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A Word of Thanks from INMM's Outgoing President

This is my last note to you as president of INMM. The past two years have passed very quickly for me. We experienced the tragedy of September 11, 2001, the war on terrorism, and a slowdown in the economy. For me it has been a busy and exciting time. I have spent most of this period in Washington, D.C., serving as a technical advisor to the Director of the DOE/NNSA Office of International Material Protection and Cooperation.

INMM had a very successful fiscal year 2001 and everything indicates that fiscal year 2002 also will be a success. The positive position in fiscal year 2001 was due in part to the highly successful INMM participation in the PATRAM Symposium held in early September 2001 in Chicago and the INMM Annual Meeting in Indian Wells, California, in July 2001. INMM has agreed to continue to be involved in future PATRAM meetings.

We have established a sound financial basis to sustain the technical services to our membership and the larger international nuclear materials management community.

A draft of a new INMM strategic plan has been developed and we seek your input as we finalize it. A meeting will be held June 26, 2002, during the Annual Meeting for members to offer suggestions. One of our goals is to make the INMM more meaningful to students and those new to the nuclear materials management field. A student and his professor are attending the annual meeting this year as guests of the Southwest Chapter. In addition, four other student papers will be presented in various sessions. Please look for these papers and give these students encouragement.

I would like to express my gratitude to some of the invaluable volunteers who continue to make significant contributions to the Institute. Secretary Vince DeVito and Treasurer Bob Curl deserve special recognition. They have a vast store of management expertise and institutional knowledge that provides the solid foundation of the INMM. Their presence ensures continuity of knowledge and a smooth transition during the periodic changes in the Executive Committee. Without their support and guidance, incoming presidents would find the challenge significantly more difficult. Thanks as well to Past President Debbie Dickman for her continued support of the INMM. Her interest in the long-term future of INMM and willingness to keep our operations manual current is extremely valuable to all who participate in the official activities of the Institute. I am also grateful to you, the members, for your past, present, and anticipated future support. This is a volunteer organization and we are thankful for all of the efforts you contribute to INMM.

It is my pleasure to pass the gavel to John Matter as the next president. John will officially assume his new duties on October 1, 2002. He has been a longtime supporter of INMM and brings a great deal of experience to the position. The newly elected Executive Committee will face challenges as they direct the Institute in the years ahead. I encourage you to provide input to the Executive Committee to assist it in making decisions that make the INMM stronger and provide the highest quality member benefits.

I have in the past and will continue in the future to urge each of you to identify one or more of the technical divisions in which to become active. A description of the interests of each division is given on the INMM Web site and in the membership directory. A copy of the INMM constitution and bylaws, information about awards and various INMM forms are also included in the directory. A big thanks goes to the Communications and Membership Committees and the Headquarters Staff for their efforts in producing the directory.

One of the greatest pleasures of serving as president has been the opportunity to work closely with INMM members and professional colleagues around the world. It has been a privilege to represent the members of the INMM in this role and have the opportunity to work with other dedicated nuclear materials management and nonproliferation professionals.

I continue to encourage all of you to get more involved. We have both new and continuing leaders of the technical divisions and standing committees; all need more volunteers and they would be very interested in hearing from you.

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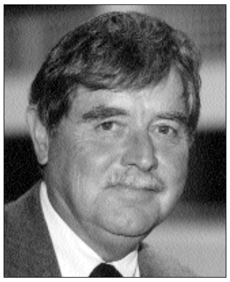
The FMCT, IAEA, and the NPT: A Looking Ahead



We owe our thanks to Jim Larrimore, chair of the INMM International Safeguards Technical Division, for soliciting the technical articles that appear in this issue of *JNMM*. Jim worked extremely hard to make this happen. The general theme that he pursued was what role the International Atomic Energy Agency might play in future nuclear arms control or proliferation-related agreements or treaties, i.e., the future beyond the Nuclear Nonproliferation Treaty (NPT). The range of articles that resulted is indeed fascinating.

Most focus on the Fissile Material Cut-off Treaty (FMCT), which is possibly the treaty next in line to address not only horizontal nuclear arms proliferation, whereby a nonnuclear weapon state (NNWS) acquires a nuclear weapon capability, but also vertical proliferation, the increasing stockpiles of the states that already have nuclear weapons. These states are categorized as the original nuclear weapon states (NWS), China, France, Russia, the United Kingdom, and the United States, and the three nuclear-weapons possessing states (NWPS)—India, Israel, and Pakistan. It is envisioned that all states would have to be signatories to the FMCT. Interestingly, because of the agreements under the NPT, the NNWS in effect have already *de facto* committed to the principles of the FMCT. Those that would be most impacted are the NWS and the NWPS.

Several articles discuss the possible verification regimes that might be negotiated under an FMCT. Of issue is whether verification should be "equal verification for all" or should verification in the NWS and NWPS be different from that in the NNWS. The argument is made that the purpose of verification in the NWS and the NWPS addresses vertical proliferation, whereas the verification in the NNWS addresses horizontal verification, and thus the regimes can and should be different. The politics are also interesting. I believe you will take special interest in the writings of Hui Zhang who provides a Chinese view of the FMCT.

I trust you will enjoy *all* of the articles, and I would personally like to thank the authors for devoting their time in writing these splendid pieces. The range of discussion is quite interesting.

You have read in previous issues of the *JNMM*, as well as in our President's Message in this issue, that a strategic plan is being developed for the Institute under the leadership of the Executive Committee. I echo INMM President J.D. Williams' request that you attend the special meeting on this strategic planning at the Annual Meeting on June 26.

Also, at the Annual Meeting, I encourage you to discuss any issues—critical to constructive—you may have on this *Journal* with any of us who are involved in producing it. The names of the assistant editor, the associate editors, and the managing editor are listed in the front of every issue. Look us up at the Annual Meeting. As always, should you have any comments, please feel free to call.

A New Look for *JNMM*

With the Fall 2002 issue of *JNMM*, we will be unveiling a new look. Months of planning and revisions have gone into the redesign and we think the change is a noticeable modernizing of in the appearance and readability of the *Journal*. At the same time, we promise that some things will not change: Our commitment to providing the highest quality technical papers for nuclear materials professionals remains strong.

We look forward to your feedback on the redesign next fall.

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Correction

The Spring 2002 issue of *JNMM* indicated that Charles Pietri was the author of the International Target Values. In fact, this was a misprint. Charles was one of several contributors to the ITV report and should not have been singled out. We apologize for any misinformation.

Nuclear Nonproliferation: The Role of Complementary Regimes

■

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■

Note: *This paper reflects the views of the authors and does not necessarily represent Australian government policy.*

Abstract

The Nuclear Nonproliferation Treaty (NPT) is commonly perceived as dealing primarily with horizontal proliferation: this is where it has the most detailed provisions and is the area of greatest achievement—the IAEA's comprehensive safeguards system. However, the NPT also deals with vertical proliferation—all parties are to pursue effective measures relating to cessation of the nuclear arms race and to nuclear disarmament.

Nuclear disarmament will not be possible without supporting regimes and confidence-building measures. This is recognized by the NPT—parties commit not only to nuclear disarmament, but to pursue "a treaty on general and complete disarmament under strict and effective international control." The form the latter treaty or treaties might take, though clearly relevant to the achievement of NPT objectives, is beyond the scope of this paper, which focuses on nuclear-related regimes.

One important complementary regime is the proposed Fissile Material Cut-off Treaty (FMCT). The FMCT would be a major step in containing vertical proliferation and would bring the three threshold states into the nuclear arms control process. Another important complementary regime is the Comprehensive Nuclear Test Ban Treaty (CTBT), which has benefits in terms of both vertical and horizontal nonproliferation.

Horizontal and vertical proliferation are two sides of the same coin: effective containment of horizontal proliferation is an essential precondition for nuclear disarmament—but lack of real progress on disarmament could over time erode the norm against horizontal proliferation. Hence, furthering the conditions needed for nuclear arms reductions and eventual disarmament must be a priority—including resolving the considerable verification challenges involved.

Introduction

From the advent of the nuclear age, political and institutional arrangements against the proliferation of nuclear weapons have been an essential element of national and international security. Initially nonproliferation relied on national measures—export controls and safeguards inspections by nuclear suppliers. Following the International Atomic Energy Agency's establishment in 1957, the application of safeguards became an agency responsibility. Since its conclusion in 1968, the centerpiece of the nonproliferation regime has been the NPT and the IAEA safeguards system that underpins it.

The success of the NPT should not distract our attention from the fact that there are other regimes, existing and prospective, important to the achievement of nonproliferation objectives. Export controls continue to make a major contribution. Regimes such as the CTBT and the FMCT have a vital role to play. Also important are the various regional and bilateral regimes dealing with nuclear issues, and verification arrangements underpinning reductions in nuclear arsenals and release of fissile material from weapons programs. As discussed in the next section, a whole range of security and arms control agreements outside the nuclear area—with associated verification and confidence-building measures—are essential to complement nuclear nonproliferation.

The NPT and the Broader Security Environment

The NPT is commonly described as a two-way bargain, between the nonnuclear-weapon states (NNWS) to forego the acquisition of nuclear weapons, and the nuclear-weapon states (NWS) to divest themselves of nuclear weapons. In fact, the NPT is a good deal more complex than this.

First, this simplistic dichotomous view overlooks that the NPT also comprises a bargain amongst the NNWS themselves not to acquire nuclear weapons—observance of this commitment is just as important to fellow NNWS, arguably even more so, as it is to the NWS. Second, Article VI of the

NPT links the nuclear disarmament commitment of the NWS to a commitment on all parties, NWS and NNWS alike, to pursue general disarmament. In this respect, the negotiators of the NPT recognized that a major motivation behind the acquisition of nuclear weapons has been concern about imbalances in nonnuclear forces—underscored by current concerns about chemical and biological weapons (CBW) programs. It is unrealistic to expect the eventual elimination of nuclear arsenals without effective steps to address these other concerns.

It is a feature of NPT Review Conferences that many NNWS routinely berate NWS for insufficient progress in the fulfillment of the disarmament commitment in Article VI of the Treaty. While some impatience is understandable, the NNWS would do well to reflect that this is not a matter for the NWS alone—appropriate action by the NNWS themselves will be essential in establishing the conditions under which nuclear disarmament can progress.

In the context of the NPT itself, an essential step for all NNWS is to conclude Additional Protocols (INFCIRC/540) accepting the application of strengthened safeguards. The IAEA safeguards system that all NNWS NPT parties are committed to accept is not static, fixed for all time as safeguards were in 1970 when the NPT came into force. The basic comprehensive safeguards agreement, INFCIRC/153, did not even exist then. In the three decades since INFCIRC/153 was introduced, safeguards have undergone considerable evolution. Today, the most developed and most effective form of comprehensive safeguards is *strengthened* safeguards, the combination of INFCIRC/153 and INFCIRC/540—this represents the contemporary NPT safeguards standard. For a NNWS NPT party to remain outside strengthened safeguards will raise concern about its commitment to nonproliferation—this is not conducive to establishing the level of confidence required to encourage nuclear disarmament.

Outside the scope of the NPT, it is clear that a wide range of political agreements and associated confidence-building measures will be an essential part of establishing an international security environment in which nuclear nonproliferation can be sustained and nuclear disarmament progressed. Some of these will be global—e.g. effective regimes against CBW and associated missile systems—and some will be regional or even bilateral (a comprehensive Middle East peace settlement is just one regional possibility that comes to mind).

The NPT's reference to "a treaty on general and complete disarmament under strict and effective international control" is not to be taken literally—rather than a single treaty, there is bound to be a series of agreements, advancing toward this objective incrementally, and today alas *complete* disarmament seems too utopian an ideal. While the meaning of "strict and effective international control" has yet to be elaborated, at the least this will require effective verification, which has been such a hallmark of the NPT.

Consistent with the pragmatic principle of "trust, but verify," the NPT has derived great strength from the IAEA safeguards system. What verification might look like in other regimes will be determined by a range of factors, including: the level of assurance required politically, what is practical, what is acceptable, and what is affordable.

The verification regime under the Chemical Weapons Convention, for example, is a good deal less rigorous than IAEA safeguards, reflecting practicalities as to the scale and diversity of the chemical industry, and perhaps a political judgment that use of chemical weapons might not have the same devastating consequences as use of nuclear weapons. Failure to reach agreement on what would constitute an effective regime for the Biological Weapons Convention would have serious implications for the broader nonproliferation environment, since undoubtedly the "general and complete disarmament under strict and effective international control" referred to by the NPT will have to encompass biological weapons, and concern about biological weapons (BW) programs will influence national decisions regarding nuclear weapons. What combination of verification and other confidence-building measures can convincingly address the BW issue remains to be seen. This, and a whole range of other political and arms control matters, however, are beyond the scope of this paper.

Regimes Complementing the NPT

Containing the Spread of Proliferation-Sensitive Technologies

As already mentioned, national controls on the export of proliferation-sensitive technologies—particularly enrichment and reprocessing—were the earliest nonproliferation measures, and they continue to have a vital role. National controls have been given multilateral frameworks through the Nuclear Suppliers Group (NSG) and the Zangger Committee.

The NPT itself makes no provision for limiting the spread of proliferation-sensitive technologies. While some states have argued that acceptance of safeguards—full-scope or otherwise—should be sufficient qualification to acquire any nuclear technology for "peaceful" purposes, it is generally recognized that restraint both in supply *and acquisition* of sensitive technologies is an essential complement to the NPT. Safeguards in themselves will not provide the assurance required by the international community if there are suspicions about a state's future intentions.

In this regard, an important concept was introduced by INFCE (International Nuclear Fuel Cycle Evaluation) in 1980, when it recommended that sensitive facilities should be owned and operated, not by individual states, but on a multi-nation basis, perhaps servicing the requirements of a region. Another example of the recognition that the spread of sensitive facilities should be limited—and particularly in regions of tension—is the 1992 Joint Declaration on the Denuclearization of the Korean Peninsula, in which the Republic of Korea and the DPRK undertook not to possess enrichment or reprocessing facilities. This agreement should serve as a precedent for other countries in regions of tension, like Iran, seeking such fuel-cycle capabilities.

Currently, an interesting development is the increasing attention being given to the establishment of proliferation-resistant fuel-cycle technologies. "Proliferation resistance" has yet to be defined—an illustration is technologies that allow for plutonium recycle without the necessity for full separation of plutonium—but it is clear that technical barriers, making proliferation more difficult and increasing the warning time to the international community, can play a vital role in reinforcing the nonproliferation regime. Whether this approach will constitute a regime in itself, eg. by being formalized through agreements or international understandings, remains to be seen.

Fissile Material Cut-Off Treaty

The intention underlying the proposed FMCT—set out in the negotiating mandate agreed by the U.N. Committee for Disarmament (CD)—is for "a nondiscriminatory, multilateral, and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons and other nuclear explosive devices." Production of fissile material for peaceful purposes and for nonproscribed military purposes (such as propulsion) would continue, but under multilateral verification to ensure there is no diversion to proscribed (i.e. explosive) purposes. The FMCT would be a major step in containing vertical proliferation, placing a quantitative cap on fissile material for weapons programs, and bringing the three *threshold states* (India, Israel, and Pakistan) into the nuclear arms control process.

While the objective of the FMCT is agreed, commencement of negotiations in the CD have been delayed for some years over other, unrelated issues, and the final form the FMCT may take is as yet uncertain. Some states have said it should not be prejudged that IAEA safeguards will constitute the FMCT verification mechanism. Nonetheless, two points are clear:

- The verification issues involved with the FMCT are very similar to those dealt with by the IAEA, and the IAEA's substantial experience should be used to advantage in ensuring that the FMCT is implemented effectively;
- In the case of NNWS parties to the NPT, comprehensive safeguards already fully meet the FMCT objective. In principle, therefore, the FMCT should not involve any additional commitments from states that have in place both an NPT safeguards agreement and an Additional Protocol.

For the five NWS and the states outside the NPT (principally India, Israel, and Pakistan), the FMCT would involve substantial new commitments—to produce fissile material only under verification to assure the material is not used for weapons. This will bring new verification challenges. Perhaps it is in this sense that some states have queried the role of IAEA safeguards—if they are thinking of *comprehensive* safeguards they may have a point: truly comprehensive safeguards covering all nuclear material cannot apply in the NWS (and threshold states) while they retain, outside verification, nuclear material (including weapons) existing when the FMCT enters into force; and the cost of verification on the comprehensive safeguards model in the NWS would be prohibitive.

It can be argued that the verification objectives of comprehensive safeguards and the FMCT are qualitatively different. Comprehensive safeguards have a degree of rigor that reflects that, in countering *horizontal* proliferation, the acquisition of one nuclear weapon will defeat the verification objective. FMCT verification on the other hand will be aimed at *vertical* proliferation—for states that already have nuclear arsenals, the same degree of rigor would not be essential.

The authors advocate what has become known as the focused approach: verification focused on the most sensitive facilities and materials will be both appropriate and credible, provided the regime includes an effective counter to the possibility of undeclared production (i.e. after entry-into-force or EIF). Under this approach, verification would be concentrated on the facilities that produce fissile material, i.e. enrichment and reprocessing plants, and on separated plutonium and HEU produced after EIF. It is envisaged that the FMCT regime would include, inter alia, routine and non-routine verification activities, managed access, verification measures against possible undeclared production activities, and mechanisms for special and/or challenge inspections.

Comprehensive Nuclear Test Ban Treaty

The CTBT has both vertical and horizontal nonproliferation benefits—it would place a qualitative cap on nuclear weapons programs and present a substantial barrier to would-be proliferators (ab initio states).

The commitment not to conduct nuclear tests, embodied in the CTBT, is assuming the status of an international norm, having been signed by 165 states and ratified by ninety—and a de facto moratorium on testing has been observed for three years (or six years if one excludes the Indian and Pakistani tests of 1998). Although the CTBT is not in force—it has yet to receive the necessary ratifications, including by the United States—the treaty expressly provides that its verification system (the International Monitoring System—IMS) is to be capable of meeting the requirements of the treaty at entry-into-force. The Preparatory Commission for the CTBT Organization is therefore engaged in a major program in preparation for EIF, including the establishment/upgrading of 337 monitoring facilities around the world, and the provisional operation of these facilities.

It is surprising, and disappointing, that one of the reasons cited by the United States for deciding against ratification is that the CTBT is unverifiable. Effective verification is key to the credibility of the treaty, and a great deal of effort has been expended over the last twenty years to develop and implement an effective IMS. A basic design parameter for the IMS is that it should be able to detect and identify a one-kiloton explosion in any terrestrial environment. In many cases, however, the level of sensitivity will be considerably greater. Calibration tests of the IMS have shown good results for 100-ton explosions. A number of IMS stations also detected the (relatively) quite small explosions that resulted in the sinking of the Kursk submarine in August 2000.

The unverifiability assertion may relate to the fact that there are some practical limits to the IMS detection capabilities—some very small-scale supercritical testing might proceed with a low risk of detection. Such testing however would be very difficult for an *ab initio* state, and would not add greatly to the knowledge of a state with full-scale test experience. Obviously the NWS are in a position to refine existing designs, and to a certain extent develop new designs, based on activities not proscribed by the treaty, eg. using simulation programs and data from previous tests, as well as conducting subcritical tests—whether for weapon development or stockpile stewardship. However, major changes to existing designs and development of substantially new designs are likely to require full-scale testing. Thus the treaty will impose substantial qualitative limits on what the NWS (and threshold states) can do. While there are some in the NWS who are concerned about this limitation, clearly it is consistent with the NPT commitment to the eventual elimination of nuclear weapons.

While *ab initio* states could develop a simple nuclear weapon without testing (e.g. a "gun-type" HEU weapon), such a weapon would require a relatively large amount of fissile material—a disadvantage when a clandestine enrichment program is relied on—and its size and weight could limit delivery options. A basic implosion design could be developed with subcritical testing, but without the benefit of full-scale testing an *ab initio* state could not be confident how well such a design would work in practice—and small-scale tests, if not well conducted (and without testing experience that would be problematic), will risk detection. Development of more advanced designs requiring boosting would require full-scale testing. Thus the CTBT, while not a complete barrier to an *ab initio* state, will increase the risks and substantially limit the options available to such a state.

Regional and Bilateral Regimes

There are two broad categories of regional arrangements relevant to nuclear nonproliferation: those establishing political nonproliferation commitments; and those establishing international organizations responsible for applying regional safeguards.

In the first category are the nuclear weapon-free zone (NWFZ) treaties—and the right to conclude such treaties is expressly recognised in the NPT (Article VII). Currently there are four: the Treaty of Tlatelolco, the Treaty of Rarotonga, the Treaty of Pelindaba (yet to enter into force), and the Bangkok Treaty. Mention might also be made of the Antarctic Treaty, which proscribes military activities, nuclear explosions, and disposal of radioactive waste in Antarctica. A fifth NWFZ—covering Central Asia—is currently under development. Although the NWFZ treaties contain verification provisions, it is notable that they do not establish separate safeguards systems but adopt IAEA safeguards.

In the second category are the Euratom Treaty, establishing the European Atomic Energy Community, and the Bilateral Agreement between Brazil and Argentina establishing ABACC, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials.

Both the NWFZ treaties and the regional/bilateral safeguards arrangements serve an important confidence-building/transparency function. This can be seen particularly in the case of the ABACC agreement, which enabled the introduction of comprehensive safeguards in Argentina and Brazil ahead of the time when the conditions were right for both states to be prepared to join the NPT. Both states continue to appreciate the mutual transparency in nuclear activities provided through ABACC.

The ABACC model—safeguards inspections undertaken by the IAEA and the parties jointly—establishes a valuable precedent for other states—states such as India and Pakistan, outside comprehensive safeguards, where mutual confidence-building measures could be an important element in winding back nuclear weapon programs, and NNWS that find themselves in circumstances where confidence-building measures additional to IAEA safeguards could play a useful role, eg. perhaps the Republic of Korea and the DPRK, and, when conditions are more favorable, Iran and Iraq.

Nuclear Weapon Dismantlement, Irreversibility

Effective verification will be an essential component in establishing the confidence necessary for nuclear disarmament to progress. A range of verification objectives will be involved including that no undeclared weapons are retained; there is no undeclared fissile material production (the object of the FMCT); that weapons submitted for dismantlement are in fact dismantled; and that fissile material released from military programs for peaceful use remains in peaceful use (irreversibility).

The Trilateral Initiative between the United States, Russia, and the IAEA, under which agreed quantities of plutonium and HEU are to be released from weapons programs under verification to ensure irreversibility, sets an important precedent. U.S. and Russian experts have developed verification instruments that can be used by IAEA inspectors to confirm that fissile material in canisters presented for verification meets required quality and quantity parameters, without revealing sensitive information (such as the precise isotopics or the mass and shape of weapons components). A verification approach has been developed to cover storage of canisters under surveillance, processing under "black box" arrangements to remove sensitive characteristics (shape, mass, isotopic composition), and submission of the resultant unclassified fissile material to IAEA safeguards. This work serves as a foundation for the further verification methodologies that will be required as disarmament proceeds.

Irreversibility—ensuring that fissile material committed to peaceful uses does not return to weapons programs—involves issues that are as much political as technical. Pragmatically, it could be argued that released fissile material needs to remain under verification only until it is degraded into a form that would require nuclear upgrading (enrichment or reprocessing) to return it to weapons use. This would be achieved: (a) in the case of HEU, once it is downblended to LEU; and (b) in the case of plutonium, once it is fabricated as MOX fuel and irradiated (incidentally, degrading the isotopics). In circumstances where the United States and Russia still have substantial excess weapons material, and are reducing weapons numbers, it is highly unlikely they would re-enrich or reprocess released material for weapons use (though this argument might not be as persuasive in the case of states with much smaller nuclear arsenals).

The alternative view is that it might be unacceptable to the international community to have incomplete safeguards in place, that once the material is submitted to safeguards it should remain under safeguards until it becomes practicably irrecoverable. This argument would be very neatly resolved by proceeding with the FMCT without further delay—a verified peaceful use commitment would then apply to all new fissile material production (defined, in the case of the focused approach, as production of HEU and separation of plutonium), thus effectively ensuring irreversibility for released material once it has been downblended or irradiated.

