whether these actions signal a true change of attitude with respect to transparency, they do indicate that proposals for openness that only a few years ago would have been greeted with outright skepticism may today be given thoughtful consideration.

CONCLUSION: BENEFITS AND LIMITATIONS

Despite U.S. opposition, Japan, in cooperation with many Western European nations, is embarking on an ambitious program of civilian plutonium reprocessing and recycling. The fairly simple transparency measures outlined above could serve as a useful supplement to conventional safeguards techniques in addressing this policy.

What security benefits might be expected if some or all of these transparency measures were put in place in Japan? First, a precedent would be set as the world's advanced nuclear nations move towards the use of plutonium in their civil fuel cycles. This precedent could have broad implications for the management of nuclear materials in the United States and the world. As argued above, Japan is not alone in planning to operate large-scale bulk-handling civil nuclear facilities. France and the United Kingdom are already well along in this area, and Russia and China are on their way to joining them.

Of course, China and Russia are weapon states and as such are not bound by the NPT to accept international safeguards, although they have extended voluntary safeguards offers to the IAEA on some facilities. But current international trends make it possible that at least some their sensitive nuclear facilities could come partially under IAEA safeguards, as could happen in the weapon states if, for example, a treaty banning the production of fissile material for explosive purposes were concluded. However, if rigorous transparency measures have voluntarily been implemented in Japan by the time China and Russia start to bring large reprocessing plants into their civil fuel cycle, and if these measures have resulted in some degree of institutional innovation in the international management of civil fuel cycles, these two nations could feel some pressure to undertake similar measures, even though they are less affected by swings in public opinion than the Western democracies. If this were to happen, the United States and the international community would have increased information about the nuclear programs of these two powers. The potential security benefits of such transparency could be a useful

confidence-building measure.

Furthermore, if, as alluded to above, transparency measures implemented in Japan do eventually affect such potential international instruments as a fissile-material cut-off treaty, there will be implications for U.S. security and the nuclear weapons complex. It is, therefore, in the U.S. interest to begin considering at an early stage the form such transparency measures could take.

Finally, increased transparency could lessen the fears of Japan's neighbors, as well as the concerns of other nations around the world. Although neither transparency nor NPT safeguards should be expected to erase these fears, such measures could increase confidence within these states that Japan's nuclear expertise and capabilities are not being misused, potentially reducing pressures to proliferate within these countries.

While transparency measures, if properly designed and implemented, could have some security benefits, it is important not to expect more of them than they can deliver. They will have only a relatively minor effect on the fundamentally political problem of proliferation. If Japan, in particular, decides that it must have nuclear weapons, there is little reason to believe that transparency measures, or international safeguards in general, will stop that. They are not designed to do so, and should not be expected to do so. On the other hand, Japan is pioneering the use of civil plutonium on a broad scale. It is creating a model for other nations to follow if they also decide upon that route. Through its drive to become a permanent member of the U.N. Security Council and by dint of its economic weight, Japan is taking on the status, and therefore the responsibilities, of a great power. By taking additional transparency measures upon itself, it could help chart a positive course for others in the years to come.

[1] The author is grateful to Joseph Pilat, William Stanbro, Chad Olinger, and John Puckett of Los Alamos for stimulating discussions on this and related topics.

[2] See M. Hayashi, S. Asai, Y. Motoda, and M. Kikuchi, "Present Status of Safeguards Implementation in Japan," in *International Nuclear Safeguards 1994: Vision for the Future*, Vol. 1, (Vienna: IAEA, 1994), p. 63.

[3] See Eugene Skolnikoff, Tatsujiro Suzuki, and Kenneth Oye, *International Responses to Japanese Plutonium Programs* (Cambridge, MA: Working paper from the Center for International Studies, MIT, 1995); and Motoya Kitamura, "Japan's Plutonium Program: A Proliferation Threat?" *The Nonproliferation Review* 3 (Winter 1996).

[4] Hayashi *et al.*, "Present Status of Safeguards Implementation in Japan," p. 63.

[5] David Albright, Frans Berkhout, and William Walker, *World Inventory of Plutonium and Highly Enriched Uranium 1992* (Oxford: Oxford University Press for SIPRI, 1993), p. 78.

[6] *Ibid.*, p. 109.

[7] Masao Senzaki and Katsuya Ikeda, "Nonproliferation Efforts by PNC" (Tokyo: Power Reactor and Nuclear Fuel Development Corporation, 1996), p. 3.

[8] Albright *et al., World Inventory of Plutonium and Highly Enriched Uranium 1992*, p. 87.

[9] *Ibid.*, pp. 94 and 99.

[10] Kitamura, "Japan's Plutonium Program: A Proliferation Threat?" *passim*.

[11] In this vein, see the English translation of the *Long-Term Program for Research, Development and Utilization of Nuclear Energy* (Tokyo: Atomic Energy Commission of Japan, 1994).

[12] LWR fuel contains about 10 kg plutonium per MT of spent fuel.

[13] See U.S. Congress, Office of Technology Assessment, *Nuclear Safeguards and the International Atomic Energy Agency*, OTA-ISS-615 (Washington, D.C.: U.S. Government Printing Office, June 1995), Appendix A.

[14] William D. Stanbro, Richard Libby, and Joshua Segal, "Studies in Support of an SNM Cutoff Agreement: The PUREX Exercise," Los Alamos Report LA-UR-95-1993, paper delivered to the 36th Annual Meeting of the Institute for Nuclear Materials Management in Palm Desert, CA, July 9–12, 1995.