Some Other Verification Issues

The classical safeguards system, which developed with a focus on verifying declared nuclear material inventories in the context of horizontal proliferation, is not necessarily the most appropriate model for all verification requirements. While some argue for a universal system as a matter of policy, practical considerations are likely to dictate otherwise.

For new verification regimes, addressing new situations and new objectives, a greater emphasis on qualitative approaches may be more appropriate—for example, as discussed earlier, FMCT objectives can be seen as being quite different than those of comprehensive safeguards, and less rigorous verification measures may well be acceptable. Indeed, as comprehensive safeguards are developed further to better address a *qualitative* objective—assurance of the absence of undeclared nuclear activities—comprehensive safeguards themselves, at least in the form of *integrated safeguards,* are placing less emphasis on routine verification activities.

This qualitative difference between regimes might well be reflected in different verification standards—again, looking at the FMCT, if in the case of NWS undetected fissile material production sufficient for a low number of weapons is an acceptable risk, different detection parameters might be acceptable compared with classical safeguards, where the objective is to detect diversion of just one *significant quantity* (an amount sufficient for one weapon). Of course, such differences raise important policy issues and need to be considered very carefully.

Examples of wholly qualitative mechanisms which are likely to become increasingly important in nuclear verification include: surveillance through use of satellite imagery and instruments such as the Open Skies Treaty; and measures to promote greater transparency between states. While objective verification by a competent multilateral agency—the IAEA—will be essential to maintain credibility, bilateral and regional confidence-building measures to complement multilateral verification—as exemplified for example by ABACC—can also be expected to play an important role in particular situations.

While the theme of this discussion is the need to tailor verification mechanisms to suit specific circumstances—rather than pursue a "one-size-fits-all" approach—clearly there will be substantial areas of commonality, and the differences between NNWS and NWS will reduce as nuclear arsenals run down. Thus over time the trend is likely to be towards *convergence* between different systems—e.g. between comprehensive safeguards and FMCT verification—though it is too early to say in which direction this will occur. As the capability of safeguards to provide assurance about undeclared activities strengthens, a substantial simplification of safeguards can be expected for material other than unirradiated *direct-use material* (HEU and separated plutonium)—thus comprehensive safeguards may well evolve towards FMCT verification rather than vice versa.

Conclusions

When the NPT was concluded in 1968, the negotiators demonstrated considerable farsightedness and realism. They recognized that the division of states into two groups—the five NWS existing at that time, and the NNWS—could not be sustained permanently. While containment of horizontal proliferation was the immediate priority, nuclear disarmament was also an essential objective, since otherwise the norm against horizontal proliferation could erode over time.

Hence the NPT sets out a framework for dealing with vertical as well as horizontal proliferation. Since the elimination of nuclear weapons must be seen as a *long-term* objective, the NPT recognizes the need for further agreements elaborating the treaty framework. Of particular importance, the NPT recognizes the direct relationship between nuclear disarmament and effective arms control and disarmament in nonnuclear areas. This is especially pertinent today with heightened concern about the development of chemical and biological weapons. Progress in nuclear disarmament will be closely linked to progress in addressing these concerns.

In the nuclear area, near-term steps to advance NPT objectives include:

- Further action against horizontal proliferation—particularly the general adoption of the Additional Protocol and continued development of strengthened safeguards capabilities;
- Action against vertical proliferation—particularly consolidation of the moratorium on nuclear testing through bringing the CTBT into force and agreement on an FMCT.

Effective verification will continue to be an essential element in curbing horizontal proliferation. Likewise, effective verification will be required to curb vertical proliferation and to progress nuclear disarmament. Here, there will be major challenges—but the Trilateral Initiative shows how novel situations can be met by ingenuity and innovation. The challenges are not entirely technical—policy makers too have to be receptive to new ways of achieving verification objectives.

21st Century: Toward the Nuclear-Weapons-Free World

■

T. Zhantikin
Kazakhstan Atomic Energy Committee

S. Tukhvatulin and M. Mukusheva
National Nuclear Center of the Republic of Kazakhstan

■

"The twentieth century. It was a time when humanity first disturbed the eternal rest of atom, and the atom bit back, showing that it was stronger than scientific imagination.

"Its awakened power proved that the atom was not merely an object to satisfy human curiosity in a part of the world, but that it was something greater. That it was above the world and not of it, that people did not determine its fate, but, on the contrary, the fate of humanity lay in the atom's infinite energy.

"People learned to control nuclear energy, but they did not learn to control themselves. They lost trust in people and developed trust in nuclear power."

From *Epicenter of Peace* by N. Nazarbayev, the president of the Republic of Kazakhstan.

On August 29, 1991, by decree of the president of the Republic of Kazakhstan, the Semipalatinsk Nuclear Test Site was closed. Ten years have passed since that great day. This event gave rise to many disputes and deliberations all over the world. But everyone was touched by it. On the initiative of Kazakhstan President Nazarbayev, on the eve of the tenth anniversary of the test site closure, an international conference—21st Century: Toward the Nuclear-Weapons-Free World—was held in Almaty, Kazakhstan, to discuss relieving the world of the nuclear threat.

Well-known politicians and scientists from around the world, international experts, and representatives of public movements participated. During two days, conference participants discussed global nonproliferation problems; opinions were expressed about main aspects of the present-day situation in the field of nuclear disarmament and nonproliferation. Having evaluated the experience of the twentieth century, the conference attendees emphasized the insanity of the development of weapons of mass destruction to achieve foreign policy goals. In his welcoming speech, K. Mazoora, UNESCO director general, said that "a long-term stability and safety should not be built upon a fear of the unknown but on mutual understanding based on predictability, transparency, openness, information exchange, and dialogue forms, which respect life interests of other parties."

By closing the Semipalatinsk Test Site, Kazakhstan took its opportunity to build a violence-free world.

The nuclear heritage of the past caused serious damage to the environment and, above all, to mankind. Within this context, the Semipalatinsk Test Site is a striking example.

Kazakhstan scientists and international experts once again stated that the elimination of the nuclear test consequences in the region of the former Semipalatinsk Test Site will still take considerable manpower and financial resources. Today this issue gains international importance. The Kazakhstan government makes all-out efforts to rehabilitate the economics of the former Semipalatinsk Test Site region. Utilities are reconstructed and vital functions are again provided in Kurchatov. A unique experimental base at the Baikal and IGR reactor complexes was preserved; today research is conducted there on U.S., Russian, and Japanese requests. At the former test site territory, commercial coal and table salt is produced, and mineral exploration is carried out in support of the Comprehensive Test Ban Treaty (CTBT), a seismic monitoring system was developed and functions in the National Nuclear Center of the Republic of Kazakhstan (NNC RK) covering almost the whole Kazakhstan territory in the network of the CTBT International Monitoring System. At the same time, it is obvious that a real economical rehabilitation of the region is possible with solid investments only.

It should be noted, that along with the Semipalatinsk Nuclear Test Site, the Republic of Kazakhstan has inherited from the USSR a tremendous set of environmental and socioeconomic problems. It is apparent that neither Kazakhstan alone nor in cooperation with other states (including the United States or Russia) will be able to solve these problems *in corpora.* The successful accomplishment of these tasks is only possible with participation of the whole world society and the leading role is primarily given to such international organizations as the United Nations. In

December 1997, the 52nd U.N. General Assembly adopted a specific resolution on the Semipalatinsk Test Site. U.N. General Secretary's paper, *International Cooperation and Coordination for Humanitarian and Ecological Rehabilitation and Economical Development of Semipalatinsk Region in Kazakhstan,* was reviewed at the 53rd U.N. General Assembly Session. In November 1998, a resolution was adopted urging the international society to pay attention to the necessity for rendering assistance in solving humanitarian and ecological issues in the Semipalatinsk region.

In his closing statement, Kazakhstan Minister of Foreign Affairs E. Idrisov underlined the vital importance of the ideal of nonproliferation of weapons of mass destruction for the Kazakhstan people. Since gaining its sovereignty, Kazakhstan follows a policy of peace and has entered the international society as a state fully supporting the nonproliferation ideals. Having closed the Semipalatinsk Test Site, the Republic of Kazakhstan made the first step in the process of banning nuclear tests. The next step was to accede to CTBT. At present, Kazakhstan is an active party in the CTBT. The developed system of geophysical nuclear test monitoring (a network of seismic and infrasound stations with a data-processing center in Almaty) is one of the best national systems consolidated in the nuclear-test-monitoring regime. Kazakhstan was one of the first ten states with seismic stations incorporated into the International Monitoring System.

In 1994, the Republic of Kazakhstan became a member of the International Atomic Energy Agency (IAEA). At present, Kazakhstan's nuclear facilities are covered by comprehensive IAEA safeguards. As a large supplier of fissionable materials, in its export activities Kazakhstan follows international requirements aimed at barring illegal transactions with nuclear materials and ionizing-radiation sources. Since 1997, Kazakhstan has followed the Nuclear Suppliers' Guidelines in the export of nuclear materials and technologies. On April 21, 1995, a more than yearlong process of nuclear weapon withdrawal from Kazakhstan territory was completed.

Summing up the conference, Kazakhstan Deputy Prime Minister V. Shkolnik said that the politics of the Republic of Kazakhstan in the sphere of nonproliferation of weapons of mass destruction is based upon equal partnership with other states without discrimination against any political motives. The only indispensable condition for cooperation is rigorous observation of nuclear nonproliferation principles. This is the only way to prevent a recurrence of the splitting of the world into adversarial camps threatening to annihilate mankind.

"The new world system demands good understanding of the fact that not subordination, suppression, search for unilateral benefit and striving for superiority but only readiness for cooperation based on equality of rights and between states can govern the twenty-first century in the era of peace and progress," Mr. Gensher said at the Conference.

Kazakhstan has made its major and ineffaceable gift to humanity by relieving itself and its environment from nuclear threat.

How to Reduce Nuclear Material Available for Nuclear Weapons

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Introduction

For more than forty years, the International Atomic Energy Agency (IAEA) has gathered experience in the verification of nuclear materials and the safeguarding of nuclear facilities. This is done in the course of implementing nuclear safeguards based on international agreements between the IAEA and its member states in the context of international treaties: the Treaty on the Nonproliferation of Nuclear Weapons (NPT) and similar treaties.

Over the recent few years, this experience has been used to implement, under the safeguards agreement with the United States, a verification regime for nuclear material no longer required by the U.S. nuclear-weapons program and declared to be irreversibly released from it ("excess material"). Such a regime is currently implemented for twelve metric tons of excess material in storage in the United States and, additionally, to the downblending process of approximately fifty tons of highly enriched uranium to commercially usable, lower-enrichment levels.

The safeguards agreement with the United States is a so-called *voluntary offer* safeguards agreement; the IAEA has concluded voluntary offer safeguards agreements with all nuclear-weapons states recognized by the NPT (China, France, Russia, the UK, and the United States).

The application of safeguards is one of the agency's core activities. The agency's Statute (in Article III.A.5) stipulates "to establish and administer safeguards … and to apply safeguards to any … state's activities in the field of atomic energy." For nonnuclear-weapon states, IAEA verification activities under a comprehensive safeguards regime are mandatory for all nuclear material and nuclear activities, pursuant to Article III of the NPT.

The NPT, in Article VI, however, also stipulates "negotiations … on effective measures … to nuclear disarmament … under strict and effective international control." These measures may be different in intention and scope than safeguards under Article III; both, however, involve nuclear processes, with nuclear material and nuclear facilities, and they will require an effective verification methodology for implementation.

It must be noted that the IAEA has a very clear and explicit mandate regarding safeguards (under Article III of the NPT); it has no such mandate under Article VI.

Against this background, the verification of the excess material in the United States began in 1994 and continues today, with the expressed commitment by the United States that the material will not return to nuclear-weapons use.

In 1996, the Trilateral Initiative was launched, between the Russian Federation, the United States, and the IAEA, to develop a new verification system for weapons-origin nuclear material, for implementation by the IAEA, in both states. Agency verification of this material is intended to promote international confidence that this material remains irreversibly removed from nuclear-weapons programs.

Nuclear material and processing facilities are the key ingredients for the production of nuclear weapons. The agency's technical capabilities, skills and experience in understanding the relevant nuclear and nuclear-related processes may offer a cost-effective road to the establishment and operation of monitoring and verification regimes to assure states that specified facilities in nuclear-weapon states will not be misused for proscribed activities under an international treaty limiting such activities. The IAEA has a well-trained and experienced core of nuclear inspectors available, and an infrastructure exists to expand activities beyond NPT safeguards, should member states so wish.

Governments have recognized this; those represented at the Conference of Disarmament have consulted the IAEA on technical issues relating to a fissile material production cut-off.

International Safeguards

The IAEA was established in 1957, triggered by the famous "Atoms for Peace" speech by U.S. President Eisenhower in December 1953 at the U.N. General Assembly. Consequently, the initial activities of the new agency focused more on the promotion of research, development, and on practical applications, generally, on the transfer of relevant scientific and technical knowledge and technology (materials, services, equipment and facilities) rather than on aspects of safety and safeguards. However, the agency's statute included from the very outset the establishment and application of safeguards, to ensure that any assistance or supplies made available through the agency should not be used to further any military purposes. The agency was also asked "to apply safeguards, at the request of the parties, to any bilateral and multilateral arrangement, or at the request of a state, to any of that state's activities in the field of atomic energy" (Statute, Article III.A.5).

In 1958, the Safeguards Division was established, but it was not before 1962 that the first safeguards inspection took place. In August and September 1967, a first inspection at a reprocessing plant in the United States was carried out (at West Valley in New York State) to test procedures for the accounting of all declared nuclear material at that facility.[1] This activity was based on a set of agreements approved by the agency's Board of Governors in 1965 and 1966, which is commonly referred to as INFCIRC/66, and based on those safeguards verification activities still taking place in a now small number of states.

The NPT[2] entered into force in 1970. At that time, the agency's safeguards staff had already sufficient experience to embark on a much broader task than applying safeguards under INFCIRC/66-type agreements: to negotiate and implement comprehensive safeguards agreements with all non-nuclear-weapon states party to the NPT. It is noted that the Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean (Treaty of Tlatelolco), though a regional nonproliferation undertaking for Latin America and the Caribbean area, has the same requirements. Because of that, the Agency for the Prohibition on Nuclear Weapons in Latin America and the Caribbean (OPANAL), the Tlatelolco watchdog, designated the IAEA as the verification body for the states' nonproliferation commitments to the treaty (Article 13). In the meantime other regional treaties aim, as Tlatelolco does, at regional nuclear-weapon free zones (e.g., the Rarotonga Treaty for the South Pacific, the Pelindaba Treaty for Africa, and the Bangkok Treaty for South East Asia).

From 1970 onward, the entire nuclear-fuel cycle and all other nuclear activities of states party to the NPT had to be brought under IAEA safeguards; in fact, *all* source and special fissionable material in all peaceful nuclear activities had to be declared to the agency under a comprehensive safeguards agreement.[3] The agency has the right to verify, independently, and by the means of its own choice, that there had been no diversion of this material to nuclear weapons or other nuclear explosive devices.

The United States and the United Kingdom offered to place all their civilian nuclear plants under IAEA safeguards, although the NPT does not require nuclear-weapon states to do so, and France had volunteered some nuclear plants for safeguards. In 1982, the Soviet Union announced that it was also ready to have the agency apply safeguards to certain nuclear facilities on its territory, and in 1988, China made the same announcement. Eventually, all nuclear-weapon states negotiated voluntary-offer safeguards agreements (VOAs) with the agency, and IAEA safeguards were implemented to the extent required and possible. The application of safeguards under VOAs was significantly reduced after a review of priorities in the early 1990s.

Soon after the discovery of Iraq's clandestine nuclear activities after the Gulf War in 1991, the agency began strengthening the safeguards system. The strengthening process culminated in the approval of the Model Additional Protocol[4] by the IAEA member states in 1997. To help establish the strengthened universal safeguards regime, sixty-one states have signed such a protocol additional to their safeguards agreement, including all five (recognized) nuclear-weapon states; the Additional Protocol has entered into force in twenty-five states and, in addition, is being applied in Taiwan, China (March 2002).

Over the years, the IAEA safeguards has produced approximately 12,000 person-years of verification experience, more than 9,000 of those over the last twenty years. In that time, more than 5,500 person-years of in-field inspection was accumulated, 4,000 of those since 1981. At the current staffing level of more than 500, IAEA safeguards accrues additional experience at a fast rate.

Safeguards are applied to all types of nuclear fuel cycle facilities, including conversion, enrichment, reprocessing plants, and storage facilities. In 2001, IAEA safeguards inspectors performed about 2,500 inspections in just under 600 nuclear facilities worldwide, generating a total of a little more than 10,000 person-days of inspection. More details are provided in the annual Safeguards Implementation Report[5] to the IAEA Board of Governors, of which excerpts are available on the IAEA's Web pages.[6]

Since 1980, when the United States signed its VOA with the agency,[7] the IAEA has implemented safeguards under this agreement in various U.S. facilities. Under the VOA, the state provides a list of facilities eligible for the application of safeguards, from which the agency may then choose some (or all) facilities. In contrast to safeguards in nonnuclear-weapon states, nuclear-weapon states are permitted to withdraw nuclear material from safeguarded facilities and to remove nuclear facilities from the eligible list. The United States has pledged to include all civilian nuclear facilities on this eligible list, which has currently about 250 entries. The agency had, for certain time periods, always selected some facilities from that list, for the application of safeguards.[8] In a similar way, all other nuclear-weapon states have voluntary offer safeguards agreements, and the IAEA implements safeguards in some of those facilities.

Excess Material from Nuclear Weapon Programs

In 1993, U.S. President Clinton declared at the United Nations in New York that there were significant amounts of nuclear material considered in excess of what was "needed for national defense purposes" in the United States. Some of that material was to be placed under IAEA safeguards. By 1998, the U.S. government had designated 174 metric tons of HEU (highly enriched uranium) and fifty-two metric tons of plutonium as excess material.

Subsequent to President Clinton's announcement, the relevant facilities were included on the U.S. eligible list and some of the excess material was submitted to and selected for IAEA safeguards (using the existing VOA). Extra-budgetary U.S. funding was provided for this activity. The U.S. government stated the irreversibility of the decision of no return to nuclear weapons for this material.

In 1994 and 1995 twelve metric tons of such excess material were placed under IAEA safeguards, ten tons of HEU in Tennessee, followed by approximately one ton of plutonium in the state of Washington, and one more ton of plutonium in Colorado. All these materials are in storage facilities, and, as such, the application of safeguards was fairly straightforward and its implementation, relatively speaking, uncomplicated. However, the initial inventory verifications required very intensive work and a significant presence of safeguards inspectors. The entire inventory of the facility had to be brought under safeguards in a short period of time.[9]

In 1997-1998, a verification experiment was conducted on thirteen metric tons of HEU, which were down-blended to LEU at the Portsmouth Enrichment Plant. The reason for calling it an experiment was that some of the basic IAEA safeguards criteria, including the required nuclear material accountancy, could not be met at the time.

In addition to the above, IAEA safeguards was applied to a down blending process at a nuclear facility in Virginia, first to approximately 600 kilograms of HEU reported to come from Kazakhstan ("Sapphire"), then, and still ongoing, to fifty metric tons of HEU. For this facility, safeguards for the down blending is based on the operator's declarations with unattended agency inline instrumentation measuring the input and output flows. This is accomplished with the use of flow monitors, flow totalizers, and enrichment and concentration monitors. The safeguards approach includes the use of an encrypted mailbox system that is, in connection with a random-unannounced inspection scheme, to limit the actually needed inspections. However, like in the fissile material storages, one physical inventory verification per year plus eleven interim inventory verifications are currently carried out. Most unfortunately, due to process changes and problems with some of the (new) measurement equipment, there were difficulties in attaining the safeguards goals. These problems, however, are believed to have been overcome.

Most recently, the United States has begun to process the safeguarded material in Colorado for better safety and maintenance; it plans to continue to apply safeguards to that material (or equivalent) again once the processing is complete. By that time it may have moved to a new location in South Carolina, where IAEA safeguards will be applied again.

The Trilateral Initiative

In September 1994 and May 1995, respectively, both President Clinton and President Yeltsin made public statements regarding the transparency and irreversibility of nuclear arms reductions. The 1995 NPT Review and Extension Conference, which strongly supported the strengthening of safeguards, also agreed on principles and objectives calling upon the nuclear-weapon states to renew their efforts leading to nuclear disarmament. Similar principles were included in the final document of the 2000 NPT Review Conference.[10]

On September 17, 1996, U.S. Secretary of Energy Hazel R. O'Leary, Russian Minister of Atomic Energy Viktor Mikhailov, and IAEA Director General Hans Blix met to consider practical measures to fulfill previous statements made by the presidents concerning the application of IAEA verification of weapon-origin fissile materials; the Trilateral Initiative was established.

The initiative was then viewed as a significant contribution to the fulfillment of the principles and objectives agreed upon at the NPT Review and Extension Conference. The ministers also noted that this initiative was complementary to the commitments made by presidents Clinton and Yeltsin in 1994 and 1995 regarding the transparency and irreversibility of nuclear arms reductions. They also agreed to discuss technical methods designed to protect sensitive nuclear-weapons information and to prevent its disclosure, and to hold appropriate consultations with the IAEA on this matter. It was essential to ensure that IAEA verification of relevant fissile materials would not undermine U.S. and Russian obligations under Article I of the NPT.

The IAEA was tasked to draft a new model verification agreement and to prepare technical criteria and measurement procedures to provide agency inspectors with sufficient information to ascertain the presence of the declared fissile material, but also to prevent any proliferation of nuclear-weapons-related information through inspection or related verification activities.

Since 1996, the three principals have met at least once a year, usually during the IAEA General Conference, to take stock of the progress of the Trilateral Initiative. The most recent meeting was held on September 17, 2001, between U.S. Secretary of Energy Spencer Abraham, Russian Minister of Atomic Energy Rumyantsev, and IAEA Director General Mohammed ElBaradei.

In 1999, the director general reported to the IAEA Board of Governors on the initiative[11] and the IAEA Secretariat produced a first discussion paper for the Board of Governors on the options for the financing of such activities.[12] It is noted that presently all costs of the Trilateral Initiative are borne by the United States and provided to the agency outside the regular budget.

It is important to note that both states have earmarked nuclear facilities (K-Area Materials Store in the United States and the Mayak Storage Facility in Russia) to be included under the corresponding verification regime, once the agreements are approved both by their relevant authorities and the agency's Board and General Conference. However, further discussions are on the way to determine the relevance of these earlier selections.

Since then, the work on the drafting of the model verification agreement has reached the final stage. Similarly, details on the verification methodologies and associated measurement techniques have been developed to the extent that prototype instrumentation is being developed now. (The Trilateral Initiative and further details on the proposed verification methodology will be presented elsewhere in this *Journal.*)

The Plutonium Management and Disposition Agreement

In September 2000, the United States and the Russian Federation also signed a *bilateral* Plutonium Management and Disposition Agreement (PMDA).[13] This new agreement commits each party to the disposal of thirty-four metric tons of plutonium from its weapons program. It foresees the construction of new industrial-scale facilities to convert this plutonium into mixed-oxide fuel for commercial use in power reactors and, in the case of the United States, to dispose through immobilization of impure plutonium by incorporation of high-level vitrified radioactive waste. It also defines the target date for the operation beginning in 2007, with a minimum disposition goal of two metric tons per year initially and with an annual target quantity of four tons later. It is understood that some of the disposition options are currently being re-evaluated.

Bilateral and multilateral consultations continue. They include the G-8, which focuses particularly on the funding aspect of the Russian disposition facilities.

Article VII of the PDMA foresees consultations with the IAEA regarding an international verification system leading to the disposition of the weapon-grade plutonium. However, these consultations have not yet started. The relationship between the agency's role under the PMDA and the Trilateral Initiative has not been defined yet. Although it may be the IAEA Secretariat's current wish to include PMDA verification in the agreement coming out of the Trilateral Initiative, however, it is not clear at this stage whether that will be the future path to take.

The Fissile Material Cut-Off Treaty

The agency's NPT safeguards experience and the progress verifying that excess nuclear material remains removed from nuclear-weapons programs have influenced the development of the concepts under the Trilateral Initiative, its draft agreement and the verification methodology. However, the reduction of existing fissile material available for nuclear weapons is only credible if there is also a halt on the production of such new material. This is what the Fissile Material Cut-off Treaty (FMCT) is to accomplish.[14]

Its future is still undetermined, as negotiations in the Conference on Disarmament (CD) on a treaty have been requested but not started yet. The basis for negotiations in the CD is the Shannon Mandate of 1995, largely based on a U.N. General Assembly resolution, adopted in December 1993. In that resolution, the General Assembly recommended the negotiation of a "nondiscriminatory, multilateral, and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices." It also requested the IAEA "to provide assistance for examination of verification arrangements for such a treaty as required."

While no negotiations have taken place in the CD, individual delegations have put forward different concepts for the verification of an FMCT. It is clear that nonnuclear-weapon states party to the NPT have already committed themselves not to produce fissile material for nuclear weapons or other nuclear explosives, and that these commitments are being verified by the IAEA.

Hence, the verification provisions under a FMCT focus on the states that do not have a comprehensive safeguards agreement, the five nuclear-weapon states (China, France, Russia, the UK, and the United States), and India, Israel, and Pakistan.

The different concepts for an FMCT are often described as the extensive approach and the focused approach. In the extensive approach, all fuel-cycle facilities of the states concerned should come under verification. In the focused approach, verification would only involve facilities capable of producing direct-use nuclear material—essentially enrichment and reprocessing facilities. In that view, material not directly usable to make a nuclear explosive device, like natural or lightly enriched uranium production facilities should not be covered. (Further details on the FMCT will be available in other articles in this *Journal.*)

While the essential commitment of states party to an FMCT would be to cease production of fissile material for proscribed purposes, it has already become clear that the question of material produced before the entry into force of the treaty is of importance to a number of states. In as far as specific measures regarding such material would be agreed upon in the context of a FMCT, the agency's experience with verifying stocks of nuclear material and, in particular, its experience in designing measures for stocks of material from nuclear-weapons programs under the Trilateral Initiative is of value.

Irrespective of whether the negotiations would gravitate toward an extensive approach or a focused approach, the experience of the IAEA for the necessary verification activities to be carried out is of direct relevance. The agency has a wealth of experience in verification activities; it has a trained corps of inspectors; it has the necessary logistics in place and possesses an effective support infrastructure: it has a standing network of support programs to carry out research and development; it has safeguards agreements in force with all eight states concerned and it is widely regarded as a competent organization.

Conclusions

The agency has more than forty years of experience in applying safeguards in seventy states. This experience has been used to provide safeguards to the excess material, nuclear material irreversibly released from the nuclear-weapons program in the United States. The agency's safeguards experience has also helped to put the Trilateral Initiative on a fast forward track. The basic work on an agreement and on technical verification details is well on the way and may feed seamlessly into the PMDA.

Since *fissile material remains the most essential part* of a nuclear weapon, technology and approaches currently used for safeguards in non-nuclear-weapon states may be utilized, or further developed, to assure the international community that such material remains irreversibly removed from weapons programs. The agency's *experience in understanding relevant processes* from the nuclear-fuel cycle permit the application of *monitoring regimes* in nuclear facilities and their operation to assure that these facilities cannot be misused for proscribed activities under an international treaty that would ban the production of weapons-usable material.[15]

It must be remembered that the application of safeguards pursuant to the NPT is an agency's core activity. There is no such explicit and forceful mandate for the agency concerning of nuclear disarmament, unless an international agreement or treaty would designate the agency to become the verification organization for that agreement, too. The agency statute requests the agency to "conduct its activities … in conformity with policies of the U.N. furthering the establishment of safeguarded worldwide disarmament.…"[16] Technical skills and experience exist. A path from the IAEA's international safeguards regime of today leading to a verification arrangement under an FMCT may be possible.

References

1. Fisher, David. 1997. *History of the International Atomic Energy Agency, The First Forty Years*. Vienna, Austria.
2. IAEA. 1970. *INFCIRC/140: The Treaty on the Nonproliferation of Nuclear Weapons.* Vienna, Austria.
3. IAEA. 1972. *INFCIRC/153 (Corr.): The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Nonproliferation of Nuclear Weapons.* Vienna, Austria.
4. IAEA. 1997. *Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540 (Corrected),* Vienna, Austria.
5. IAEA. 2001. *The Safeguards Implementation Report for 2000.* Vienna, Austria.
6. The IAEA's Web page can be found at www.iaea.org.
7. IAEA. 1980. *INFCIRC/288: Agreement Between the United States of America and the Agency for the Application of Safeguards in the United States of America.* Vienna, Austria.
8. Ikonomou, Pantelis, and Dirk Schriefer. 2000. IAEA Safeguards in the USA: Past, Current and Future Activities. *Proceedings of the INMM 41st Annual Meeting.*
9. Schriefer, Dirk, and Thomas Shea. 1999. IAEA Perspectives on Excess Material. *Proceedings of the INMM 40th Annual Meeting.*
10. United Nations. 2000. *2000 Review Conference of the Parties to the Treaty on the Nonproliferation of Nuclear Weapons, Final Document, NPT/CONF.2000/28.* New York City, New York, U.S.A.
11. IAEA. 1999. *IAEA Verification of Weapon-Origin Fissile Material in the Russian Federation and the United States of America, GOV/INF/1999/8.* Vienna, Austria.
12. IAEA. 1999. *Financing Agency Verification of Nuclear Arms Control and Reduction Measures, GOV/INF/1999/9.* Vienna, Austria.
13. U.S. Department of Energy. 2000. Agreement Between the Government of the United States and the Government of the Russian Federation Concerning Management and Disposition of Plutonium as No Longer Required for Defense Purposes and Related Cooperation, September 1, 2000. In: U.S. Department of Energy: http://www.doe-md.com/ docs
14. There is no FMCT in force or in draft. Documentation is available from the U.N. Conference on Disarmament in Geneva, http://www.unog.ch/, but also from other organizations, i.e. the Institute for Science and International Security, on http://www.isis-online.org/publications/fmct, the Federation of American Scientists, on http://fas.org/nuke/control/fmct etc.
15. Schriefer, Dirk, Piet de Klerk, and Thomas Shea. 2001. The IAEA's Activities to Reduce Fissile Material for Nuclear Weapons. *Proceedings of the INMM 42nd Annual Meeting.*
16. IAEA. 1989. Statute. Vienna, Austria.

Nuclear Disarmament—The Role of International Safeguards

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Introduction

In 1995, when its validity was going to expire after twenty-five years, it became necessary to decide upon the future of the Treaty on the Nonproliferation of Nuclear Weapons (NPT). At the review and extension conference held at the United Nations headquarters in New York, something extraordinary happened, when it was decided to extend the validity of the NPT without time limit. This decision was linked to the conditions laid down in the "Principles and Objectives" of the final document. One essential element is related to the reduction of the nuclear arsenals in the nuclear-weapon states. This nuclear disarmament would have to take place under international control matching with the vision of the international nuclear safeguards in the non-nuclear-weapon states. With view to the next NPT Review Conference, which will take place in less than three years, it is interesting to look at the status of nuclear disarmament in the nuclear-weapon states, its control and interface with the international safeguards executed by the International Atomic Energy Agency (IAEA).

This paper begins by discussing factors and processes that are of relevance for disarmament and safeguards. Subsequently, the quantities and categories of nuclear material are presented that are under discussion for possible disarmament negotiations and that, in principle, could fall under international control and safeguards. As the Trilateral Initiative and a possible Fissile Material Production Cut-off Treaty are instruments offering visions for future disarmament, the paper concludes with a discussion of their statuses and perspectives.

Factors and Developments of Importance for Disarmament and Safeguards

The following factors and developments may be of importance for the outlined problem and can give some indications for a possible interface and have some impact on disarmament and safeguards.

Military Area

The disintegration of the former Soviet Union resulted in a new military constellation requiring a revision and reduction of the strategic nuclear potential on the part of the two super powers, i.e., Russia and the United States. Moreover, the technological development of new nuclear weapons leads to their miniaturization and, thus, to a reduction of the nuclear material quantities required for the weapons. Under these circumstances and with regard to their nuclear-weapons programs, the United States and the Russian Federation are able to manage with significantly less nuclear material in terms of both highly enriched uranium (HEU) and plutonium, so that, in principle, excess weapons material would be available for peaceful uses. It is the task of the international control to ensure, by the application of safeguards, that demilitarized material remains in the peaceful area.

International Terrorism

The events of September 11, 2001, shed a new light on the risk perception of terrorist attacks. Although the attack had been carried out using *conventional* means, the possibility of terrorists using weapons of mass destruction (WMD) has gained new topicality.

Generally, it is no longer possible to make a clear-cut separation between physical protection and safeguards. Basic technical assumptions on scenarios involving misuse and diversion by sub-national groups on the one hand, and national attempts at manufacturing weapons of mass destruction on the other hand, are becoming more and more similar. The ongoing evaluation process regarding the different risk levels of misuse and diversion lead to the conclusion that a holistic view of the overall nuclear materials control should be applied and standards set without differentiating between national and sub-national threat structures.

The IAEA has tightened its physical protection program in general and, in particular, with regard to the theft as well as diversion of nuclear materials. From a technical point of view measuring and monitoring systems designed for and applied in safeguards could also be used for physical protection.

Globalization and Liberalization of Energy Markets

It is realized that, due to the globalization and advancing liberalization of energy markets, activities in the nuclear sector are also more and more meshed at the international level. This is particularly true for the nuclear services related to supply and waste management. Germany, for instance, is supplied with uranium enrichment services in the frame of the multinational company URENCO. In addition, the increasing globalization will further reduce the structural differences between nuclear-weapon states (NWS) and non-nuclear-weapon states (NNWS) as far as the commercial use of nuclear energy is concerned.

Global Change and Sustainable Development

With a view to the assessment of innovative technologies under the aspect of future supply scenarios, the concept of sustainable development has proven to be a successful tool in the energy sector. This includes anticipated innovations in the nuclear sector as well. The eminent assessment criteria are acceptance, economic efficiency, availability of resources, and climate protection. In the frame of INPRO as well as of Generation IV[1] innovative nuclear energy technologies are being assessed using these criteria. Acceptance analyses place particular emphasis on the aspects of plant safety and nonproliferation. The question is: To what extent are the innovative nuclear technologies under investigation able to provide an inherent increase of nonproliferation resistance?

It can be concluded that trends in the military area suggest a transfer of excess weapon-grade material to the civilian sector. Globalization of energy markets and the concept of sustainable development ask for common standards when safeguarding the peaceful use of nuclear energy in all countries, i.e., weapon states and non-weapon states. Both the increased risk of terrorist acts against nuclear installations and the possible misuse of nuclear materials ask for the strengthening of these standards.

Characterization of Nuclear Material Flows

The starting point for the control of the nuclear material in the nuclear fuel cycle is the uranium mining. However, the starting point for the quantitative recording and balancing for safeguards purposes is the production of yellow cake from which nuclear fuel elements are manufactured. This is when the nuclear material has a configuration appropriate for accounting measures.

From the perspective of verification, the nuclear materials present in the nuclear technical processes can be categorized as:

- Civilian nuclear materials under IAEA safeguards
- Nuclear materials not under IAEA safeguards (i.e., predominantly military but also civilian materials)
- Nuclear waste materials.

In the NNWS of the NPT there is the possibility of terminating IAEA safeguards on nuclear wastes under certain conditions. In the NWS as well as in the states not party to the NPT, nuclear waste is not under safeguards.

With regard to the termination of safeguards on nuclear wastes the following can be stated. While it would be possible to exempt vitrified wastes from reprocessing from safeguards, this would not be possible for irradiated fuel elements from nuclear power reactors. In 1988, an international consensus was reached to keep spent fuel under IAEA safeguards as long as nuclear safeguards persist in the future. That is why the IAEA already is interested in studying safeguards measures that might be appropriate for monitoring decommissioned, backfilled, and sealed geological repositories filled with spent fuel.

Table 1 summarizes the nuclear materials that the IAEA has under its control. The materials are exclusively designated for civilian purposes in the states using the materials, e.g., for electricity generation as well as research and development. The distinction is made between the plutonium, HEU, uranium-233, depleted, natural and low-enriched uranium (DU, NU, LEU), thorium, and *source material.* In contrast to uranium, plutonium is not characterized by its isotopic composition. The uranium-235 isotopic content of HEU is 20 percent and higher, while for DU it is less than 0.7 percent. NU contains 0.7 percent uranium-235 and LEU between 0.7 percent and 20 percent. The term source material is applied for NU, DU, and thorium in metallic form, alloy, chemical compound, and concentrate.

Civilian materials may not be subjected to IAEA safeguards for two reasons:

- The materials are used in states that have not adhered to the NPT. According to the INFCIRC/66 model agreement, in these states only part of the nuclear fuel cycle is under IAEA safeguards, whereas there are also nuclear activities not under IAEA safeguards. Therefore, nobody is really able to decide, to what extent these activities have civilian or military character.
- In the five NWS, i.e., China, France, Russia, UK, and the United States, having concluded voluntary-offer agreements with the IAEA, the predominant part of the civilian sector remains without IAEA safeguards.

For all of these states reliable information is lacking on the quantities of nuclear materials not under safeguards.

As the IAEA does not control the military sector, the quantities of weapons materials distributed around the globe and their status of production can only be estimated.[2] Moreover, there are very large quantities of enriched uranium used for the propulsion of military submarines. Table 2 gives the quantitative estimates of materials in the military sector.

Table 1. Nuclear Material Quantities Under IAEA Safeguards
(as of end of 2000; quantities given in tons; IAEA Annual Report 2000, Vienna, July 2001, p. 102)

Material Type	States with INFCIRC/153-type or Equivalent Safeguards agreements in force	States with INFCIRC/66-type Safeguards Agreements in Force	Nuclear Weapons States (*)
Pu contained in irradiated fuel	534.4	27.9	80.5
separated Pu outside reactor cores	12.5	0.1	59.7
Recycled Pu in fuel elements in reactor cores	10.3	0.4	0
HEU	11.0	0.1	10.7
LEU	42,147	2,786	4,041
Source material	78,942	1,646	11,089

(*) including material from dismantled weapons

Table 2. Nuclear Material Quantities in Military Uses
(as of end of 1999; estimated quantities given in tons, with uncertainties;
Institute of Science and International Security (ISIS), www.isis-online.org)

State	Plutonium	HEU weapon-grade uranium equivalent	Status
United States	100	635	Production halted
Russian Federation	130	970	Production halted
UK	7.6	15	Production halted, but could purchase HEU from United States
France	5	24	Production halted
China	4	20	Production believed to be halted
Israel	0.51	?	Production continues
India	0.31	small quantity	Production continues
Pakistan	0.005	0.69	Production likely accelerated in 1998
DPRK	0.03-0.04	–	Production frozen
South Africa[1]	–	0.4	Nuclear weapons dismantled, stocks converted to civilian use

[1]*South Africa destroyed its nuclear weapons, adhered to the NPT, and subjected all its nuclear material to IAEA Safeguards.*

From the information about the quantities of peaceful and military nuclear materials and their relevant categories the following can be derived: First, the separation of peaceful and military nuclear activities in NWS, in particular in Russia and the United States, is considered an important step toward disarmament. However, due to the complexity of their nuclear fuel cycles, this process will not be easy and will take a long time, i.e., there is a major practical obstacle. It can be seen from the European example that such a process can be successful, as in the UK and France; due to their Euratom commitments, such a separation has been achieved. Furthermore, it is expected that the liberalization of the energy market and also of the nuclear energy market will give an important push toward separating peaceful and military activities.

Secondly, the question of the safeguards effort must be addressed, if the quantities of nuclear material listed above are offered for disarmament and would come under international control. It will be a matter of adapting the safeguards intensity, in order to come up with cost effective solutions. Compared to safeguards in the NNWS, frequency and scope of inspections may have to be reduced, but the safeguards principles should remain the same, e.g., accountancy, terminating, and starting of safeguards. In conclusion, declaration standards should be equal in all states, whereas verification standards could be different.

Regarding the categories of material, the weapon-grade plutonium is of special concern. For this material, customized equipment that avoids the transfer of proliferation-relevant information and know-how has to be developed. In the frame of the Trilateral Initiative the principle of an information barrier has emerged to tackle this problem.

Future Verification in Nuclear Disarmament

With regard to the future control of nuclear materials resulting from nuclear disarmament, two options can be identified: (1) the Trilateral Initiative and (2) the future Fissile Material Production Cut-off Treaty (FMCT).

Trilateral Initiative

In 1996, the IAEA, the Russian Federation, and the United States launched investigations on technical, legal, and cost aspects in order to enable IAEA verification of weapon-origin fissile materials in Russia and the United States. This effort became known as the Trilateral Initiative.

In the framework of the Trilateral Initiative, the United States, Russia, and the IAEA intensely negotiate on the role of IAEA safeguards related to the verification of nuclear disarmament. The objective is to place nuclear materials dismantled from warheads under IAEA safeguards, while these nuclear materials must not be re-transferred into the military sector.

So far, the government agreement of 2000-09-01 foresees that the United States and Russia each isolate thirty-four tons of unirradiated plutonium from their warheads and transfer this material to facilities where the IAEA can verify and monitor it. A measuring method that would allow the initial measurement of sensitive nuclear material upon receipt by the IAEA without disclosing secret, i.e., proliferation-relevant, information to the IAEA inspectors is under development.

Basically, two questions remain unresolved:

- When should the IAEA safeguards be terminated? and
- Is it possible to substitute materials?

The Fissile Material Production Cut-off Treaty (FMCT)

The attempts at limiting the production of weapons-grade materials reach back to the early stages of using nuclear energy in the early 1950s. However, only the end of the Cold War gave tangible form to proposals by the Russian[3] president in 1989 and by the U.S. president in 1993.

These proposals finally led to a mandate for the Conference on Disarmament (CD) in Geneva. This mandate, CD/1547, dated August 11, 1998, reads:

"Draft Decision on the Establishment of an ad hoc Committee under item 1 of the Agenda entitled 'Cessation of the Nuclear Arms Race and Nuclear Disarmament' ... which shall negotiate, on the basis of the report of the Special Co-ordinator (CD/1299) and the mandate contained therein, a nondiscriminatory, multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices."

In addition, three years before the CD mandate was laid down, resulting from the 1995 NPT Review Conference, the Objectives and Principles for Nonproliferation and Disarmament demanded a "nondiscriminatory and universally applicable Convention banning the production of fissile materials for nuclear weapons and other nuclear explosive purposes."

Principal Requirements of the FMCT

In order for the FMCT to be effective and efficient, four requirements—derived from the aforementioned results of the 1995 NPT Conference—are considered to be of utmost importance:

I. **Universality:** The FMCT shall be universally applied on a global basis. This requires accession to both the future fissile material production cut-off and the comprehensive test ban treaties, not only by the present NWS but also by the threshold states of India, Israel, and Pakistan and by the present NNWS. It is anticipated that India, Israel, and Pakistan will play key roles in the entry into force of the FMCT, i.e., without these states the FMCT could not be considered universal.

II. **Nondiscrimination:** All rights and obligations arising from the FMCT have to be equally applied to all parties to the treaty.

III. **Irreversibility:** Fissile material inventories once declared for civilian uses must not be devoted to military purposes.

IV. **Transparency:** The compliance with both the prohibition of fissile material production for military purposes and non-transfer of civilian inventories into military uses must be reliably verified. The kind and scope of the remaining military inventories must be as transparent as possible.

Scope of the FMCT

The FMCT should regulate the prohibition of the future production of fissile material for the manufacturing of nuclear weapons or other nuclear-explosive devices. In contrast, the permitted processing for "known purposes" should include the downblending of weapon-origin material, the fabrication therefrom of mixed-oxide fuel assemblies and their use/irradiation in civilian reactors, alternatively the mere dilution and immobilization of ex-military material in a stable matrix, and the direct final disposal of spent/irradiated fuel or immobilized material in geological repositories. Also, the fabrication of fuel assemblies for ship propulsion should be considered a permitted use. Facilities that have been used to produce material for military purposes should be in the focus of the FMCT, such as certain reactor types, enrichment plants, and reprocessing plants.

Secondly, the FMCT should regulate the prohibition of the transfer of fissile material from civilian uses to military uses. In particular, fissile material that had been declared to be in excess of what was needed for defense purposes and had been submitted to IAEA safeguards is not to be re-transferred to military uses, like under the Trilateral Initiative. These materials should then be categorized under "permitted processing for known purposes" as specified above.

Verification of the FMCT

In Table 3, INFCIRC/540 forms the *top layer* of the safeguards system discussed in the following. The goal is to arrive at a universal IAEA integrated safeguards system by superseding the existing safeguards agreements, i.e., INFCIRC/153- and INFCIRC/66-type agreements as well as voluntary-offer agreements. According to these agreements, the states are categorized into three major groups, i.e., NNWS, NWS, and threshold states. In addition, there exist regional safeguards agreements and the Trilateral Initiative between Russia and the United States, which can be used to further subdivide the states into seven individual groups—G1 through G7.

Table 3. Possible Treaty Situations in Anticipation of the Implementation of the IAEA Integrated Safeguards System

INFCIRC/540 + 153			INFCIRC/540 + Voluntary-offer agreement			INFCIRC/540 + 66
SSAC[1] G1	RSAC[2] G2	RSAC[3] G3	G4	RSAC[4] G5	Trilateral Initiative G6	RSAC[1] G7
All NNWS Parties to NPT (182)	All NNW within the EU (13)	Argentina, Brazil	China	France, United Kingdom	Russia, United States	India, Israel, and Pakistan
Integrated IAEA Safeguards	Integrated IAEA Safeguards + Euratom Safeguards	Integrated IAEA Safeguards + ABACC Safeguards	Some kind of integrated IAEA Safeguards	Some kind of integrated IAEA SG + Euratom Safeguards	Some kind of integrated IAEA Safeguards	Some kind of integrated IAEA Safeguards

[1]. *State System of Accounting and Control*
[2]. *Regional System of Accounting and Control: Euratom Safeguards Office*
[3]. *Regional System of Accounting and Control: Argentine Brazilian Agency for the Accounting and Control of Nuclear Material*
[4]. *In France and the UK, defense purpose materials are exempted from Euratom safeguards.*

In groups G1 through G3, comprehensive safeguards agreements exist under the NPT according to the INFCIRC/153 Model Agreement for NNWS involving full-scope safeguards under the IAEA's current safeguards system.

In groups G2 and G5, the treaty establishing the European Atomic Energy Community (Euratom Treaty) involves equivalent safeguards conducted by the Euratom safeguards Office in all European Union (EU) states including the NWS France and the UK.[4] While France and the UK (see group G5) concluded voluntary-offer agreements with the IAEA, up until now the IAEA has performed safeguards activities only in connection with nuclear trade related to NNWS. For all EU states the Additional Protocol will enter into force on the date when the IAEA receives written notice from the EU states and the Euratom Safeguards Office that their respective requirements for entry into force have been met.

The Quadripartite Safeguards Agreement (QSA) between the IAEA, Argentina, Brazil, and the Argentine Brazilian Agency for the Accounting and Control of Nuclear Material (ABACC) regulates the safeguards requirements in Argentina and Brazil (see group G3). In addition, the QSA satisfies the requirements of Argentina and Brazil under Article III of the NPT to conclude a safeguards agreement with the agency. However, Argentina and Brazil have not signed the Additional Protocol.

China (see G4) has a voluntary-offer agreement with the IAEA and an Additional Protocol in force.