[15] INFCIRC/153 is conveniently reprinted in Appendix V of David Fischer and Paul Szasz, *Safeguarding the Atom: A Critical Appraisal* (London: Taylor & Francis, 1985).

[16] *Ibid*.

[17] International Atomic Energy Agency, *IAEA Safeguards Glossary, 1987 Edition* (Vienna: IAEA, 1987), Item No. 107.

[18] *Ibid*., p. 24.

[19] On these and related issues, see Thomas Shea, Stein Deron, Fredy Franssen, David Hope, Nurul Islam, Shirley Johnson, Erwin Kuhn, Gabor Laszlo, Dean Neal, and Therese Renis, "Safeguarding Reprocessing Plants: Principles, Past Experience, Current Practice and Future Trends," *Journal of Nuclear Materials Management* 21 (1993), pp. 17–27.

[20] Particularly in the LASCAR (Large Scale Reprocessing) forum. See OTA, *Nuclear Safeguards and the International Atomic Energy Agency*, p. 111.

[21] The IAEA, and the international community in general, was rudely surprised by the extent of the clandestine Iraqi nuclear-weapon program, which was carried out at facilities Iraq had not declared to the IAEA. The focus of Programme 93+2 has therefore been on assuring that a country's declarations to the IAEA are complete. The ultimate provisions of 93+2 are currently under debate at the IAEA and in national capitals, and many important details remain unclear.

[22] On Programme 93+2 see Richard Hooper, "Strengthening IAEA Safeguards in an Era of Nuclear Cooperation," *Arms Control Today* 25 (November 1995), pp. 14–18; David A.V. Fischer, "New Directions and Tools for Strengthening IAEA Safeguards," *The Nonproliferation Review* 3 (Winter 1996); and Mark H. Killinger, "Improving IAEA Safeguards Through Enhanced Information Analysis," *The Nonproliferation Review* 3 (Fall 1995). It should be stressed that while many of these measures were developed in an attempt to increase the Agency's ability to address the possible existence of clandestine nuclear-weapon facilities, they could also have a profound impact on safeguards implementation in declared facilities. It should also be stressed that no accusations of clandestine nuclear activities in Japan have ever been made.

[23] This is Kitamura's conclusion as well. See Kitamura, "Japan's Plutonium Program: A Proliferation Threat?" p. 14.

[24] Some of the options proposed below were anticipated in a general way in Lawrence Scheinman, *Assuring the Nuclear Non-Proliferation Safeguards System* (Washington, D.C.: The Atlantic Council of the United States, October 1992), p. 25.

[25] Hooper, "Strengthening IAEA Safeguards in an Era of Nuclear Cooperation," p. 18.

[26] Thomas E. Shea, Fredy Franssen, and Therese Renis, "Implementing

IAEA Safeguards at the Rokkasho Reprocessing Plant," in *International Nuclear Safeguards 1994: Vision for the Future*, Vol. 2, pp. 23–33.

[27] See Charles W. Nakhleh, William D. Stanbro, Louis N. Hand, R.T. Perry, Jr., William B. Wilson, and Bryan L. Fearey, "Noble-Gas Atmospheric Monitoring for International Safeguards at Reprocessing Plants," forthcoming in *Science & Global Security*.

[28] See Hooper, "Strengthening IAEA Safeguards in an Era of Nuclear Cooperation," p. 16. For a review of some of the problems and technologies involved in environmental monitoring, see U.S. Congress, Office of Technology Assessment, *Environmental Monitoring for Nuclear Safeguards*, OTA-BP-ISS-168 (Washington, D.C.: U.S. Government Printing Office, September 1995).

[29] For a review of current continuous remote monitoring systems, see S.F. Klosterbuer, J.K. Halbig, W.C. Harker, H.O. Menlove, J.A. Painter, and J.E. Stewart, "Continuous Remote Unattended Monitoring for Safeguards Data Collection Systems," in *International Nuclear Safeguards 1994: Vision for the Future*, Vol. 1, pp. 641–649.

[30] Hiroyoshi Kurihara, "Toward Better Management of Nuclear Materials in Japan and Asia," *Journal of Nuclear Materials Management* 25 (November 1996), pp. 23–24.

[31] The technical details of the Monju sodium leak were provided to the author in a presentation given at the Monju site on November 20, 1996, by Dr. Tadao Aoki of the Monju Construction Office of PNC.

[32] Briefing to the author by Monju staff on November 20, 1996.

[33] For example, the worker dose was less than 2 mSv (milli-Sieverts), or less than the estimated mean annual dose one would receive living in Colorado [Ronald Kathren, *Radioactivity in the Environment* (London: Harwood, 1984), p. 87], and environmental measurements at Tokai immediately after the accident showed minute Cs-137 activity levels on the order of 1 μBq/cm^3 (micro-Becquerel/cubic centimeter). These environmental activity levels returned to their normal values a day or so after the accident. The author happened to be at Tokai the day after the fire and explosion, and benefited from discussions with PNC personnel at Tokai. Up-to-date detailed information on the accident is posted regularly by PNC on its Web page: http://www.pnc.go.jp, where the dosage and activity data were obtained.

[34] See, e.g., "Japan Admits Nuclear Accident Cover-up," Reuters, April 16, 1997.

[35] Power Reactor and Nuclear Fuel Development Corporation, *Stage '96: PNC's Year in Review* (Tokyo: PNC, 1996), p. 15.

[36] *Ibid*.