The United States and the Russian Federation (see G6) have voluntary-offer agreements with the IAEA and signed INFCIRC/540. Both states have embarked on the Trilateral Initiative that aims at the IAEA verifying weapons-origin fissile materials released from the defense sectors and declared excess materials. This is intended to be enabled by concluding bilateral safeguards agreements between the IAEA and either state.

Finally, group G7 consists of India, Israel, and Pakistan. While India and Pakistan demonstrated and confirmed nuclear explosions, Israel has not done so. All three states are termed threshold states, and it is in the highest interest of the world community to include them into the global nonproliferation regime. They have INFCIRC/66-type safeguards agreements in force with the IAEA. However, neither of them has signed the Additional Protocol.

Summarizing the treaty situations, it can be stated that the Additional Protocol INFCIRC/540 is the latest attempt at overcoming the disparity of existing IAEA safeguards systems under INFCIRC/153, INFCIRC/66, and voluntary-offer agreements by implementing a universally accepted approach. Moreover, it is the intention of the Russian Federation and the United States that the IAEA is involved in the nuclear disarmament process. The universal conclusion of a FMCT would add another treaty layer, which might not necessarily add new safeguards.

In principle, arrangements under existing safeguards agreements persist. Additionally, INFCIRC/540 foresees expanded declarations and universal reporting on the part of the states, extended inspector access, environmental sampling, and acquisition of additional information from open sources including commercial satellite imagery on the part of the IAEA.

The Additional Protocol provides the institutional framework for extending the scope of nuclear material control also to materials that will come under safeguards through disarmament negotiations. While the basic technical tools and instruments are available to implement this task, the question is whether the IAEA will have available the additional budget and resources to cope with the effort. As already stated, the trend is to save inspection effort in traditional safeguards in connection with the implementation of the integrated safeguards. This can serve as a model to reduce verification effort without compromising basic safeguards principles.

Conclusions

Following the 1995 NPT Review and Extension Conference there have been both advances and a stalemate regarding nuclear disarmament and its verification. Advances are related to the development and implementation of integrated safeguards, which are now being successfully introduced in the IAEA. On the other hand, the adherence on the part of important states to the new protocol additional to the safeguards agreements has not at all been satisfactory so far. The Additional Protocol, with its different versions applying to nuclear-weapons states, nonnuclear-weapons states, and states outside the NPT, will provide a basis for the verification in the nuclear disarmament sector.

For neptunium, a control scheme has been developed and implemented, which is characterized by effectiveness and efficient measures while forgoing detailed accounting and follow-up measuring (low-level verification). In the area of the Trilateral Initiative, a model agreement emerges that is still awaiting its implementation.

Regarding the FMCT, no progress can be reported.

In order to pave the way for the future application of nuclear energy, an international effort will be required to counter the risk of terrorist attacks while enhancing the nonproliferation regime as regards both horizontal and vertical proliferation. In the civilian nuclear sector, the latter has been achieved by introducing the provisions of the INFCIRC/540 Additional Protocol. In the military nuclear sector, adequate steps will be necessary, such as:

- Separating civilian and military nuclear activities
- Implementing the Trilateral Initiative
- Concluding the FMCT, and
- Providing a proliferation resistant fuel cycle.

Coming back to the question asked initially, whether after the 1995 NPT Conference, which resulted in the unlimited extension of the validity of the NPT, sufficient and necessary steps were made toward nuclear disarmament, the answer is that some promising steps have been made and are still being made. However, they do not at all meet the expectations.

Finally, it can be clearly stated that the IAEA is ready to play the central role in the international control of nuclear materials, facilities, and activities, which are of relevance for disarmament. This is supported by the implementation of the Additional Protocol and a new control scheme for neptunium, negotiations related to the Trilateral Initiative, and developments of new technical safeguards systems. Also, the efforts in introducing a stronger cost-effectiveness element in safeguards will support the agency's role in this process.

Literature

Andrew, G., W. McCarthy, and A. Barlow. 2000. The Scope and Verification of a Fissile Material Cut-off Treaty. *Proceedings of the 41st INMM Annual Meeting.*

Carlson J., and V. Bragin. 2000. FMCT Verification—Precedents from other Regimes. *Proceedings of the 41st INMM Annual Meeting.*

Holgate, L.S.H. 1999. Plutonium Disposition: A Case Study of Nuclear Materials Management. *Proceedings of the 40th INMM Annual Meeting.*

Mueller H., and N. Schörnig. 2001. Revolution in Military Affairs; *Hessische Stiftung Friedens- und Konfliktforschung, HSFK-Report* No. 8, 2001.

Richter, B., W.-D. Lauppe, G. Stein, and H.H. Remagen. 1999. The Future Fissile Material Cut-off Treaty: The Verification Issue. *Proceedings of the 40th INMM Annual Meeting.*

Schaper, A. 2000/2001. Principles of the Verification for a Future Fissile Material Cut-off Treaty (FMCT); *Hessische Stiftung Friedens- und Konfliktforschung, PRIF-Report* No. 58.

Shea, T. E. 2001. Report on the Trilateral Initiative: IAEA Verification of Weapon Origin Material in the Russian Federation and United States. *IAEA Bulletin,* Vol. 43, No. 4.

Stein, G. 1999. The Fissile Material Cut-off Convention: Problems and Challenges. *Bulletin of Arms Control,* No. 34.

End Notes

1. INPRO (Innovative Nuclear Fuel Cycle Program) and Generation IV are initiatives in the IAEA and United States to identify nuclear fuel cycle and reactor concepts that will satisfy future energy needs complying with Sustainable Development.
2. Although the Democratic People's Republic of Korea (DPRK) has adhered to the NPT, it is not clear whether the DPRK possesses weapons material, as the IAEA inspections necessary to resolve the problem are inhibited by the DPRK government.
3. In 1989, the Soviet Union still existed.

How to Deal with Monitoring and Verification Challenges in a World with Low Numbers of Weapons and Large Stocks of Nuclear Material

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Note: The views expressed here are personal and do not represent official positions of the Los Alamos National Laboratory, the University of California, or the U.S. government.

Achieving deep reductions in numbers of nuclear weapons, leading to their ultimate elimination, has been a goal of some in the international community for many years. However, only with the end of the Cold War has there been even a remote possibility of starting down this path. The 1990s saw a number of studies and reports relating to the desirability and feasibility of a nuclear-weapon-free world, including, for example, the Canberra Commission report,[1] the *Getting to Zero* project of VERTIC,[2] and *The Nuclear Turning Point.*[3] The NPT 2000 Review Conference drew attention to the progress, or lack thereof, depending on one's views, made by the nuclear-weapons states on Article VI of the treaty. In a statement of the five nuclear powers, the delegations of France, China, Russia, the United Kingdom, and the United States "…reiterate our unequivocal commitment to the ultimate goals of a complete elimination of nuclear weapons and a treaty on general and complete disarmament under strict and effective international control."[4]

The final document issued by the 2000 NPT Review Conference noted that among "the practical steps for the systematic and progressive efforts to implement Article VI… and… the 1995 Decision on Principles and Objectives for Nuclear Non-Proliferation and Disarmament…[is] the further development of the verification capabilities that will be required to provide assurance of compliance with nuclear disarmament agreements for the achievement and maintenance of a nuclear-weapon-free world."[5] Effective verification, although important to arms reduction in general, is central to the question of whether or not a nuclear-weapon-free world is believed to be more or less secure, and has been the subject of a number of reports.[6] Verification and supporting technical monitoring measures can potentially cover a very broad spectrum of activities and indicators, including delivery systems, production and manufacturing infrastructures, stockpiles of weapons and nuclear materials, and the processes associated with the reduction, dismantlement, and disposition of nuclear weapons. In the context of ensuring irreversibility of arms reductions, the control of nuclear materials is seen as playing a central role in future agreements and treaties such as a production cut-off and the monitored transfer of excess military materials to civilian uses as a part of their disposition. It is the question of monitoring nuclear materials in support of arms reductions that I want to address here.

There is, of course, considerable international experience in monitoring nuclear materials for nonproliferation, and it is tempting to merely *import* these international safeguards measures for arms reduction. However, the goals and objectives of nonproliferation and arms reductions may not be similar, at least until there are no longer any known nuclear weapons, and there are important pragmatic issues to be addressed for arms reductions for which nonproliferation monitoring solutions may not constitute the best approach. At the least, a reasoned debate is warranted regarding international approaches to monitoring nuclear materials for arms reduction purposes.

It is widely acknowledged that verification systems cannot provide 100 percent assurance of compliance with treaties and agreements. Furthermore, if one is willing to set aside the political significance of low levels of noncompliance to focus on militarily significant cheating, the required performance of monitoring systems and the quality of verification conclusions are very much a function of the overall security environment. The question of how effectively we must monitor nuclear materials in a world with zero nuclear weapons is already answered to some degree by the standards adopted in the nonproliferation context, although these standards, which would almost certainly have to include universal adherence to the new strengthened safeguards measures, might be re-examined as zero is approached. The International Atomic Energy Agency (IAEA) system of safeguards, the monitoring system of the NPT, is designed for "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."[7]

The standards adopted by the IAEA are such that a significant quantity is related to the quantity of material required to manufacture a nuclear explosive device; taken to be 8 kg in the case of plutonium.[8] Thus, what arms controllers might term the "breakout" quantity of material for nonproliferation is the amount that would be required to go from zero to one weapon, and it would seem in a world with zero nuclear weapons, a standard like this one would have to be applied universally. In some sense, from a policy perspective, this is the trivial case of the nuclear materials monitoring problem—everything and everyone must be held to the same standards, whatever they may be. It is worth emphasizing, however, that reliable implementation is unlikely to be trivial. Monitoring, and reaching verification conclusions, will provide the utmost challenge to technologists and inspection institutions, and will have to address very difficult questions such as confidence in initial inventory declarations and the possible existence of hidden stockpiles.

The nontrivial nuclear materials monitoring policy questions arise in situations that range from the present conditions to those that would obtain with very low, but non-zero, numbers of nuclear weapons. Although some have suggested that all controls over nuclear materials for arms control/reduction purposes should be similar to international safeguards, this view may not be practical or cost-effective. Thus, there is the possibility of nuclear materials monitoring systems with dual standards, one for states with nuclear weapons engaged in deep reductions or already at low levels, and one for nonnuclear weapons states committed to nonproliferation. Would such dual standards be possible? Would they facilitate irreversible deep reductions? Would they undermine nonproliferation standards or otherwise damage cherished nonproliferation norms? Would dual standards make the eventual transition from low numbers to zero more or less secure? Does the concept of universality mean complete participation in the undertaking or the application of the same standards to all regardless of circumstances? Finally, would dual standards be desirable?

To help address these questions, consider the following scenario. The world consists of a handful of states with nuclear weapons, each with no more than 250 weapons total—strategic, tactical, reserve, etc.[9] Peace has not broken out, and these weapons are an integral part of each state's security posture. The NPT remains in force and a universal fissile materials production cut-off treaty with associated monitoring provisions has been implemented. Nuclear materials resulting from weapons dismantlements are declared excess to defense needs and placed under international monitoring using IAEA-state bilateral agreements based on a model developed under the Trilateral Initiative. Civil nuclear power and its associated inventories of nuclear materials remains in use at today's levels, resulting in civil inventories of plutonium, both separated and in spent fuel, that greatly exceed the quantities produced for all the weapons programs. All the world's civil facilities and materials are under some form of international safeguards. Thus, all states are party to a treaty requiring the monitoring of some or all of its nuclear materials. The IAEA has the job of monitoring all the nuclear materials in the world subject to these treaties and agreements. The question of dual standards can now be addressed in the context of a proposal; that the allocation of scarce inspection resources—both technological and personnel—within the IAEA Secretariat should be based on pragmatic considerations in support of the technical objectives of the relevant agreements, taking account of the technical risks, and the consequences of failures in the monitoring system.

To focus the discussion (and to stimulate debate), it is useful to derive a crude arms reduction equivalent to the safeguards significant quantity (8 kg of plutonium). In doing this, however, it is important to emphasize that these significant quantities are being used here, in part, as symbols for a larger and more complex set of inspection standards and procedures.

For a state with 250 weapons, breakout by another weapons state with 250 weapons is taken to be a doubling—to a total of 500 weapons. In a nuclear materials monitoring context, this requires an amount of material for 250 weapons and the ability to rapidly (or without detection) fabricate them. If we postulate experienced weapons states might be more efficient in their manufacturing than assumed by the IAEA,[10] and take a hypothetical mass of 4 kg as sufficient for one nuclear explosive device, then the arms control breakout quantity becomes 1,000 kg, or one metric ton of plutonium. From a security standpoint, the monitoring system to ensure compliance by the weapons states with their arms reduction commitments should be designed and implemented to detect the rapid (within one year?) production or diversion of one metric ton. (There would also have to be comparable confidence in initial inventory declarations and the absence of hidden stockpiles.) At the same time, the corresponding standard for nonproliferation commitments on civil materials in non-weapons states would remain 8 kg (with a detection time on the order of weeks for pure materials). Although not all inspection activities and resource requirements are a function of these quantities, these two standards would lead to very different inspection systems and utilization of resources within the IAEA.

It is worth noting that advances in monitoring and inspection technologies will be important for all nuclear materials verification activities, and can potentially play a role in diminishing the apparent large differences in these proposed arms reduction and nonproliferation inspection standards. For example, continuous, unattended surveillance systems for plutonium stores are likely to look very similar whether the goal is the detection of diversion of 8 kg or 1,000 kg. On the other hand, significant differences will arise in areas such as inventory (re)verification in which the two standards dictate different levels of intrusiveness and inspection effort.

Returning to the questions posed earlier in the specific context of this scenario:

Is it possible to apply different standards for monitoring nuclear materials within one institution such as the IAEA? Technically, the answer should be yes. Inspection systems can be designed and inspectors trained to meet different objectives. Today the IAEA conducts inspections under INFCIRC/66 (limited to specific facilities and subject material) and INFCIRC/153 (full-scope safeguards). Furthermore, some states have signed and ratified the additional protocol (INFCIRC/540) while others have not, leading to the prospect of differing standards as these measures are implemented. Different standards might complicate life somewhat, but they should not present a fundamental obstacle to implementation.

Would different standards for international nuclear materials monitoring facilitate deep reductions? Most likely, yes, (although some might argue unilateral actions with no required monitoring would result in the most rapid reductions). States with nuclear weapons will be reluctant to expose more of their sensitive national security apparatus to monitoring and inspection than is necessary to meet the technical objective of ensuring irreversible reductions. Standards derived from arms reduction and related security considerations (e.g., breakout) are likely to be embraced more readily than those that are seen as not contributing directly to enhanced security. Cost will also likely be a significant consideration, with all states being unwilling to pay for measures with marginal demonstrable contribution to improving security.

Would different standards undermine nonproliferation standards and norms? The technical dimension of this answer is no, but the political dimensions are more complex and could be seen as yes. In this regard, the obligations of the nuclear weapon state (NWS) parties to the NPT relate to Article VI, and do not include a commitment to submit to equal pain under safeguards. Nevertheless, as illustrated by the so-called voluntary-offer agreements (VOA) undertaken by each of the NWS, there has been some desire in the international community to at least make the NWS aware of the pain of safeguards. In addition, there has been a desire by the United States to lead by example and to submit to VOA measures, including placing unclassified excess weapons materials under IAEA safeguards. The interest of some states subject to safeguards in lessening their perceived burden should not be discounted either. Adopting arms reduction monitoring standards for safeguards, although not justified technically, would be tempting for those who believe that current safeguards are excessive (at least for them).

Would different standards make the ultimate transition to zero more or less secure? The answer here is it depends on how the standards are managed, along with many other key provisions, as true zero is approached. Some argue that true zero is so uncertain and the monitoring and verification challenges so daunting that we should understand *zero* to mean numbers like 200 weapon cores separated from warheads and delivery systems.[11] In any case, evolving arms reduction-based nuclear monitoring standards, and perhaps those for nonproliferation as well, from a world near zero to one of true zero, will be one of the more straightforward problems.

What about universality? In this scenario, all states are participating in some kind of nuclear materials monitoring, either for arms reduction or nonproliferation purposes. Thus, there is a universal norm associated with the control of nuclear materials; however, the standards applied to monitoring and inspection activities are specific to the technical objectives of the agreements to be verified. This kind of approach has been discussed for a fissile materials cut-off treaty, in which states under full-scope safeguards (and their associated standards) would be considered to meet the obligations of a cut-off treaty, while weapons states and those not under safeguards might be subject to a focused verification approach for cut-off that concentrates on enrichment, reprocessing, high-enriched uranium, and separated plutonium and that, for example, does not require inspections at power reactors and spent fuel repositories.[12]

Finally, and as a conclusion, are dual standards for monitoring and verification desirable? On balance, the answer is yes, because pragmatism and cost-effectiveness must win out over more political agendas if we are to reach the very ambitious goals represented by a world with even low numbers of nuclear weapons. The opportunities are too great and the costs of failure are too high to sacrifice the possibility of adequately verifiable deep reductions for the sake of the “purity” of a common monitoring and verification standard applied to all states under all circumstances. There is much to be learned from the application of international safeguards, and proven technologies to be borrowed, but it is not necessary or desirable to apply safeguards to all nuclear materials until true zero is reached.

References

1. *The Canberra Commission on the Elimination of Nuclear Weapons.* Available at http://www.dfat.gov.au/cc/cchome.html.
2. Summaries available at http://www.vertic.org/verification/verification.html.
3. Harold A. Feiveson, ed. 1999. *The Nuclear Turning Point: A Blueprint for Deep Cuts and De-Alerting of Nuclear Weapons.* Brookings Institution Press, Washington, D.C.
4. Available at http://usinfo.state.gov/topical/pol/arms/stories/00050104.htm.
5. Available at http://usinfo.state.gov/topical/pol/arms/stories/finaldoc.htm.
6. See, for example, Annette Schaper and Katja Frank. 1999. *A Nuclear Weapons Free World—Can it be Verified?* Peace Research Institute. Frankfurt. PRIF Reports No. 53.
7. The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, INFCIRC/153.
8. 1987. *IAEA Safeguards Glossary* 1987 Edition, IAEA/SG/INF/1 (Rev.1). This paper will consider only plutonium for the sake of brevity.
9. *The Nuclear Turning Point,* Chapter 10, Completing the Deep Cuts Regime, contains an extensive discussion of low numbers, including the notion of equal numbers for all states with nuclear weapons.
10. In a paper on safeguards requirements for a fissile cut-off treaty, Thomas E. Shea of the IAEA writes, "…an amount of 8 kg is considered adequate for a state to produce its first nuclear weapon, taking into account process losses and the need to be conservative in the design, absent the benefit on nuclear tests." From Reconciling IAEA Safeguards Requirements in a Treaty Banning the Production of Fissile Material for Use in Nuclear Weapons or Other Nuclear Explosive Devices, Thomas E. Shea, *Disarmament Forum,* Federation of American Scientists Web site, http://www.fas.org/nuke/control/fmct/
11. Mortin H. Halperin. 1998. Defining Zero and Getting There. In *The Road to Nuclear Zero: Getting There,* CASI Report. Center for the Advanced Study of India, University of Pennsylvania, Philadelphia, Pennsylvania.
12. The Federation of American Scientists Web site, http://www.fas.org/nuke/control/fmct/, has links to papers expressing differing views on the scope and verification standards for an FMCT, for example, Victor Bragin and John Carlson; FMCT: Some Significant Divisions in the Scope Debate, and Annette Schaper, Verification of a Fissile Material Cut-Off Treaty.

The Trilateral Initiative: Getting Ready

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Abstract

This paper summarizes the accomplishments of the Trilateral Initiative to date and identifies the future steps foreseen.

Fissile material controls offer perhaps the most obvious means through which the international community can participate in verifying progress towards nuclear disarmament. Controls on excess military stocks of fissile materials can provide assurance that those fissile materials are not returned to military use, and provide one means through which the international community can encourage nuclear arms reductions and steps to decrease the nuclear-weapon production capabilities of states possessing nuclear weapons. The Trilateral Initiative was launched in 1996 to investigate the technical, legal, and financial issues associated with IAEA verification of weapon-origin fissile material released from the military programs in Russia and the United States. Most of those fissile materials remain in classified form, or with classified characteristics. The high costs and long process times required for the disposition of those materials suggest that for the Trilateral Initiative to provide a significant impact, the amounts of fissile material submitted must be as large as possible and as soon as possible; hence, the IAEA must be able to verify fissile material with classified characteristics.

Six years on, technical concepts and prototype equipment suitable for such a verification mission have been developed and demonstrated, the elements of a legal framework have been defined and drafted, preliminary cost estimates have been made and alternative financing arrangements have been identified. The Trilateral Initiative has come to the point where several challenges must now be met: the technologies and inspection procedures must be proven under realistic conditions so that the national certification and IAEA authentication concerns can be assured; several bilateral issues need to be resolved between the United States and the Russian Federation; and the legal framework and some remaining verification issues need to be settled.

Introduction

In the Final Document of the 2000 NPT[1] Review Conference, under the part pertaining to Article VI of the Treaty,[2] all 187 NPT state parties agreed to include the following action: "Complete and implement the Trilateral Initiative." Placing this statement in the Review Document gives the Trilateral Initiative a certain amount of recognition and places it on the future NPT agenda. It is number eight of thirteen points to be taken up at the next review of Article VI in 2005, and at the preparatory committee meetings leading up to the 2005 NPT review.

The Trilateral Initiative was launched in 1996 following independent statements by the president of the United States beginning in 1993, and by the president of the Russian Federation in 1996. It is an initiative between the IAEA, the Russian Federation, and the United States in the context of Article VI of the NPT. The Trilateral Initiative has endured change and challenge; new governments have been elected in both countries since then and all of the principals guiding this initiative have changed.

Every nuclear weapon uses one or more fission energy elements, and every fission energy element of every nuclear weapon requires certain fissile material, generally plutonium containing 93 percent or more of the isotope ^{239}Pu, or highly enriched uranium. Controls on the possession, production, and use of such materials are the basis for the international nonproliferation regime. For the same reasons, as the nuclear-weapon states party to the NPT move to meet their obligations under Article VI of the treaty, controls on fissile materials will be important: a treaty banning the production of fissile material for use in nuclear weapons or other nuclear explosive devices, together with a framework for placing fissile materials from dismantled nuclear weapons under verification will be a central part of a future international nuclear disarmament regime.

The Trilateral Initiative was undertaken to examine the technical, legal, and financial issues associated with IAEA verification of weapon-origin and other fissile material released from military programs in those two countries. The initiative has been pursued with a constructive cooperation of seeking solutions to the unique challenges posed. The climate has from the beginning been one where the technical experts from the two states and the IAEA could come together to find solutions that would represent a balance between three perspectives: the perspective of the victim, in which the state and facility operators would have to accept intrusive IAEA inspections in sensitive locations and perhaps on classified items; the perspective of the benefactor, in which each state would obtain information on the other through a cooperative arrangement that would contribute to continued improvement of the bilateral relations; and the perspective of the salesman, providing the international community with an important role in relation to nuclear disarmament, and information on progress towards nuclear disarmament, so much so that the international community would be willing to pay the fees required for IAEA inspections.

In this sixth year, the Trilateral Initiative has come to the point where the nature of the work and the challenges are changing. Some have to do with the work completed so far, some arise from the bilateral relations between the two states, and some have to do with the upcoming 2005 NPT Review Conference.

In this article, progress under the Trilateral Initiative will be summarized, and the issues ahead will be examined.

Aims and Objectives

The initiative is intended to establish a verification system under which states possessing nuclear weapons might submit excess weapon material. It involves only Russia and the United States; if it is successful, meaning that agreements are concluded with both states, then to some extent, the outcome of the initiative will serve to encourage other states possessing nuclear weapons to undertake similar arrangements.[3]

There are various possibilities for the starting point of such a verification system and, depending on when it occurs and on the scope of verification, placing excess weapon material under IAEA verification could serve different purposes:

- If the fissile material has been processed to the point that it no longer has any properties that could reveal classified information, then bringing that material under inspection with an undertaking that it cannot be re-used for any military purpose serves two purposes: a) capping the capabilities of the state (especially when combined with a production ban) and b) providing a means to build confidence and thereby encouraging further arms reductions and increasing the amounts of excess material subject to inspection.
- Including provisions for inspecting fissile materials that still contain classified information could add an additional benefit: allowing the submissions to proceed much faster than otherwise, given the high costs and lengthy periods required for converting weapon materials to unclassified forms. Allowing IAEA verification of weapon materials having classified properties can only be considered if the state—and the IAEA—is convinced that the verification process will not reveal such properties.
- Including provisions to confirm that the properties of items submitted are characteristic of nuclear-weapon components could allow monitoring of the arms reduction process.
- If the measures above are implemented, then in principle, it would be possible to begin verification at the point where warheads are de-mated from their delivery systems, allowing for verification of specific arms reduction measures.

Under the Trilateral Initiative, verification encompasses the first *two* steps. There are significant challenges in these two steps, and success here may open the possibility of broader measures in the future, as progress towards nuclear disarmament warrants. Under the Trilateral Initiative, most of the technical work carried out thus far has been devoted to developing verification methods that would allow the states to submit fissile material with classified characteristics, including intact components of dismantled nuclear warheads.

Starting with classified forms of fissile material is justified on two grounds. First, waiting for the processing needed to remove the classified properties could require decades to pass before the weapon materials could be submitted for verification. Delays of that sort could make controls on fissile materials pointless. Second, if a verification scheme for classified forms of fissile material could be implemented, it would provide useful transparency and encourage further steps, while opening the possibility for extending the role of international verification in relation to nuclear disarmament.

In participating in the Trilateral Initiative, the IAEA Secretariat has recognized the unique opportunity to develop the first international verification in relation to nuclear disarmament. Accordingly, the IAEA Secretariat has maintained that three fundamental conditions would be essential for IAEA participation in such a mission:[4]

- Each state would decide which fissile materials it would submit to IAEA verification, in what form they would be and where they would be located. But once submitted, the commitment by the state would be irrevocable—the fissile material would not be used thereafter in any military program.
- Moreover, in the spirit of the language of Article VI of the NPT, once fissile material is submitted, IAEA inspections would be obligatory.
- IAEA inspections would only be undertaken if assurance could be provided that those inspections would lead to credible and independent findings.

Each of the parties has brought other interests, but from the point of view of the IAEA Secretariat, these conditions are seen as essential.

Technical Requirements and Methods

To verify classified forms of fissile material, the states must restrict the information provided to the IAEA and must control inspector activities to ensure that IAEA inspectors do not acquire classified information relating to nuclear-weapon design. There are further requirements that the states may impose given the sensitive nature of the facilities involved. The classification systems in place in Russia and the United States share many common elements, however each has specific features that have no parallel. These requirements make it necessary to depart from the normal practices applied by the IAEA in safeguarding plutonium or highly enriched uranium employed in peaceful nuclear activities. They impose new requirements on the verification processes and equipment that can be used by the IAEA. Allowing for classified forms of fissile material is justified on the basis that waiting for the conversion of those materials would marginalize the value of this effort, and raise questions to the point that financial support might not be forthcoming.

The Trilateral parties agreed to pursue a verification concept under which certain attributes characteristic of the classified forms of fissile material would be confirmed.[5] Accepting this attribute verification concept followed a period of examination in which every known measurement method was considered, beginning with those currently used by the IAEA in safeguarding plutonium and highly enriched uranium in non-nuclear-weapon states. It was concluded by the security authorities of the two states that *every* quantitative method identified could reveal classified information if IAEA inspectors were allowed access to the raw measurement data. Therefore, direct, quantitative measurements following normal IAEA safeguards practices were ruled out.

Since there were no acceptable measurement methods that could be used without restrictions on the data that inspectors could see, it was agreed that the measurement methods capable of revealing secret information could be used if ways could be found that would block the quantitative measurement information from inspector view.

Two "levels" of verification are foreseen: one, Level 1, would provide a screening measurement on 100 percent of the items submitted to verification, and would either test only one attribute (e.g., plutonium presence) or would test more than one attribute, but with a relatively large measurement uncertainty; the other, Level 2, would test all attributes with sufficient precision and accuracy so as to confirm the declaration of the state.

The technique incorporated in both Level 1 and Level 2 systems is referred to as "attribute verification with information barriers." If successful, meaning that in a given application, both the state and the IAEA would confirm that their respective requirements are met, such systems would allow verification measurements to be made by the IAEA on classified forms of fissile material, including warhead components, in a way that would make it impossible for any secret information to be revealed. At the same time, "attribute verification with information barriers" should make it possible for the agency to conclude that the verification is credible and independent. While developed under the Trilateral Initiative, this approach was awarded the distinction at the Los Alamos National Laboratory of being an *enabling technology* potentially suitable for use in a range of arms control initiatives.

Verification equipment intended for use in facilities where fissile material with classified characteristics is present will have to meet national certification requirements against espionage. While in principle it might be possible for the IAEA to provide its verification equipment for certification, if the equipment were to fail to meet the state's certification requirements, the state would probably not reveal the reasons for its rejection. Moreover, if the equipment met the certification requirements, given the types of examinations that certification would entail, the IAEA might not be able to confirm that the equipment hadn't been modified. Rather than face this risk, the more promising avenue, and the one being pursued, is to agree that all such verification equipment be manufactured in the country where it will be used. But this approach poses an additional problem, as normal IAEA authentication practices cannot be used under these circumstances. To cope with this situation, a new authentication approach is being developed. Authentication remains the most challenging IAEA task.

This attribute verification system with information barriers comprises a neutron multiplicity assay system integrated with a high-resolution gamma ray spectrometry system, within a special environment that must prevent classified information from being transmitted or otherwise conveyed beyond its borders, while preventing any external signals from tampering with the operation of the system. *A security watchdog system* will disable the entire measurement system in the event that any access way is opened, and the computational block and transmission devices to the inspectors' readout provide the agreed outcomes without breaching security restrictions. For short, the verification system is referred to as an AVNG system.

The Trilateral parties agreed that the concept showed promise, and on the basis of that, a *general technical requirement* and *functional specifications* were provisionally adopted. Under a contract between Los Alamos National Laboratory and the Russian Federal Nuclear Center at Sarov, a full-capability AVNG system is being constructed for test and evaluation in Russia. That AVNG system will be certified by competent Russian authorities, and assuming it passes all tests, would be suitable for use in a Russian facility storing large amounts of weapon-origin fissile material.

A separate contract will provide plutonium reference materials for that AVNG system, intended to be used by the IAEA if the decision is made to proceed with a legal agreement. The plutonium reference materials alternatively pass and fail all of the attributes in the test suite. The measurement system and the reference materials will be certified by the security officials of the state, and will be authenticated for use by the IAEA. There remains significant work to reach the point where this measurement system can be accepted by the state and the IAEA, including the ongoing certification and authentication requirement and the routine inspection procedures—especially for data collection, analysis and evaluation. A technical workshop is foreseen in the summer of 2002 to continue to investigate the requirements, available mechanisms and complementary staging of authentication and certification.

Other technical work on inventory monitoring systems has also been underway, emphasizing the elements of such systems that might then be applied at specific facilities. In addition to the work described on the full attribute verification systems, work is also proceeding on inventory monitoring systems for dedicated storage facilities for weapon-origin fissile material, that will track material within the facilities and assure that its identity, integrity and location are verified at all times. These inventory monitoring systems will combine the traditional safeguards containment and surveillance measures. Where applicable, the protection of classified information will be essential, national certification will be required, and authentication remains a concern.

The bulk of this work has been carried out at laboratories in the two states and at the IAEA. In the last year, however, a technical visit was made to the BNFL plutonium storage facility at Sellafield in the United Kingdom, and technical workshops were carried out at the JNC Plutonium Fuel Production Facility in Japan and at the European Commission Joint Research Centre in Ispra, Italy. These visits made it possible to benefit from the experience gained in developing and applying IAEA safeguards at peaceful nuclear facilities holding fissile materials.

As the work of the Trilateral Initiative moves past the initial emphasis on concepts and basic system designs, the focus of work now will be on getting ready for implementation. In effect, there is a need for the security authorities of the states and agency experts to try out such systems in an environment where there are no classified forms of fissile material present. Discussions are underway to establish a program of cooperative research and development at JRC-Ispra, with the intention of having scientists from the weapon laboratories of both states in residence, working with IAEA and Ispra staff.

Legal Framework

Appropriate legal arrangements are necessary to engage the IAEA in the implementation of any new verification role. For the IAEA, this would require the Board of Governors to approve the legal document accepting the terms and conditions, including the financing arrangements foreseen. Each of the states would have to conclude such agreements in accordance with its constitutional requirements. In principle, suitable arrangements might be achieved through modifying existing agreements or by introducing new agreements. Each has pros and cons.

Under the Trilateral Initiative, we first examined whether or not the IAEA voluntary-offer safeguards agreements (VOAs) currently in force in the Russian Federation and the United States might be suitable. There are advantages and disadvantages. The chief advantage in using the VOAs is that they already exist. However, there are some fundamental problems with using the VOAs. For example:

a. The voluntary-offer safeguards agreements are just that: voluntary-offer agreements—they allow nuclear-weapon states party to the NPT to submit nuclear material and facilities to IAEA safeguards as they decide, which would not be acceptable as the basis for implementing a verification regime related to nuclear disarmament;
b. Verification by the IAEA under the voluntary-offer agreements depends on the availability of resources, but there are currently no resources available for such verification—and the VOAs do not provide a means to secure the funding necessary for obligatory inspections. In the context of the NPT, it would be best if financing for verification of nuclear disarmament carried out in the context of Article VI of the NPT were based on a reliable and predictable broad based arrangement in which all NPT states contribute, in much the same manner and for the same reasons as for safeguards under Article III;
c. The state must make declarations in accordance with standard safeguards requirements on the material and facilities submitted to safeguards under the VOAs—but if classified forms of fissile material are submitted to verification, neither the Russian Federation nor the United States could declare the properties of classified forms of fissile material without violating Article I of the NPT and their respective national laws;
d. Under IAEA safeguards, the IAEA carries out nondestructive measurements of all relevant physical and chemical properties of the nuclear material subject to IAEA safeguards, and takes representative samples in which all properties, including impurities, are measured to the highest standards of precision and accuracy—for classified forms of fissile material, such measurements could clearly not be undertaken; and
e. The VOA safeguards agreements are a part of the nonproliferation system; that system is intended to prevent nonnuclear-weapon states from acquiring even one nuclear weapon. In the present case, both states possess thousands of nuclear weapons and are in the process of reducing those to substantially lower

levels, but the incremental reductions have very little to do with proliferation, and the safeguards timeliness, quantity and detection probability requirements appropriate for nonproliferation are correspondingly inappropriate for nuclear disarmament.

These shortcomings might be remedied through suitable modifications to the VOAs. One advantage of staying with the VOAs is that it might be easier for the governments to approve a modification to an existing agreement than to approve a new agreement. The Trilateral Initiative does not seek to fulfill any treaty obligations,[6] after all, having its origin in voluntary commitments expressed by presidents who are no longer in office. To accommodate these provisions, the protocols required would differ fundamentally from the basic agreements to which they are attached, and could give the appearance of creating special beneficial arrangements for the application of IAEA safeguards in nuclear-weapon states. Any such step that could undermine the IAEA nonproliferation safeguards system would be a non-starter.

Moreover, there is another issue that bears mention: to the extent that nuclear disarmament verification is undertaken under a modification to a nonproliferation agreement, it would lack the specific character and identity of an agreement concluded specifically for the intended purpose of international verification in the context of nuclear disarmament.

Anticipating that it might be preferable to develop new agreements, extensive work has been carried out under the Trilateral Initiative to define and draft the elements required for new verification agreements. That work has progressed to the point that the basis exists for negotiating individual agreements between each state and the IAEA when each state is ready to proceed.

Financial Considerations

What will it cost and who will pay for it?

Estimating the costs required for verification will depend upon several factors, including:

a. The number of facilities to be inspected and the amounts of fissile material or number of items containing fissile material to be subject to inspection;
b. The nature of the operations to be carried out, recognizing that the requirements will be lowest for static storage facilities and will increase, particularly for bulk handling facilities, and especially for facilities requiring a continuous inspection presence;
c. The physical layouts of the facilities and the operational modalities;
d. The technical verification requirements, including the frequency of inspections and the type and intensity of inspection activities to be required;
e. The verification approaches adopted, especially reflecting emphasis on technology as a means to limit the numbers of inspectors required and the duration of inspections, and making use of operator equipment, where possible, or unattended monitoring systems, and remote monitoring, where the security conditions allow; and
f. Whether the facilities are located in the same geographic area or are dispersed.

As neither state has made any commitments thus far, it would be speculative to suggest estimates. It is clear that continuous inspection presence would be expected for facilities converting classified forms of fissile material, and thus those operations would be perhaps the most cost intensive.

The IAEA Board of Governors will be the body to decide who will pay. A number of possibilities have been identified, all of which represent a balance between the wish to have a "polluter-pays-principle" in effect, to the sense that the implementation of inspections in the context of the NPT is a shared responsibility for a shared benefit, equally valid for inspections required in non-nuclear-weapon states under Article III and for future inspections carried out in relation to Article VI.

The Steps Ahead

Preparatory meetings for the 2005 NPT Review Conference will begin in the winter of 2002. As the completion and implementation of the Trilateral Initiative is specifically called for in the review of Article VI in the 2000 document, it is certain to be on the agenda. The attention given to the Trilateral Initiative may be greater because it represents the only hope for international verification in relation to nuclear disarmament at present. Concluding verification agreements before 2005 could contribute to the success of the conference.

The Trilateral Initiative has already succeeded to a considerable extent. It has served as an active forum for joint development of solutions to common problems, and has brought the IAEA into a new context. The prevailing spirit has been one of mutual respect and cooperation, which has encouraged the give and take needed for common solutions to emerge.

But, after all, there is no commitment by either state that the initiative will lead to a new verification role. That will depend upon success in a number of areas, principal among which are:

a. Continued improvement in the bilateral relations between the Russian Federation and the United States, especially in the areas of strategic arms reductions, missile defense systems, nonproliferation of weapons of mass destruction and counter-terrorism;
b. Securing the funding required and implementing the PMDA, including the early consultations with the IAEA;
c. Establishing acceptable arrangements for IAEA inspections that do not conflict with bilateral transparency measures; and
d. Proving to the satisfaction of the security authorities of both states and to the satisfaction of the IAEA that

the inspection arrangements, procedures and equipment can be implemented in sensitive facilities without risk of divulging nuclear-weapon design information, while allowing the IAEA to obtain credible and independent assurance that the state's declarations are complete and accurate and that the commitments made by the states are honored.

These problems are complex, and at this point it is not clear when the conditions will be ripe for commencing inspections, and bringing the Trilateral Initiative to a close. It is clear that in the forthcoming year, the Trilateral Initiative will focus on the last point, and when the verification concepts, procedures and equipment have been proven, then the other issues will be more urgent.

End Notes

1. The Treaty for the Nonproliferation of Nuclear Weapons (the NPT).
2. Article VI of the NPT is as follows: "Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control."
3. When the fissile material cut-off treaty is drafted, provisions could be included allowing states possessing nuclear weapons to submit excess military material for verification, in which case the Trilateral Initiative precedents will prove to be useful.
4. For the IAEA to enter into an agreement to carry out such a mission, approval by the IAEA Board of Governors and the General Conference of member states would be needed. The Trilateral Initiative has not advanced to the point where it would be appropriate to seek such approval. In the meantime, the Director General informs the Board and the General Conference of progress, and funding to support IAEA Secretariat activities is provided through extrabudgetary contributions.
5. For plutonium, for example, the agreed set of attributes consists of: a) presence of plutonium; b) isotopic composition characteristic of plutonium used in nuclear weapons: $^{240}Pu/^{239}Pu = 0.1$; and c) plutonium mass exceeds an agreed threshold value.
6. Note that under the Plutonium Management and Disposition Agreement (PMDA) signed in summer 2000, the two countries agreed to the symmetric disposition of 34 metric tons of weapon-origin plutonium. There is a requirement in the PMDA for early consultations with the IAEA in relation to a verification role foreseen for the IAEA. The fissile materials identified in the context of the Trilateral Initiative overlap to some extent those identified in the PMDA, and hence there may be a connection.

The FMCT from an Industrial Perspective

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Introduction

Since the adoption in 1995 of the "Shannon Report" and the "Shannon Mandate," many meetings have tackled the question of how to progress toward a Fissile Material Cut-off Treaty (FMCT). Many ideas have flourished but, despite the good will of most, the negotiations have not yet begun and that is likely to remain the case for a long time.

The reasons for this paralysis lay, among other factors, in the inability of some states, i.e nuclear-weapon states, which will be directly concerned with the implementation of such a treaty, to reconcile the different terms of the mandate with the political realities of the moment.

It may seem a bit dangerous to encourage the development of many bright ideas and discussions that concur on only one fact—what was envisioned in 1995 does not appear realistic in 2002—without providing a way out.

When you create too many expectations for nonnuclear-weapon states (NNWS) or for the public in general about nuclear disarmament, you also create a risk of distrust if you fail, and more significantly you run the risk of weakening the overall nonproliferation regime already in place, thereby threatening the viability of nuclear energy and nuclear business.

The governments, industries, and individuals involved in the development of the peaceful uses of nuclear energy should pay attention to that risk. Likewise, it should be the concern of all industries involved to react to the pessimistic assessment of the situation, or to an abusive exploitation of the difficulties encountered, and to propose ways to progress, although they might be viewed as a bit iconoclastic.

The Context

It is useful to place the negotiation of an FMCT in the more global context of international efforts and commitments to a nuclear-weapon-free world as compared to the regional notion of nuclear-weapon-free zones.

The establishment of the International Atomic Energy Agency in 1957, followed by the issuance of safeguards agreements with member states and the Nonproliferation Treaty (NPT) in 1970 were indeed major victories for the nonproliferation regime. Whereas the NPT rests on a discriminatory basis reflecting the situation in 1968, and differentiates NNWS from nuclear weapon states (NWS), Article VI of the treaty committed the NWS signatories to work toward nuclear disarmament.

This commitment resulted in arms control negotiations (SALT I and SALT II) and the Comprehensive Test Ban Treaty (CTBT)—which is still subject to the ratification process in the United States—and also in the development of an export-control policy embodied at the international level in the nuclear suppliers' guidelines.

An FMCT should be viewed as a further step in the direction of arms limitation with a comparable aim as was reached by the NPT in relation to horizontal proliferation (to avoid additional states having nuclear weapons) but directed toward vertical proliferation (to prevent states already possessing nuclear weapons from producing new material to increase their arsenals). Hence, as many accept, the objectives and the verification regimes should not be identical and this differentiation, which is not synonymous with discrimination, should be accepted at the outset.

From the Fundamentals of the Shannon Mandate

The objective of the Shannon Mandate is a "ban on the production of fissile material for nuclear weapons or other nuclear explosive devices." This poses questions about what fissile material should be taken into account and about the definition of production.

Author's note: Although the text of the mandate seems clear in its reference to production, thereby excluding the stockpiles of material already produced at the time of the entry into force, the Shannon Report itself states that the question of stockpiles might be addressed. This statement does not simplify the discussion.

In addition, three principles are expressed. The treaty should be *nondiscriminatory, multilateral,* and *internationally and effectively verifiable.* Again, these are only principles that should guide the negotiators and are subject to interpretation. Without discussing each of these items in depth, it is worth noting some examples of the issues raised.

Does nondiscrimination mean nondiscrimination between all signatories or within each of the two categories of states, which could be defined on a larger basis than the NPT does as states possessing or not possessing a nuclear weapon? Does nondiscrimination in the light of the safeguards agreements including INFCIRC/540 allow for some differentiation, taking into consideration the overall national situation and information provided?

Does multilateral mean universal? If the general concept is that this type of treaty should be open to any state, would it really be a violation to consider that multilateral could also be interpreted as encompassing specifically targeted states, that is, the states possessing a nuclear weapon that are referred to below as the nuclear-weapon possessing states (NWPS), encompassing India, Israel, and Pakistan (and not only those NWS defined in the NPT)?

Although there is little doubt that the words *internationally* and *effectively* verifiable do not necessarily imply that the IAEA should be the verification tool, it is commonly understood that this should be so. The flexibility remaining in the mandate should be preserved, since it might be useful to consider other verification methods or a mixture of different verification tools. One question that is addressed by the terms relates to the credibility of the implementation but also to its efficiency, and this introduces the necessary consideration of the financing arrangements.

Toward a Step-by-Step Approach

As is indicated above, the arms control and nonproliferation commitments and endeavours are a complex and ongoing process of which the FMCT is only a part and not, at least in the NPT spirit, a final touch. The time may come when a complete disarmament is implemented.

Today, if the negotiations have not yet started, it is because of the complex issues that are at stake. Without entering into the detail of those issues, which have already been thoroughly and thoughtfully explored by various experts on this topic, I would like to concentrate on the description of a step-by-step approach within the logic of the FMCT, which would go beyond the concept of a focused approach as we know it today.

I. A Reduced and More Realistic Approach

a) *A limited scope*

Bearing in mind the main objective of the FMCT described here, banning the production of fissile material for nuclear weapons in a vertical nonproliferation perspective would be a very valuable achievement.

Accepting that as a priority, it is necessary to have NWPS commit to stop producing the material for this use. If holding stocks of such existing material is allowed, then the verification that no more material is produced should be satisfactory.

Assuming that those states that have developed elaborate programs are not to be considered terrorists and that, above all, they possess sufficient numbers of ready-made weapons or weapons-grade material in stocks, then it would be nonsense for them (politically and economically) to engage in the diversion of civil, lower-grade material. In comparison to the terms of the Shannon Mandate, the words "or other nuclear explosive devices," which make sense for NNWS under the NPT, would be deleted.

The scope of verification would then have to focus on the definitive closure of those facilities that were dedicated to the production of high-grade plutonium or highly enriched uranium, that is, the material used in nuclear weapons, and in the absence of clandestine facilities for such production.

b) *A selected membership*

For the reasons explained above, this focused approach to the facilities or material subject to verification would have meaning for the NWPS. For the NPT NNWS states, this commitment has already been made and its verification is already being implemented under the NPT.

A focused participation limited to NWPS would facilitate the negotiation process and avoid the tricky comparison of the regimes that could be implemented under such an arrangement with the comprehensive safeguards concept underlying IAEA verification in NNWS. At the same time this would entail more reasonable budgetary implications.

c) *A specific verification instrument*

Given the concerns that one may have for not contributing to proliferation, it would be wise to consider the possibility of a peer-review system to strictly limit the number of people and possibly countries involved in the verification of the dedicated, specific facilities, and at the same time achieve an efficient system based on the proper expertise.

Considering the interest for an NNWS to be guaranteed that one of the NWPS is not building up its stocks of weapons-grade material (which are still unknown), it is of utmost importance for each of those NWPS to be assured that none of their counterparts are cheating. Therefore, the credibility of the focused verification instrument should not be questioned by the outsider states.

II. *An Evolutionary Approach*

a) FMCT—The focused approach

The system described previously should be viewed as addressing one of the main challenges of the exercise, that is, bringing the three non-NPT states in the international arena of nonproliferation commitments without challenging the NPT order.

Once such a system is in place, it will be possible to raise the issue of verification for material that might be used for other explosive devices, and to find a way to provide a satisfactory and achievable verification arrangement. A focused approach on some target facilities, as has been suggested, might be implemented.

In that respect, the system should benefit from the use of already existing structures. Not only should the verification of dedicated countries through a specific agreement (among the eight NWPS) be preserved, but where other multilateral tools exist, like Euratom safeguards in the UK and France, or the IAEA safeguards under voluntary offer agreements, they should not be duplicated.

b) *An extensive FMCT approach*

A further step would be to encompass the existing stocks, and beyond that, the weapons to be dismantled. Once the political situation is ripe, and when there is a general agreement of all NWPS, one could consider an almost uniform system of verification worldwide, giving the IAEA the task of inspections but taking into account the existence of other tools with the appropriate relationship, to ensure the trustworthiness of their activities. This might well be in a very distant future when the political and the technical background is dramatically changed. It is therefore preferable to leave the question open.

Conclusion

As a French saying goes, "Better is the enemy of good." And at least sometimes this may be true. Regarding the expansion of the discussions about a FMCT, it is indeed important to maintain the momentum, but the risks of a negative effect on nonproliferation should not be overlooked. One should never forget the general aim that lays behind the ambitious Shannon Mandate. Governments should be reasonable and realistic and, without rejecting the fundamentals of the mandate, review their expectations in a long-term perspective.

A View on the FMCT: Its Importance and the Verification Scheme

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Abstract

A global regime of nuclear disarmament and nonproliferation of nuclear weapons should evolve along with the changes in the international environment. These changes have occurred throughout history. During the early stage of the Cold War era, the Nonproliferation Treaty (NPT) was created and became the centerpiece of the global nonproliferation regime.

The NPT Extension Conference in 1995 and the 2000 Review Conference identified that the negotiation and early conclusion of the Fissile Material Cut-off Treaty (FMCT) is a priority. Due to several reasons, however, the discussions on the FMCT at the Conference on Disarmament are not progressing. The importance of the FMCT is increased by the recent changes in the international political situation, i.e. problems with the Comprehensive Test Ban Treaty, START, and the Additional Protocol to the NPT. When it does materialize, the FMCT will cap future increases of nuclear weapons. Moreover, if the international community chooses the approach of limiting the treaty's scope to the future production of fissile material only, and hence the treaty does not touch upon the present stocks, it may be possible to obtain the agreement of some nuclear weapon states (NWS) on the substance of the treaty. Thus, commencement of discussions on the FMCT will contribute to progress on global disarmament and nonproliferation considerations.

Many issues should be discussed regarding the content of the FMCT. Scope, definitions, verification schemes, structure of the treaty, and conditions for the entry into force are examples. Among those, the authors primarily will discuss the verification issue.

The authors believe that the early conclusion of the negotiations is most important in the present political environment; therefore, the authors believe that some sort of compromise is needed in selecting a verification scheme. The authors will recommend that a type of focused verification approach be taken. Then, the authors will discuss the starting and termination points, initial inventory, and verification activities against a state's declared and/or undeclared activities using routine and non-routine inspections.

Finally, the authors will express their opinions on possible measures to accelerate the progress of international discussions on the FMCT.

Introduction

Since it is not possible to restrict the possession of nuclear weapons to a very small number of nations, and the possession of nuclear weapons is synonymous with being a "hegemony" nation in the world (or in the region), and further that excessive numbers of nuclear weapons have been accumulated in the nuclear weapon states during the Cold War, the agenda for nonproliferation and disarmament is a very important political issue.

The global regime of nuclear disarmament and nonproliferation of nuclear weapons has been developed and has evolved in order to meet an ever-changing international political and security environment.

Though the International Atomic Energy Agency (IAEA) was established in 1957 and nuclear safeguards to detect and deter the diversion of nuclear material to military use have been incorporated into one of the major agency objectives, the important instrument for controlling nonproliferation in the world in the earlier days was not international but rather bilateral measures. Nuclear supplier countries required the conclusion of a governmental agreement with each recipient country before supplying nuclear material, equipment, facilities, and technology, which gave suppliers control rights, including safeguards and prior consent for the transfer to a third party. Thus, a bilateral safeguards system was implemented in the early stage, and Japan had the experience of receiving American and Canadian inspectors in connection with U.S.- or Canadian-origin nuclear material in Japan.

With the entry into force of the NPT in 1970, the IAEA was required to establish a comprehensive safeguards system based on the Article 3 of the NPT. This system (INFCIRC/153 and recently INFCIRC/540, the Additional Protocol) is now widely used for the verification of nuclear material and activities in nonnuclear weapon states (NNWS) party to the NPT. The NPT has become the most widely recognized arms-control treaty (187 parties as of 2001). Thus, the NPT and the IAEA safeguards system based on the NPT is a centerpiece of the global nonproliferation regime. It is not a panacea for the global nonproliferation objective. A permanent nonproliferation regime is a mosaic of various independent measures. Some examples of the pieces of the mosaic are nuclear-weapon free zone treaties (NWFZ) e.g., the Tlatelolco Treaty, export control measures (nuclear suppliers guidelines, etc.), the Convention of Physical Protection of Nuclear Material and other physical protection measures, Euratom safeguards, the Argentine-Brazil safeguards organization, bilateral governmental nuclear cooperation agreements, Korean Peninsula Energy Development Organization, and national material protection, control, and accounting programs including the SSAC (State System of Accounting for and Control of Nuclear Material).[1] The CTBT is mainly a treaty for nuclear disarmament, but it contains a nonproliferation element as well.

In the area of nuclear disarmament, again one can see that several independent measures compose the general disarmament regime. The major ones are nuclear weapon reduction treaties, such as the Strategic Arms Reduction Treaty, commonly called START I and START II, and the CTBT.

An FMCT could be a useful international instrument both for nuclear disarmament and nonproliferation. The start of actual negotiation is much anticipated, but it has not yet occurred. The authors would like to describe in this paper possible elements of the treaty. Specifically, the authors will argue for the desirable formulation of the verification scheme.

Importance of the FMCT

Along with other disarmament and nonproliferation proposals, there have been proposals since the 1950s for an agreement to end the production of fissile material for nuclear weapons. The United Nations General Assembly adopted Resolution A/RES/48/75/L on December 16, 1993. This resolution recommends "the negotiation in the most appropriate international forum of a non-discriminatory, multilateral, and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons and other nuclear explosive devices."

Since then many efforts were made at the Conference on Disarmament (CD) in Geneva to capture this context. The most comprehensive and successful effort was the Shannon Report of 1995 (CD 1299), which articulated a mandate to negotiate a non-discriminatory, multilateral, and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices. Since then, the pertinence of the Shannon Mandate has been reaffirmed many times. Further the NPT Extension Conference in 1995 and the NPT Review Conference in 2000 recommended early commencement of negotiations on the FMCT as a very important subject on the nuclear disarmament/nonproliferation agenda. The CD, however, has failed to commence the negotiations up to now. Is the FMCT still an important issue for negotiation in the present international political situation?

There has been no significant progress in the field of nuclear disarmament in recent years. START I was implemented, but START II was not approved by the United States and Russia. Discussion on further disarmament between the United States and Russia seems not to be progressing. Entry into force of the CTBT is not hopeful, at least in the near future. The United States is tending to shift to the direction of unilateral rather than multilateral undertakings. This tendency looks unchanged after the terrorist attacks in New York City and Washington, D.C., on September 11, 2001.

As far as the sphere of nonproliferation is concerned, we have many useful instruments available for this. However, there are problems of universality or effectiveness. The conclusion of the Additional Protocol to the IAEA Safeguards Agreement (INFCIRC/540) is a remarkable achievement, but only some twenty states have yet put it into force. An NPT Safeguards Agreement itself has not been ratified by about fifty parties to the NPT, though none of those states has significant nuclear activity in its territory. NWFZs were created in the major part of the Southern Hemisphere as well as Southeast Asia, but international efforts to create it in other regions have not yet materialized.

Generally speaking, we cannot help but say that the present situation is in stagnation or possibly a setback. We need a breakthrough. Opening the discussion on the FMCT, in addition to the merit for the progress on the disarmament and nonproliferation objective in itself, can be a symbol of reactivation on the subject.

In the authors' view, the FMCT gives us very significant benefits. Those include:

- The FMCT would put in place a worldwide, legally binding, and internationally verifiable ban on the production of fissile material for nuclear weapons or other nuclear explosive devices. This is far better than the present situation in which only some NWSs have declared voluntary moratoria on production;
- The FMCT would accelerate the discussions on the stocks of fissile material in NWS, even if the FMCT does not deal with stocks directly;
- The FMCT would be a very important supplementary measure to the NPT for nonproliferation purposes. The threat of proliferation of nuclear weapons or other nuclear explosive devices by non-state actors

became more serious after September 11, 2001, and collective efforts by the international community are called for. The FMCT could be useful for this purpose; and,
- The world of nonproliferation is one of discrimination. Conclusion and entry into force of the FMCT according to the Shannon Mandate will help to decrease the discrimination brought by the NPT.

As far as the possibility of the commencement of negotiations and the successful conclusion of the FMCT are concerned, the authors believe that the keys are: (a) whether the CD succeeds in breaking the linkage problem or the international community decides to use another forum than the CD, and (b) the contents of the FMCT, especially the scope of the treaty, verification modes, and the conditions for the entry into force (EIF). The authors will discuss these issues in the following sections.

Scope of an FMCT

The authors would like to discuss three different topics under this title: they are (1) stocks, (2) definitions (materials to be dealt with in the treaty, etc.), and (3) import and transfer from a third party.

Stocks

Whether stocks of fissile material should be within the scope of an FMCT has been a critical issue in the international discussions. Most argue that the stocks would not be dealt within the treaty, reasoning that the complexity of the situation of stocks in NWS causes great difficulty in reaching a satisfactory resolution. What are the stocks? Are stocks the fissile material in the warheads of nuclear weapons and materials reserved for military purposes only, or do they include fissile material for civil purposes? Andrew Barlow discusses stocks of civilian purpose in his paper.[2] It seems that discussions on the definition of stocks are necessary. The complexity of the situation regarding fissile material for weapons purposes is recognized, but does fissile material for civilian use have a similar level of complexity? U.S. experts point out that multilateral discussions are underway to enhance transparency and irreversibility for the fissile material in the NWS that is no longer needed for defense purposes by application of IAEA verification, i.e., the Trilateral Initiative.

Recognizing the complexity associated with the situation in the NWS, and understanding the fact that a successful conclusion could not be reached without the consent of the NWS, the authors propose that the scope of an FMCT be limited to the verification of nuclear activities after EIF. However, as discussed in the later section, the authors will propose that the initial inventory of material to be declared by the member state should include an inventory of all fissile material existing in the state at the time of EIF, excluding fissile material for nuclear weapons or other nuclear explosive devices.

Definitions

The authors will examine two definitions, namely *fissile material* and *production of fissile material.* Fissile material that will be banned for production of nuclear weapons or nuclear explosive devices should be:

- Unirradiated plutonium of all grades (except that containing 80 percent or more Pu-238);
- Unirradiated highly enriched uranium (HEU), i.e., uranium enriched to 20 percent or greater in U-235 or U-233;
- Any material containing one or more of the foregoing; or
- Any material defined as fissile material for the purpose of the FMCT by a governing body of an FMCT after EIF.

Low-enriched, natural, and depleted uranium or thorium cannot be used directly to produce nuclear weapons or other nuclear explosive devices. Likewise, plutonium and HEU contained in spent nuclear fuel cannot be used for manufacturing nuclear weapons, unless it undergoes chemical reprocessing. Tritium is used in hydrogen bomb, but it is not fissilematerial. Therefore, such material should not be defined as fissile material. Minor isotopes such as neptunium and americium could be included at a later stage as fissile material, if necessary.

The authors believe that *production of fissile material* means the following activities under an FMCT:

- Separation of plutonium or HEU (including U-233) from irradiated nuclear material at chemical reprocessing or other relevant facilities;
- Recovery of plutonium or HEU (including U-233) from radioactive waste;
- Increasing the abundance of the isotopes U-235 or U-233 in uranium or the isotope Pu-239 in plutonium through any isotope separation process;
- Changing the use of fissile material[3] from civil or non-nuclear weapon or explosive device use to nuclear weapon or other nuclear explosive devices use after EIF; or,
- Any acquisition of fissile material for use in nuclear weapons or nuclear explosive devices after EIF, which does not fall into one of the previous activities.

Further, the authors will not consider the import of fissile material for production of nuclear weapons or other nuclear explosive devices into the territory as production, but such action should be prohibited by an FMCT. The next section describes this point in detail.

Import of fissile material for nuclear weapons or other nuclear explosive devices

The authors examined whether importing fissile material for nuclear weapons or other nuclear explosive devices (which constitutes an expansion of stocks to be used for such purpose) is prohibited by other international/multinational *a) Under NPT*

Exporter	Importer	Prohibition	Verification
NPT-NWS[1]	NPT-NNWS	yes	Article 3–IAEA SG[2]
NPT-NNWS	NPT-NWS	none or ?[3]	none
NPT-NWS	NPT-NWS	none or ?	none
NPT-NNWS	NPT-NNWS	?	Article 3–IAEA SG
Non-NPT State	Non-NPT State	none	none
NPT-NWS	Non-NPT State	yes	IAEA SG by Article 3.2
NPT-NNWS	Non-NPT State	none or ?	IAEA SG by Article 3.2
Non-NPT State	NPT-NWS	none	none
Non-NPT State	NPT-NNWS	yes	Article 3–IAEA SG

Notes:

1) "NPT-NWS" means nuclear-weapon state that is a party to the NPT, and "NPT-NNWS" means nonnuclear-weapon state that is a party to the NPT.

2) Article 3–IAEA SG means IAEA safeguards based on Article 3.1 and 3.4 of the NPT.

3) Nuclear weapons or other nuclear explosive devices are not transferred under the NPT, but it is doubtful whether the transfer of fissile material constitutes a condition of prohibition included in Article 1 or 2 (especially, without specifying that it is for nuclear weapon use).

instruments. The result is the following:

(b) Present export control regime

All regulations in the existing export-control regime for nuclear-related items are related to the transfer to NNWS. Transfer to NWS is outside of the scope of the export control regime (except re-transfer to a third country).

By this analysis, the authors believe that there are some problems for the regulation of the import of fissile material for nuclear weapons or other nuclear explosive devices in the present regime. Therefore they recommend the inclusion of provisions for the prohibition of import of fissile material for nuclear weapons or other nuclear explosive devices in an FMCT.

Verification

Verification activities required by an FMCT should be guided by three basic criteria: effectiveness, non-discrimination, and cost considerations. In a way, effectiveness and cost are related. Seeking higher effectiveness requires higher cost. We must find an optimization of both requirements. Generally speaking, a comprehensive approach would have a higher cost, but can have more thorough verification results. A comprehensive approach would be a more satisfactory solution from the non-discrimination requirement viewpoint. Adoption of a comprehensive approach would apply the same verification mode to both NWS and NNWS, while a focused approach would apply a different verification strategy to NWS and NNWS. In this case, one could recall the bitter experience of discrimination/non-discrimination discussions in connection with the NPT.

In the next sections the authors will discuss the following points briefly: (1) approaches, (2) starting point, (3) initial inventory and reports, (4) non-proscribed activity, (5) termination, (6) undeclared activity, and (7) SSAC.

Approaches

There is an argument in the international community about whether a comprehensive safeguards approach is appropriate or a focused approach is better for an FMCT. In 1995, the IAEA in a working paper stated the requirement for credible verification as: "From the technical perspective, applying verification arrangements to anything less than a state's entire fuel cycle could not give the same level of assurance of nonproliferation of fissile material for nuclear weapons purposes or for use in other nuclear explosive devices as it is provided by the IAEA by implementing comprehensive safeguards agreements in NNWS."[4]

Further, the IAEA stated recently regarding fissile material subject to the treaty: "Fissile material subject to the treaty might be listed in two categories. One category could be identified as *materials eligible for verification under the treaty,* which could include *all* fissile and fissionable materials that could …The second category could be a subset of the materials eligible for verification under the treaty, …*materials potentially subject to verification….*"

However, many experts seem to hesitate to recommend a comprehensive safeguards approach because of its extremely high cost. Considering that there are more than 200 nuclear power plants in NWS, the authors believe a strict application of a comprehensive safeguards approach to an FMCT verification would not be cost effective.

The authors propose two possible approaches. One is a focused approach and the other is a focused approach with expanded requirements for reporting.

A focused approach has its starting points of verification as the uranium enrichment process (facility) or chemical reprocessing process (facility). Then verification continues at the downstream processes (e.g., chemical conversion process, MOX-fuel fabrication process, and MOX fuel in storage at a reactor), and termination of verification is either at the time when MOX fuel is transferred into a reactor core and irradiated, HEU is downblended to LEU, when there is an export to outside of its territory or upon a determination by a verification agency that the fissile material has become practicably irrecoverable.

A focused approach with expanded requirements for reporting means an approach with the same scope of verification, but the state concerned has to report the name and general nature of all facilities containing fissile and other nuclear material in its territory, and the quantities of nuclear materials (and fissile materials, if any) in these facilities used for non-weapon (and explosive device) purposes at the EIF. These facilities and nuclear material are reported only, not under verification.

The latter approach could provide a verification agency easier implementation and more accurate results.

In both approaches, verification procedures for declared activity and material and for undeclared activity and material are needed. Also, a non-routine inspection regime, such as a special inspection or a challenge inspection, will be required.

It is recognized that a focused approach has a problem of discriminatory attitude (a focused approach for NWS and non-members of NPT, while a comprehensive approach for NNWS by having FMCT verification measures rely on the NPT safeguards system). We hope that the design of the integrated safeguards concept within the NPT regime will proceed further, and, by verifying the absence of undeclared activities in a state, the burden of the comprehensive safeguards approach could be much reduced. In time, we expect the verification regime of the FMCT and of the NPT to reach a similar level.

Starting Point of Verification

The authors generally agree with the descriptions given in a paper presented by Bragin and Carlson at the Geneva Workshop in May 2001. Followings is a quotation from that paper.[5]

- "Plutonium, HEU, or U-233 contained in irradiated fuel assemblies or special targets is introduced into the initial process stage of a reprocessing plant or any other facility (e.g., hot cell) capable of separating subject material from fission products;
- plutonium, HEU or U-233 contained in active waste is introduced into the initial process stage of any facility capable of recovering and partitioning of these materials from fission products;
- any uranium (from depleted to HEU) is introduced into the initial process stage of an uranium enrichment plant or any other facility capable of uranium isotopic separation;
- any plutonium is introduced into the initial process stage of any facility capable of plutonium isotope separation."

Since the authors propose that the import of fissile material for nuclear weapons or other nuclear explosive devices from another party be prohibited under the FMCT, any importing of fissile material after EIF is also regarded as the starting point of verification.

As Bragin explained in his paper, a clear definition of the initial process stage would have to be determined for every type of facility mentioned above.

Initial Inventory and Report

One necessary element of the verification regime under an FMCT is the state declaration. A verification agency's activities rely on the contents and timeliness of declarations by the state. At the EIF, the state must submit to the verification agency its initial report, which may contain detailed descriptions of plants, facilities, or other institutions subject to verification under the treaty, and the quantity and specification of fissile material.

Fissile material in nuclear weapons or other nuclear explosive devices, or in the activities associated with manufacturing such weapons or devices, existing at the EIF is not included in an initial inventory. Such material is outside of the scope.

However, fissile material used or intended to be used for civilian (and non-proscribed military) uses or is no longer needed for nuclear weapon manufacturing purpose at the EIF should be reported to the verification agency. These figures will be the basis for further verification activities.

As described above, a focused approach with expanded requirements for reporting requires reports of the name and general nature of facilities containing fissile material used or to be used for nuclear weapons or other nuclear explosive devices, and quantities of nuclear material (other than those of fissile material to be verified by a verification agency) in a state at the time of EIF.

Provisions for subsequent reports in an adequate timeframe are needed to maintain continuity of knowledge.

Non-Proscribed Activity

While the production of HEU after EIF for naval propulsion should not be prohibited, it poses a different problem for the verification agency. The production process contains classified information, so a normal verification approach might not be adequate. It is certain that fissile material must be traced until the material enters a naval fuel-fabrication facility, and after the material used in a naval reactor enters either a chemical reprocessing facility or a storage facility (including ultimate disposal). The verification regime in between should be developed along the lines of the Trilateral Initiative pursued by the IAEA, Russia, and the United States.

Termination
Verification will terminate in the following four cases:

- By irradiation of fissile material in a reactor core to a certain high level, which prevents further use of plutonium in nuclear weapons or other nuclear explosive devices or HEU without chemical separation;
- By blending HEU or U-233 with depleted, natural, or low-enriched uranium so that the uranium is no longer defined as fissile material (i.e., less than 20 percent of U-235);
- By a verification agency determination that fissile material has become practicably irrecoverable; or
- By exporting fissile material to another state.

Undeclared Activity
In addition to the verification agency's activities on declared activities and fissile material, an FMCT should include provisions regarding undeclared activities.

We have two examples on this point, the IAEA safeguards system with measures included in Additional Protocol (INFCIRC/540) and special inspection (INFCIRC/153), and the Chemical Weapon Convention (CWC) including a challenge inspection mechanism.

When the scope of an FMCT is more precisely defined, the mechanism to verify undeclared activities could be developed in more detail. The authors consider at this time that the model of the IAEA safeguards system including Additional Protocol measures and a special inspection mechanism is more appropriate than the CWC example. Some shortcomings in the current special inspection mechanism should be rectified, and all systems should be adapted according to the specific requirements of an FMCT.

SSAC
The establishment and maintenance of a state system of accounting for and control of nuclear material (SSAC) is an essential element of a safeguards agreement under the NPT. Likewise, an SSAC has to be established and maintained for an FMCT. Within the SSAC, fissile material that requires verification activities and the other fissile material that is outside of the scope of an FMCT should be clearly distinguished.

How to Accelerate the Discussion on an FMCT
It is well known that the CD has been in trouble. After the creation of the Shannon Mandate, substantial discussion on an FMCT at the CD has never started. The so-called *linkage* problem of an FMCT and other agenda items (e.g., disarmament in space) at the CD has continued thus far. In the past few years, the governments interested in pursuing this subject have organized international or multinational workshops and seminars from time to time outside of the official CD negotiation process. This helps to keep some momentum. But sporadic meetings do not contribute to an understanding of various aspects of an FMCT. Participants, especially diplomatic participants, in those meetings change year to year; therefore, discussions must start from the beginning.

It is advisable to organize a series of meetings, inviting diplomats, experts, and policy makers to discuss the possible structure and contents of an FMCT. These meetings would be outside of official CD meetings, but must in some way closely be associated with the CD. The recent initiative of the Netherlands Permanent Mission to the CD (exercise on banning the production of fissile material) can be strongly recommended.

The authors would argue that another forum might be sought for the advancement of discussions on an FMCT, if the CD continues to fail. If by the 2005 Review Conference, the CD does not show any progress, it may be time to establish a basis for FMCT discussions at the IAEA secretariat.

Finally, the authors consider that an FMCT should have some characteristics that attract possible future member states. In the case of the NPT, the attractiveness for many NNWS is Article 4, though it is a matter of debate whether Article 4 turns out to be a real "carrot" for NNWS.

In the case of an FMCT, NWS, NNWS, and other non-NPT states are expected to be member states. What attractions there are for each category of states is a matter for future debate. The authors want to stress the importance of including attractive elements for participating states in an FMCT, apart from the original aims of arms control, nonproliferation, and disarmament, to accelerate the discussions and future acceptance of an FMCT.

Conclusion
The international circumstances for nuclear disarmament, nonproliferation, and nuclear security are at the moment in a difficult situation. Commencement of negotiation and early conclusion of an FMCT were strongly requested at the 1995 and 2000 NPT Conferences. The international nuclear community must seriously consider the acceleration of these discussions. The authors hope continual, rather than sporadic, multinational discussions, which would not necessarily be official CD negotiations, will begin so that the international community will have a breakthrough from the present stagnation in the arms control, disarmament, and nonproliferation area.

End Notes
1. The authors enumerate various supply-side measures here. The other type of nonproliferation measures (i.e., demand side measures) is not mentioned. Various political, economic, and military measures, which strengthen the disincentive to be a nuclear-weapon state or weaken the incentive to become one, fall into this category. Such measures require mostly state-by-state or region-by-region analysis, while supply-side measures apply mostly worldwide.

2. Barlow, Andrew. 2001. A British Perspective on the Scope and Value of the Fissile Material Cut-off Treaty. *Geneva Workshop on a Treaty to Ban the Production of Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices.*
3. Since the authors define the term *fissile material* as unirradiated direct-use material, which is used in IAEA safeguards, conversion of uranium to plutonium in a reactor is not considered production of plutonium under an FMCT.
4. 1995. IAEA. *A Cut-off Treaty and Associated Costs–An IAEA Secretariat Working Paper on Different Alternatives for the Verification of a Fissile Material Production Cut-Off Treaty and Preliminary Cost Estimates Required for the Verification of These Alternatives. Presented at the Workshop on a Cut-Off Treaty.* Toronto, Canada.
5. Bragin, Victor, and John Carlson 2001. Verification Arrangements for the Proposed Fissile Material Cut-off Treaty. *Geneva Workshop on a Treaty to Ban the Production of Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices.*

Verification of a Fissile Material Cut-off Treaty

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Abstract
A fissile material cut-off treaty (FMCT) would ban the production of fissile material for nuclear weapons or other nuclear explosive devices. The success of the treaty will depend, *inter alia*, upon it having an efficient and cost-effective verification regime. This paper discusses a number of the key verification issues, e.g. the materials to be covered by the treaty and the treatment of stocks. It is suggested that a treaty which focused on the materials that can be used directly to make nuclear weapons or other nuclear-explosive devices explode (i.e. essentially all grades of plutonium, and uranium enriched to 20 percent or greater in ^{235}U or ^{233}U), and which excluded stocks, would stand the greatest chance of successful negotiation. An outline of a possible "focused" verification approach for an FMCT is discussed, based on declarations of production and downstream facilities and relevant material, verification of declared facilities and material, and arrangements to detect any undeclared production facilities. The benefits of an FMCT are also briefly discussed.

Introduction
Nearly a decade has passed since 1993 when the United Nations General Assembly (UNGA) adopted by consensus a resolution recommending the negotiation of a non-discriminatory, multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices, a fissile material cut-off treaty (FMCT). Despite agreement at the Conference on Disarmament on two occasions on the mandate for such negotiations (in 1995 and 1998), no substantive progress has been made. Whenever negotiations do eventually commence, the two main issues for discussion are likely to be the scope of the treaty and its verification arrangements. These and related issues are discussed in this paper,[1] and an outline of a possible verification regime is described.

Scope of an FMCT
The discussion on the scope of the treaty is likely to focus on:
- The materials to be covered by the treaty;
- Whether, in addition to banning their future production for nuclear weapons or other nuclear explosives devices, the treaty should also cover existing stocks of these materials in some way; and
- Other related issues.

Materials
Given that an FMCT will be designed to ban the production of fissile material for nuclear weapons or other nuclear explosive devices, it is our view that it should focus on materials that can be used directly to make nuclear weapons or other nuclear explosive devices.

The key materials are:
- Unirradiated plutonium of all grades (except that containing 80 percent or more ^{238}Pu); and
- Unirradiated uranium enriched to 20 percent or greater in ^{235}U or ^{233}U, separately or in combination.

In our view, the treaty must therefore focus on these materials and should not be limited to covering just "weapons-grade" plutonium or high-enriched uranium.

Neptunium and (to a lesser degree) americium, in separated form, could also be used directly to make nuclear explosives. There is interest in the separation of these materials, primarily for long-term radioactive waste management purposes, but there is little separated neptunium and americium currently available. The IAEA has therefore already agreed a low-key regime for oversight of these materials that is commensurate with the low proliferation risk they pose in non-nuclear weapon states (NNWS). Consideration, however, will need to be given to whether these materials should be covered by an FMCT, and if so how.

By contrast with the above materials, depleted, natural, and low-enriched uranium (DNLEU) cannot be used directly to make a nuclear weapon or other nuclear explosive device. For the most part, it is also impractical for irradiated fuel to be made into a nuclear weapon or other nuclear explosive device.[2] For this reason, it would not seem appropriate for an FMCT to focus on these materials.

Stocks

The term "stocks" is often used without clear definition, but we take it to mean all stocks of unirradiated plutonium and HEU, whether they have arisen from military or civil activities. There are eight countries (China, France, India, Israel, Pakistan, Russia, the UK, and the United States) whose stocks many other states are likely to want to see covered by the FMCT in some way.

The stocks in these eight states differ in a number of ways, for example regarding:

- Their size and nature (in terms of their chemical form, purity, and isotopic composition);
- The amount of information publicly available about them;
- The proportion outside any form of safeguards or verification; and
- The extent to which they are the subjects of disposition plans.

In our view these differences would make it extremely difficult to reach an agreement on the coverage of stocks under an FMCT that would be acceptable to all eight states. Indeed, there seems to be a clear risk that trying to do so would make it even more difficult than it has already proved to achieve the straightforward ban on the future production of fissile material for nuclear weapons or other nuclear explosive devices called for by the 1993 UNGA resolution. This would be unfortunate for two reasons: first, because, as explained later in this paper, such a ban would be a worthwhile and significant step in its own right (see below); and, second, because there are other approaches for dealing with stocks that are more likely to be productive than trying to deal with this issue in an FMCT.

For example, with respect to civil stocks, the nine countries subscribing to the Guidelines for the Management of Plutonium now publish annual figures about their holdings of unirradiated plutonium. The UK and France also annually publishes figures for their civil holdings of HEU in a similar format to that for plutonium. Furthermore, in the UK and France all civil stocks of plutonium and HEU (indeed all civil materials) are covered by EURATOM safeguards. The UK safeguards agreement with the IAEA also enables the agency to inspect all such stocks (and materials) if it so chooses.

With respect to military stocks, the UK has been transparent about their size,[3] while the United States and UK have both placed under international verification material that they have declared as surplus to their defense requirements. In Russia and the United States, much surplus HEU has already been down-blended to LEU and more will be in future. The U.S./Russian Plutonium Disposition Agreement is another step forward. The Trilateral Initiative (involving the United States, Russia, and the IAEA) also holds out the prospect of these activities coming under some form of international rather than purely bilateral verification.

Such developments argue for continuing to address stocks through approaches of this sort, and for the FMCT to be aimed solely at achieving a straightforward ban on the future production of fissile material for nuclear weapons or other nuclear explosive devices.

Other Related Issues

It also follows in our view that an FMCT should not prohibit the production of fissile material either for other non-explosive military purposes (such as naval propulsion) or for civil purposes, though production for such purposes would of course have to be subject to verification. Similarly, the treaty should not prohibit the production for any purpose of tritium (which is not a fissile material), or the use of fissile material produced under verification to fuel tritium-producing reactors. In short, the treaty should only do what is required by the 1993 UNGA resolution.

Verification of an FMCT

Key Requirements

Any approach to verifying an FMCT will need to offer satisfactory assurance of detecting:

- Any diversion of fissile material produced in declared facilities after the cut-off date;
- Any undeclared production of fissile material.

Various verification arrangements for achieving these objectives are conceivable, but we believe that a focused approach is much more likely to be negotiable and cost effective.

The Focused Approach

Central to this approach would be a focus on the production and downstream use of unirradiated fissile material until it became:

- **Isotopically diluted so that it no longer met the definition of fissile material**
  (Material subject to FMCT verification, when mixed with material that is not subject, may produce a product that falls outside the definition of fissile material, e.g. down blending of HEU to LEU).
- **Irradiated to a sufficient level**
  (Important factors to be considered when defining a level of irradiation that is "sufficient" will be: the need to ensure that any diverted material would need reprocessing before it could be used to make a nuclear weapon or other nuclear explosive device; and a comparison with the risk posed by other opportunities to circumvent the treaty.)

- **Practicably irrecoverable**
  (Verification of waste materials could consume substantial effort and resources; given their low strategic importance, this is an area that will need careful consideration to achieve cost-effective measures.)

Against this background the focused approach would therefore have three key elements:

- Declarations of production and downstream facilities with relevant material;
- Verification of declared facilities and material; and
- Arrangements to detect undeclared production facilities.

Declarations of Production and Downstream Facilities

All production facilities (i.e. all enrichment and reprocessing facilities) would be declared, regardless of their operational status (i.e. operational, closed-down or decommissioned). For operational facilities, the declarations would include plans for the production of fissile material in the forthcoming year. Any production facilities that were under construction or planned would also need to be declared.

All downstream facilities that store, process or use fissile material produced after the cut-off date would be declared, for example Pu/MOX/HEU storage facilities or MOX/HEU fuel fabrication facilities and the reactors using such fuel. In order to aid measures to detect undeclared production facilities, it may also prove necessary to declare and allow access to other relevant facilities, e.g. hot cells or where equipment for reprocessing or enrichment is manufactured (as described in the Additional Protocol).

In the UK, as a minimum, declarations of key production and downstream facilities and relevant material would be required for the facilities at Sellafield (Figure 1), Dounreay (Figure 2) and Capenhurst (Figure 3).

Verification of Declared Facilities and Material

A. Reprocessing facilities

The boundary of what constitutes a reprocessing facility under an FMCT will probably need to be defined. Verification could commence at the "head end," i.e. where the spent fuel is sheared before dissolution, and could cease once termination criteria were met (see below). The details of the approach will need to have some flexibility at many of the older facilities that will become subject to verification, since these were not designed with safeguards in mind.

B. Enrichment facilities

Verification would apply to all enrichment processes, e.g. gas diffusion, gas centrifuge, aerodynamic processes, EMIS, laser enrichment processes, and chemical/ion exchange. At facilities declared to be producing only LEU, the verification measures could be designed to confirm this status. For example, environmental sampling might play a key role in achieving this at facilities that had never produced HEU in the past. Full nuclear material accountancy and control

Figure 1. Sellafield facility

Figure 2. Dounreay facility

Figure 3. Capenhurst facility

(NMAC) should only be required at facilities that are producing HEU.

C. Downstream facilities

The FMCT verification measures applied at facilities that store, process or use fissile material produced after the cut-off date would obviously depend on the nature of the facility concerned.

D. Decommissioned and closed-down facilities

The frequency and nature of inspections at relevant decommissioned and closed-down facilities would need to be appropriate to the degree of decommissioning, which can range from a facility preserved in working order to one which is fully dismantled. The procedures employed could be similar to those developed by the IAEA under NPT safeguards, which are based on the presence/absence of key equipment and an assessment of the functional capability of the facility. Past facilities that have reverted to green field or brown field sites would probably only require a single visit or the analysis of commercial satellite imagery to confirm this status.

Arrangements to Detect Undeclared Production Facilities

Measures to provide assurance that there is no undeclared fissile material production will probably include the use of non-routine inspections (e.g. challenge inspections), analysis of information (e.g. from open sources), and, possibly, Additional Protocol-related measures that are relevant to enrichment and reprocessing. In order to protect proliferation-sensitive information, managed-access arrangements will have to be permissible during any non-routine inspection. These are likely to be heavily influenced by the procedures agreed for challenge inspections under the Chemical Weapons Convention and those for complementary access under the Additional Protocol.

Other More Extensive Approaches

Other more extensive approaches to verifying an FMCT are conceivable. In particular it has been suggested that the focused approach needs bolstering by extending verification arrangements to the potential feed materials for clandestine enrichment and reprocessing facilities, i.e. to some or all of existing stocks of DNLEU and spent fuel. The coverage of all such material is the approach adopted for comprehensive safeguards agreements (CSA) with NNWS.

Application of this approach to the eight countries of particular relevance to an FMCT would be considerably more expensive than the focused approach. We also doubt if every one of them would agree to *all* their stocks of DNLEU and spent fuel being covered, and the utility of covering only *some* of them would seem to be questionable. Moreover, if, as we have suggested, it makes no sense to complicate an FMCT by trying to have it cover stocks of fissile material, this further calls into question the case for it covering stocks of DNLEU and spent fuel.

In short, it seems to us that, in the case of the FMCT, rather than expending large resources on verifying potential feed materials for undeclared production facilities, the more cost-effective approach would be to concentrate on developing satisfactory forms of non-routine inspection to detect any undeclared production facilities directly. We accept, however, that such measures would have to be suitably robust and that this is an area requiring further consideration.

IAEA Considerations

The FMCT verification regime will involve measures very similar to, if not identical to, safeguards measures applied by the IAEA. We certainly envision that, where they are applied, such measures should in general involve the same standards and criteria as IAEA safeguards. It therefore follows that the IAEA seems to us to be the most appropriate organisation to apply FMCT verification arrangements. It has the required expertise and experience, and setting up a new and separate organisation specifically to verify an FMCT would seem to be unnecessary.

The impact on the IAEA of taking on the role of FMCT verification should not be underestimated, however. Whilst it might be expected that few, if any, additional verification measures would be necessary in NNWS with CSAs and Additional Protocols in force, applying FMCT verification in non-CSA states would be a formidable task, even if the focused approach to verification is adopted rather than one of the more extensive options. The IAEA will need to recruit and train many additional inspectors, so that they can undertake verification activities at the many complex nuclear fuel cycle facilities involved. It could take years to introduce a focused approach in its entirety.

Benefits of an FMCT

An FMCT would introduce a worldwide, legally binding, and verifiable ban on the production of fissile material for nuclear weapons and other nuclear explosive devices. This would represent a considerable advance on the present situation in which only some states have declared voluntary moratoria on such production, and these are mostly unverified. In addition, an FMCT would make other measures to address stocks of fissile material more meaningful, because the benefit of such measures will always be questionable so long as there is no ban on future production. Last but not least, an FMCT would also put in place an essential requirement for nuclear disarmament, which will never be achieved without verification arrangements on fissile material production facilities.

Conclusions

- Any negotiation of an FMCT is likely to focus on the scope of the treaty and its verification arrangements;
- The scope of the treaty will be determined by the

materials it covers, whether stocks are covered in some way as well as future production, and other related issues;

- The materials it covers should essentially be those that can be used directly to make a nuclear weapon or other nuclear explosive device explode (i.e. essentially all grades of unirradiated plutonium and unirradiated uranium enriched to 20 percent or greater in U-235 or U-233, separately or in combination);
- Stocks of fissile material should not be covered by an FMCT, as this will make agreement of a straightforward ban on its future production for nuclear weapons or other nuclear explosive devices much more difficult, if not impossible. Experience has shown that there are other, more productive ways of addressing stocks;
- Seeking prohibitions on activities other than the future production of fissile material for nuclear weapons or other nuclear explosive devices would also not be a productive course to take;
- A focused approach to verifying an FMCT should be employed, i.e. one that would terminate verification arrangements on fissile material produced after the cut-off date once it no longer met the definition of fissile material, was irradiated to a "sufficient" level, or became practicably irrecoverable;
- Such an approach would involve declarations of production and downstream facilities with relevant material, verification of declared facilities and material, and arrangements to detect undeclared production facilities;
- Other more extensive approaches to an FMCT, involving a focus on DNLEU and spent fuel as well, are unlikely to be as cost-effective or technically coherent;
- It will, however, be important to ensure that arrangements to detect undeclared production facilities under a focused approach are robust;
- The IAEA seems best placed to apply any FMCT verification arrangements, but it will need substantial extra resources to do so;
- An FMCT has the potential to bring the international community many benefits.

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End Notes

1. The views expressed in this paper are those of the authors and do not necessarily represent UK government policy.
2. One exception is lightly irradiated high-enriched uranium.
3. The UK Strategic Defence Review of 1998 included publication of information on the total holdings of nuclear material for defence purposes.

A Chinese View on a Fissile Material Cut-off Treaty

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Abstract

Negotiations on a Fissile Material Cut-Off Treaty (FMCT) at the Conference on Disarmament (CD) in Geneva have been at an impasse since 1993. The 2000 Review Conference for the Nuclear Nonproliferation Treaty (NPT) called for FMCT negotiations to start immediately and to be completed in five years. China's participation in an FMCT will be critical to its success, however. Like the other four acknowledged nuclear weapon states, China is believed to have stopped producing HEU and plutonium for weapons, and China has consistently supported the FMCT negotiations. However, because of its concerns about U.S. missile defense plans, which China views as threatening the viability of its nuclear deterrent, China has recently expressed its unwillingness to enter FMCT negotiations without starting talks on agreements to prevent an arms race in outer space—since it is clear that the missile defense plans will inevitably intensify competition in outer space. To resume the FMCT negotiation, it is necessary to analyze the factors that may influence China's position. In this paper, I will explore China's possible position in upcoming FMCT negotiations, China's major security concerns, the kind of verification provisions that could be accepted by China, and the factors that might facilitate China's participation in the treaty.

Introduction

A universal fissile material cut-off treaty (FMCT) has long been seen as a key building block in nuclear disarmament and nonproliferation. Such an accord would ban the production of fissile material (separated plutonium, highly enriched uranium, and uranium-233) for nuclear weapons. A primary goal of an FMCT will be to attain the signatures of the five declared nuclear weapon states (the United States, Russia, the United Kingdom, France, China) and three de facto nuclear weapon states (India, Pakistan, and Israel), because almost all other countries will already be subject to its requirements by virtue of their ratification of the NPT as non-nuclear-weapon states (NNWS). An FMCT would make irreversible the reduction in nuclear weapon material in the United States and Russia. It would cap the size of all potential nuclear arsenals. A universal FMCT would also draw the three de facto nuclear weapon states into the nuclear nonproliferation regime.

Proposals to achieve a fissile material cut-off agreement date to the mid-1950s. In 1993 the United Nations General Assembly adopted a resolution calling for the negotiation of a nondiscriminatory, multilateral, and internationally and effectively verifiable treaty banning the production of fissile materials for nuclear weapons or other nuclear explosive devices.[1] In March 1995, the CD decided to adopt Ambassador Shannon's report and to establish an ad hoc committee to begin negotiations on an FMCT. In May 1995 at the NPT extension conference, the parties adopted a principles and objectives document that called for the "immediate commencement and early conclusion" of FMCT negotiations. After several years delay caused by debates over scope and linkage to nuclear disarmament measures, the CD agreed on August 11, 1998, to convene an ad hoc committee to negotiate an FMCT. However, the negotiations quickly ended when the CD failed to agree on renewing the Committee's mandate. The 2000 Review Conference for the NPT called for FMCT negotiations to start immediately and to be completed in five years. However, until now, the CD remains deadlocked over the resumption of negotiations, due to the linkage between FMCT and Prevention of an Arms Race in Outer Space (PAROS) and nuclear disarmament.

In practice, the FMCT does not have much impact on the U.S. and Russian stockpiles. Because of their huge size, they do not need additional fissile material. One major incentive for the declared nuclear powers to join the treaty is to draw the participation of the three de facto weapons states. China's participation in an FMCT will be critical to its success, however. Without China's participation in the FMCT, India will not sign it; Pakistan will not sign unless India does. Both South Asian countries and Israel are believed to be continuing to produce fissile materials for their stockpiles. China is believed to have stopped the production of both HEU and plutonium for weapons in the early 1990s. China announced its support for the FMCT negotiation from the beginning. On October 4, 1994, Chinese Foreign Minister Qian and U.S. Secretary of State Christopher issued a joint statement in which they promoted the "earliest possible achievement" of a treaty prohibiting the production of fissile material for use in nuclear weapons. On October 29, 1997, Chinese President Jiang Zemin and U.S. President Clinton called for "the earliest start of formal negotiations on the Prohibition of Production of Fissile Material Used in Nuclear Weapons and Other Nuclear Explosive Devices." However, because of its concerns about U.S. missile defense which will threat the viability of China's nuclear deterrent, China is less willing to enter FMCT negotiations without starting talks on agreements to prevent an arms race in outer space—since it is clear that the missile defense plans will inevitably intensify competition in outer space. Both the outer space and nuclear disarmament issues, which have closed links with U.S. missile defense plans, have prevented the CD from starting any arms control negotiations. To advance these talks, it is therefore necessary to analyze the factors that may influence China's position.

China's Major Security Concerns

China's interest in an FMCT will depend on whether it judges its existing fissile material stockpile to be adequate for its future weapon needs, which would depend on its future nuclear policy and others countries' military and nuclear weapon programs. It is reported that China stopped HEU production in 1987 and plutonium production in 1991. Some estimates suggest that China's stockpile could contain about three metric tons of weapon-grade HEU and one metric ton of separated plutonium.[2] China's nuclear arsenal is thought to include approximately 300 strategic warheads and might have as many as 150 undeployed battlefield warheads.[3] Thus, the stock of fissile materials already produced are more than sufficient for China's current nuclear arsenal and a very moderate further build-up. However, China's need for additional fissile material and nuclear weapons would be affected by the future international security environment. China has developed a very limited nuclear force for self-defense and has kept a minimum deterrence nuclear policy. To this end, on the very first day when China exploded its nuclear device, it declared a no-first-use nuclear policy. Now China's security concern is how to maintain an effective nuclear deterrence in the changing international security environment. Thus, the following major security concerns would affect China's attitude toward the FMCT negotiation.

China is expressing a serious concern on U.S. missile defense plans. The claims that missile defense is intended to defend U.S territory from missile attacks by a state of concern and unauthorized or accidental launches from Russia and China do not bear scrutiny. The missile defense goal of protecting against attacks by states of concern such as North Korea seems pointless, since North Korea and other states of concern have no ballistic missiles capable of reaching the United States presently or in the foreseeable future. Even if North Korea were to develop an intercontinental missile capability, it would not dare to use it against the United States because that would be certain suicide. Also, whether launched accidentally or deliberately, Russia's thousands of nuclear warheads would easily overwhelm the proposed U.S. defenses. However, the system being designed and developed can intercept twenty to one hundred warheads, could in principle neutralize the twenty single-warhead ICBMs capable of reaching the United States that China now has. As seen by Chinese leaders, China's own small strategic arsenal appears to be a much more plausible target of the proposed system. Thus, China worries that U.S. missile defense could politically or strategically subject China to nuclear blackmail. Such a system would give United States much more freedom to intervene in China's affairs including undermining China's efforts at reunification with Taiwan. Such concerns have increased in China, given the unclear Sino-U.S. relationship; the bombing of China embassy in Belgrade; the spy plane event; arms sale to Taiwan; and the recently released reports of the U.S. Nuclear Posture Review in which the Bush administration has reportedly directed the military to prepare contingency plans to use nuclear weapons against at least seven countries including China.

Moreover, China is concerned about the U.S. agreement on cooperative research and development of an advanced theater missile defense (TMD) with Japan. Many Chinese worry that such TMD deployment would undermine the strategic leverage of China vis-a-vis Japan. It would strengthen the Japanese military alliance with the United States to engage China on the Taiwan issue. Indeed, based on their amended Defense Cooperation Guidelines signed in September 1997, Japan and the United States could enlarge the use of such missile defense systems from the alliance's defense area to *surrounding situations,* possibly including Taiwan. Also, the co-development or transfer of a TMD system and its technologies will give Japan offensive missile capabilities and encourage Japanese militarism. Even worse, it could motivate Japan going nuclear. Japan has a civil plutonium program and a plan to stockpile civil separated plutonium. If Japan wants, the plutonium stock along with the missile technology acquired from the TMD program would allow Japan to deploy a deliverable nuclear force within a relatively short time. Eventually, Japan's TMD program will accelerate a regional arms race and seriously jeopardize regional stability. Finally, China opposes the possible cooperation on or transfer of a TMD system from any country to Taiwan, which would encourage separatism in Taiwan and represent serious interference in China's internal affairs.

China's other major security concern is the weaponization of outer space. China has concerns that U.S. missile defense plans will inevitably intensify competition in outer space. To develop strategic missile defense systems, the United States would have to develop and use its military assets in outer space and deploy space-based missile defense components that will function as a space weapon system. And the missile defense system itself could be used as anti-satellite (ASAT) weapons. Meanwhile, such a missile defense system will encourage other countries to deploy ASAT weapons. Thus, it will initiate a new arms race in outer space. China has further concerns about any U.S. program of *controlling outer space*. The United States has launched a space control technology program that will include elements of "protection, prevention, negation, and surveillance" of various space activities.[4] The goal is often stated as "space control," which would require the development, testing, and deployment of ASAT weapons based in space or on earth. The arms race of ASAT weapons would make the peaceful use of outer space much more dangerous, such as the vital communication, navigation, and environmental monitoring satellites would be countered. The development of the space control program would raise the risk of turning outer space into a battlefield. China is further concerned that the U.S. space dominance program will offer the United States absolute military superiority and be used to intervene in China's affairs. Based on these concerns, recently China expressed clearly that the prevention of the weaponization of and an arms race in outer space is an urgent and realistic issue.[5]

These security concerns affect China's willingness to participate in FMCT negotiations. Historically, the sole purpose of China building and developing its nuclear weapons was to guard itself against a nuclear threat and blackmail. If its legitimate security concerns are ignored, China would develop responses to neutralize such threat. To retain its nuclear deterrent capability, China's direct response to the U.S. missile defense could be to build more warheads and its missiles would be deployed with decoys and other effective countermeasures. China is already reportedly engaged in a nuclear modernization program to field less vulnerable mobile and solid-fueled missiles. But it has been expected that such a program will be at a slow pace and modest in size. The number of ICBMs might possibly be expanded twofold. The existing HEU and plutonium stockpile would be big enough for its modernization program under the case of non-deployment of missile defense. However, while facing a planned U.S. missile defense system, China could be driven to expand its ICBM arsenal tenfold. China would use up its existing fissile-material stockpile for the many more missiles needed to penetrate the U.S. missile defense system. Thus, China might find it necessary to produce more fissile material for its stockpile. China might then well restart production and refuse to join a global fissile material cut-off treaty. This might explain why China has linked the FMCT negotiation with talks on agreements to prevent an arms race in outer space—which would include limiting U.S. missile defense plans.

Another reason for China to rethink its position on the FMCT would be its concern about a huge gap between China's nuclear arsenal and those of the United States and Russia. This gap would remain because U.S. missile defense and its withdrawal from the ABM Treaty would end further reductions in the nuclear arsenals of the United States and Russia. Although the United States and Russia may reduce their deployed strategic nuclear arsenals to around 2000 warheads over the next ten years, it is not clear whether these withdrawn warheads will be dismantled. Even so, such a proposal limits only the number of deployed strategic warheads; there is no limit on the number of non-deployed or reserve warheads. So the United States and Russia would still keep huge nuclear arsenals. Also, China has concerns about the large existing military stocks of fissile material for weapons possessed by the United States and Russia. Although both countries have declared excess quantities of HEU and plutonium, their stockpiles remaining after reduction will still be huge. Furthermore, China has always believed that the ABM Treaty has played a pivotal role in maintaining a global strategic balance and stability as well as in keeping the momentum of nuclear disarmament process.

But without the ABM Treaty, both countries are likely to maintain a higher level of nuclear forces than they would have otherwise. This would halt further nuclear reductions. Ending the deeper cut process will not be in China's security interest. China is not willing to see the huge "strategic missile gap" between its arsenal and those of both leading nuclear powers, which pose a huge threat to China's small nuclear arsenal. Eventually, failure to proceed with the nuclear disarmament process that the nuclear weapon states have committed to under the NPT would damage the nuclear nonproliferation regime. In the white paper on China's national defense in 2000, China cited its dual concerns: "In view of the fact that the United States is accelerating its efforts for the development and possible deployment of a national missile defense system and space weapons, and that the United States and Russia still possess nuclear arsenals large enough to destroy the world many times over, it is China's position that continued nuclear disarmament and the prevention of an arms race in outer space are multilateral fora of arms control that should be given more priority than the FMCT negotiations."[6] Consequently, both the outer space and nuclear disarmament issues, which have closed links with U.S. missile defense plans, have prevented the CD from starting the FMCT negotiations.

FMCT Verification

One focus in negotiating the FMCT will be verification. Under an FMCT verification, China's sensitive nuclear facilities and sites would be accessed by the first time for international inspections. The verification measures adopted could affect China's willingness to sign the convention.

China's position on the FMCT is that the treaty should only ban the future production of fissile material for nuclear weapons or other nuclear explosive devices, and should not touch upon the existing stockpiles.[7] The treaty would ban the production of fissile material for nuclear weapons or other nuclear explosive devices. It would prohibit the diversion of fissile material produced for other purposes to nuclear weapons or other nuclear explosive devices. The verification regime of the treaty should comply with the above-mentioned basic obligations for just and effective verification. And the treaty should not undermine the legitimate security interest of the state parties.

The scope of verification will depend on the facilities and activities subject to an FMCT. It is necessary to define clearly the scope of verification. Such discussion has centered on the focused verification and wide verification approaches. Focused verification would concentrate on only sensitive fissile material production facilities, i.e., reprocessing and enrichment facilities, and fissile materials produced after an FMCT enters into force along with the facilities where these materials are present. A wide-scope approach would further cover a variety of less sensitive civil facilities such as fuel fabrication plants and civilian power reactors. For China, the wide-scope approach could pose some problems. For example, China is believed to use LEU fuel for its submarine reactors. The naval LEU fuel is fabricated at Baotou Nuclear Fuel Component Complex.[8] Under the wide verification, those LEU fuels would be required a quantitative account, which could be sensitive for China. However, under the focused approach, such a facility would not be safeguarded. It is believed that a focused approach is technically adequate and cost-effective for the FMCT.[9] It is most likely to be acceptable by the nuclear states.

Under an FMCT, China's previous military nuclear facilities and some civilian facilities would require verification. Table I lists the related major nuclear facilities in China under an focused approach.[10] The basic FMCT verification measures will include: safeguards at declared facilities similar to those administered by the IAEA; non-routine inspections involving managed access; environmental monitoring, and remote sensing involving satellite imagery. Appropriate techniques would be developed for each specific facility taking account of its status, such as whether it is under construction, closed-down, decommissioned, or operating. For facilities used only for civil purposes, such as the civilian reprocessing plants and gas centrifuge enrichment plants (CEPs), China would have no objections to IAEA-type safeguards. However, for past military facilities, China would have some concerns about the disclosure of sensitive information. As a nuclear state, China would expect that the FMCT verification system for those former military facilities in the eight target states would have to be different from the IAEA safeguards for NNWS. An FMCT is likely to permit the eight nuclear nations to hold undeclared stockpiles (from past production) and to use or process already produced fissile material for sensitive military activities including the assembly of nuclear weapons. These allowed sensitive production facilities and activities could be collocated with facilities requiring verification. Thus, like other target states, China could worry about potential loss of sensitive information at those defense-related nuclear processing sites. Also some nuclear facilities could be not established following the requirement of IAEA safeguards, so their military classified levels and their political tolerability might be lower. Consequently, some IAEA safeguards measures, which can be accepted by the NNWS, might be seen as too intrusive and not be permitted by the eight target states. Thus, less intrusive verification would be preferable.

In the following, as case studies, I will demonstrate what verification measures might be applied and accepted to China's enrichment and reprocessing plants.

Gaseous diffusion plants. China began producing HEU in 1963 at a gaseous diffusion plant (GDP) located near Lanzhou and, in the mid-1970s, started production at a second GDP in Heping.[11] It has been reported that both GDPs stopped HEU production in 1987 and that the Chinese government is preparing to decommission a number of military nuclear material processing facilities, including the Lanzhou GDP.[12] The Heping GDP may also be shut down, as China is building enough CEP capacity to supply its LEU needs.[13] This CEP capacity, which is being built for China by Russia, is to be under IAEA safeguards. Under the FMCT, it is required to verify the shutdown status of both GDPs. Here I will take Lanzhou GDP as a case study.

The Lanzhou GDP is located on the bank of the Yellow River near Lanzhou in Gansu Province. Published estimates put its initial capacity at 10-50,000 kg-SWU per year—these later increased to about 300,000.[14] A declassified Corona satellite image of the Lanzhou GDP taken on March 31, 1971, shows clearly the infrastructure of the site,[15] including the enrichment building; a mechanical cooling tower used to discharge waste heat from the enrichment processing; and coal-fired steam plant used to provide heat or electricity for the GDP. One telltale signature of the GDP operation should be the water-vapor plume coming from the cooling tower. This plume will be easy to detect with one-meter-resolution satellite images. Another important signature of the GDP operating would be the hot roof of the enrichment buildings. The elevated temperature of the roofs would be detectable using commercial satellites (such as Landsat-7 and ASTER) thermal infrared images. In short, the shutdown status of Lanzhou GDP could be monitored effectively using satellite images at visible band and thermal infrared band.[16] This approach would be the least intrusive. It is expected this approach could be applied to the case of Heping GDP as well. Such remote sensing method should be easily accepted by China.

To further confirm the shutdown status of the GDP, some onsite inspections should be allowed. These include 1) site visual observation, such as no treatment of cooling water, no electrical service for the enrichments, not hot and not noisy inside the enrichment building; and 2) continuous surveillance monitor and tamper-proof seal, such as, sealing the high-voltage disconnect switches; sealing the valves on the supply and return headers of the recirculating cooling water system; sealing the inlet and outlet block valves for the cascade piping; putting vibration and or/temperature sensors on the process equipment. These verification measures would be effective for monitoring the shutdown status of the GDP and would pose less security concerns. One concern on such a site would be the diffusion barrier technology information that most countries consider an industrial secret. However, this would be easily protected by preventing measures.

Finally, China's non-weapon HEU requirements are likely to be very small, which means China is unlikely to resume its GDPs to produce HEU. Its nuclear-power submarines are reported to be fueled with LEU that might be provided by its CEPs. Under a focused verification approach, the LEU for the naval reactors need not be quantitatively declared, and should provide fewer concerns on its naval reactor fuel. Furthermore, at Baotao's tritium production reactor, some HEU might be used for the production of tritium to offset the decay of tritium in its current warheads. However, it is estimated that such a tritium production reactor only needs some tens of kilograms HEU annually,[17] which might be provided from its HEU stocks.

Reprocessing plants. China's first plutonium production complex, Jiuquan Atomic Energy Complex, began plutonium production since the late-1960s. This complex also houses facilities for manufacturing HEU and plutonium and assembling weapons. In the mid-1970s, China built a second plutonium production complex at Guangyuan as part of China's duplicate third line of nuclear weapon manufacturing facilities.[18] It is the site of a larger plutonium production reactor and reprocessing plant. Both plutonium production complexes may have been shut down in 1991. It can be expected that under an FMCT, both complexes would keep their shutdown status.

Under an FMCT, it is necessary to confirm the shutdown or decommissioned status of the reprocessing plant. With satellite monitoring, the most likely observable characteristics would be the activity level. When operating, there will be many shipments of various forms of nuclear material to the site. For these activities, transport vehicles, such as trucks, would be large enough to be detected by one-meter-resolution images from satellites.[19] Other preferred offsite verification could include: offsite monitoring of nuclear and chemical effluents such as krepton-85. However, some kinds of onsite inspections will be required to verify that the reprocessing plant is shutdown. While inspectors conduct onsite visits and inspect the site, China could have concerns about the possible disclosure of its sensitive nuclear information. Thus, it is necessary to explore what onsite inspections China would accept. These would ensure effective onsite inspections and environmental sampling measures without compromising China's national security interests.

To monitor the status of a reprocessing plant, the most effective verification would be site environmental sampling.[20] The samples could be taken from gloveboxes in the plutonium product processing sectors, which would allow a determination of the burnup of the spent fuel, plutonium isotopic composition, and the time since separation of the plutonium. Another effective approach to detect undeclared reprocessing activities would be for inspectors to take samples from high-level waste tanks or the areas contaminated by high-level waste, which would for recent plutonium production activities, determine the important quantities—the burnup of spent fuel, plutonium isotopic composition, the irradiation time and discharge time—to reasonable accuracy through measurements of ratios of fission product and actinide isotopic ratios. This will help confirm the status of the plant.

At the same time, China may worry that onsite sampling analysis could disclose sensitive information about its past plutonium production activities, such as the power level at which production reactors had operated and how much plutonium they had produced, data that will probably not have to be declared under an FMCT. However, sampling at the reprocessing facilities would not reveal such sensitive information as long as inspectors are not able to measure total quantities of Cs-137 and Sr-90 from HLW produced at former military plutonium production facilities. Sampling methods can therefore serve as an effective and militarily non-intrusive measure for verification of an FMCT. It should be noted that it is not clear whether China, as Russia does, would take the plutonium isotopic composition as sensitive information (here we assume it would not). If so, the sampling analysis would be restricted to the appropriate level. Other onsite inspections at the reprocessing site would also be allowed, such as visual observation to show there are no activities at the spent fuel cask portal.

One major concern about the onsite verification of the Jiuquan and Guangyuan complexes could be the issue of collocated facilities. Under the FMCT, the nuclear-weapons-related activities at the complexes including the fabrication of weapons components and the final assembly of weapons should be permitted and continued. Some sensitive information, e.g., chemical composition information from these activities, might be divulged through sampling and analysis around the facilities. Therefore, it is necessary to explore whether conducting onsite sampling around reprocessing facilities could also get such sensitive information, which might depend on how far away such information is detectable from the sensitive manufacturing facilities and how close such facilities are to the reprocessing plant. For such collocated sites, a managed access approach should be applied.

Finally, FMCT verification regime would have to be designed to detect undeclared nuclear facilities, such as reprocessing or enrichment facilities. Such verification measures could include non-routine inspections including challenge inspection. However, learning from the lesson of the event of Silver River Ship, China will be unwilling to see the abuse of such kind of inspections at its sensitive and non-proscribed military and nuclear activities. To protect its national security sensitivities, it is essential to have an appropriately managed access mechanism. For example, for most cases of managed access situations, sampling around the site, without access to the inner sectors of the buildings or the appropriate control security fences, would be sufficient. However, in some locations, including the fissile material manufacturing facilities, measures would have to taken to prevent overt or covert sampling. In some cases where it will be essential for inspectors to have access areas with classified activities, appropriate measures would have to employed to protect sensitive information. For example, at the nuclear weapons assembly facility, the sensitive information—weapons component, or process machinery that provided design information—might be vulnerable to the visual access. Thus it had to take measures including shrouding and masking of sensitive equipments or other obvious method to prevent the visual access.

In short, under the FMCT, appropriate verification measures would be able to verify China's reprocessing and enrichment facilities without compromising national sensitive information.

Conclusions and Discussions

China has serious concerns about U.S. missile defense plans. Such missile defense threatens to neutralize China's nuclear deterrence. The development of missile defense would inevitably initiate the weaponization of outer space and halt deeper cuts of nuclear arsenals of the United States and Russia. All these developments would not be in China's security interest. If its legitimate security concerns are ignored, China would develop responses to neutralize such threats. To retain its nuclear deterrent capability, as a direct response to these events, China would need more warheads than otherwise. Thus, China would need more fissile material to fuel those weapons, which would inevitably affect China's willingness to join a fissile material cutoff treaty. Also China would prefer a just and effective FMCT verification without undermining its legitimate security interest. Appropriate verification techniques should be acceptable to China's nuclear facilities without compromising its national sensitive information. However, the international security environment is a concern for China. China holds that the purposes and objectives of arms control and disarmament "should serve to enhance the security of all countries; it should not become a tool for stronger nations to control weaker ones, still less should it be an instrument for a handful of countries to optimize their armament in order to seek unilateral security superiority."[21] China is against any country seeking its own security at the cost of others. However, the ending of the ABM Treaty, U.S. missile defense plans, along with other developments including the rejection of the CTBT, all run counter to the purposes and objectives of arms control and disarmament. If Chinese security concerns are not considered by other countries, and its security status quo is worsened by other countries' military and weapons programs, China's leaders would doubt the value of arms control and disarmament and would reconsider its participation in multilateral nuclear arms control treaties.

To facilitate China's participation in the FMCT, and to break the current standstill of the arms control and disarmament process, the major nuclear powers should take some measures (although they are not necessarily preconditions to the FMCT negotiation).

- Without the ABM Treaty and with the development of missile defense, there is a risk that outer space will become weaponized. Although there is at present no arms race in space, it is necessary to take some measures to prevent the weaponization of outer space before there is active conflict or even an approach to conflict in space. Since the prevention of the weaponization of and an arms race in outer space is becoming an urgent issue, the CD should start to negotiate a treaty on the prevention of an arms race in outer space (PAROS) early. The treaty should prohibit the testing, deployment, and use of weapon systems and their components in outer space.
- After the ABM Treaty, the United States and Russia should establish a new international strategic balance and stability framework based on international legal regimes. Such a framework should constitute the basis and precondition for progress in nuclear disarmament. It should also take into account the interests of every state and aim at ensuring common security. While U.S. missile defense plans would not be stopped as the Chinese hope, the policy maker should take Chinese concerns seriously, and take measures to assure China that the system will not target China, as some U.S. officials have promised. Also if the U.S.-Japan joint TMD plan can exclude Taiwan, it would greatly reduce China's concern about the regional security issue.
- The United States and Russia should reduce their huge nuclear arsenals in a verifiable and irreversible manner through legally binding instruments. Even with the conclusion of their current reduction pledge to reduce the deployed strategic nuclear arsenal to around 2,000 warheads over the next ten years, the

United States and Russia would still keep a huge total inventory of nuclear weapons. Thus, the United States and Russia should take the lead and commit to making further substantial reductions to their respective nuclear arsenals. The reduced nuclear warheads and explosives should be dismantled and disposed in a verifiable way, and not be used again as weapons in any form.

- To help reduce China's concerns about the United States and Russia's large existing military stocks of fissile material for weapons, the United States and Russia should make more significant commitments to irreversible reduction of their fissile material stockpiles including fissile material from warheads withdrawn under the deep-cut agreements. In fact, even after the planned elimination of hundreds of tons of weapons plutonium and HEU, each will retain perhaps 50 tons of plutonium and a few hundreds tons of weapons-grade HEU that is enough to make more than 10,000 thermonuclear warheads. Thus, without significant reductions of their stockpile, the FMCT would little limit the United States and Russia's nuclear arsenals.
- The nuclear-weapon states should, at an early date and in a legally binding format, unconditionally undertake a no-first-use nuclear policy. A no-first-use policy would be an important measure to strengthen the non-proliferation regime and to promote further reduction of nuclear weapons. China has taken seriously the first-use policy of other nuclear powers. Given the huge gap between China and the U.S. nuclear arsenals, if the United States makes a nuclear first strike on China's nuclear targets, the number of surviving warheads of its smaller nuclear force would be very limited. Furthermore, the retaliation capacity of those survived warheads would be neutralized by the U.S. missile defense. Thus, China's nuclear deterrence would be heavily threatened. Therefore, if the United States, as Russia has done, commits to a no-first-use policy with China, it would be very attractive to China and increase China's willingness to participate in the FMCT.

Table 1. China's main nuclear production facilities related to an FMCT

Facilities/sites	Status	Capabilities
Reprocessing plants		
Jiuquan reprocessing plant	Previous military; Shutdown; Operated '70s-'91?	—
Guangyuan reprocessing plant	Previous military; Shutdown; Operated '70s-'91?	—
A pilot reprocessing plant at Lanzhou	Civilian purpose; ready operation in 2000	50MT/yr
A proposed commercial reprocessing plant at Lanzhou	Civilian purpose; planned commission in 2020	800 MT/yr
Enrichment plants		
Lanzhou GDP	Previous military; Shutdown; Began operation in 1963; HEU production ended in 1987	300kSWU-kg/yr
Heping GDP	Previous military; Shutdown? Began operation in 1974; HEU production ended in 1987	150-590K SWU-kg/yr
Hanzhong CEP (At Shaanxi)	Civilian purpose (LEU); 1st stage=200kSWU operating; Around 2001, total=500kSWU	500 kSWU-kg/yr
Lanzhou CEP	Civilian purpose (LEU); 1st stage=200kSWU operating; Around 2002,total=500kSWU	500kSWU-kg/yr

Notes and References

1. Prohibition of the Production of Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices, United Nations General Assembly resolution 48/75L.
2. Wright, David. 1996. *Estimating China's Stockpile of Fissile Materials for Weapons.* Draft, Union of Concern Scientists Technical Working Paper, Washington, D.C.
3. Norris, Robert S. 1994. *Nuclear Weapons Databook Volume V: British, French, and Chinese Nuclear Weapons.* Westview Press.
4. Garwin, Richard L. 2000. Space Weapons or Space Arms Control. *American Philosophical Society Annual General Meeting.*
5. http://www.fmprc.gov.cn/eng/24967.html
6. Information Office of the State Council of the People's Republic of China. 2000. China's National Defense in 2000. *China Daily,* October 17, 2000.
7. http://www.fmprc.gov.cn/chn/2852.html
8. Norris, Robert S. 1994. *Nuclear Weapons Databook Volume V: British, French, and Chinese Nuclear Weapons.*
9. Bragin, V., and J. Carlson. 2000. An Introduction to Focused Approach to Verification under FMCT. *Journal of Nuclear Materials Management,* Vol. XXVIII, No. 2.
10. Sources: Norris, R. S. 1994. *Nuclear Weapons Databook Volume V: British, French, and Chinese Nuclear Weapons;* Albright, David, 1997. Plutonium and Highly Enriched Uranium 1996 Oxford; *Nukem Market Report:* World Nuclear Capacity, December 1993; also see http://www.insc.anl.gov/nre/nre.html; see http://www.fas.org/nuke/guide/.
11. Albright, David. 1997. *Plutonium and Highly Enriched Uranium 1996.*
12. Hibbs, Mark. 1999. China Said to be Preparing for Decommissioning Defense Plants. *Nuclear Fuel,* May17, 1999.
13. China's planned total nuclear capacity for 2005-2006 is about 8.6 GWe (see "China: Romancing the Dragon," *Nukem Report,* Fall 1997). Except Qinshan-4.5 heavy water reactors (2X675MWe), all the other reactors (about 7.25 GWe) require LEU. To supply LEU for this much capacity will require up to 1 million SWU/y enrichment capabilities. It is projected that the China will have a total gas-centrifuge enrichment capacity at Lanzhou and Hanzhong CEPs of about 1.5 million SWU/y by around 2005 (see Hibbs, Mark. 1999. China Moved Centrifuge Complex to Keep Enriching U at Lanzhou. *Nuclear Fuel*, May17, 1999).
14. Albright, David. 1997. *Plutonium and Highly Enriched Uranium 1996,* p. 127.
15. http://fas.org/nuke/guide/china/facility/
16. Zhang, Hui, and Frank N. von Hippel. 2000. Using Commercial Imaging Satellites to Detect the Operation of Plutonium-Production Reactors and Gaseous-Diffusion Plants. *Science & Global Security,* Vol. 8, No. 3.
17. Berkhout, Franks. 1994-1995. A Cutoff in the Production of Fissile Material. *International Security*, Vol.19, No. 3.
18. Norris, et al., 1994. *Nuclear Weapons Databook Volume V: British, French, and Chinese Nuclear Weapons.*
19. Zhang, Hui. 2000. Uses of Commercial Satellite Imagery in FMCT Verification. *The Nonproliferation Review,* Vol. 7, No. 2.
20. Zhang, Hui. 2000. Detecting Undeclared Reprocessing Activities Through Sampling Activities. *Proceedings of the INMM 41st Annual Meeting*
21. http://www.fmprc.gov.cn/eng/24967.html

Radionuclide Monitoring for the Comprehensive Nuclear Test Ban Treaty

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Note: The views expressed herein are those of the authors and do not necessarily reflect the views of the CTBTO Preparatory Commission.

Abstract

Global monitoring for relevant radionuclides in the atmosphere serves as part of the International Monitoring System (IMS) to verify compliance with the Comprehensive Nuclear Test Ban Treaty (CTBT). The radionuclide network consists of eighty stations supplemented by sixteen radionuclide laboratories. All stations have a particulate sampler and forty were selected for noble gas samplers with the option for later expansion to all sites. This paper describes radionuclide signatures, the employed measurement technologies, and achieved detection sensitivity, as well as data analysis and reporting by the International Data Centre (IDC). Finally, data fusion with seismoacoustic events and the application of atmospheric transport modelling are discussed.

Introduction

The Comprehensive Nuclear Test Ban Treaty (CTBT) had been negotiated by the Conference on Disarmament in Geneva between 1993 and 1996. It was opened for signature on September 24, 1996. As of March 15, 2002, the treaty was signed by 165 states and ratified by ninety, thirty-one of which belong to the group of forty-four states for which ratification is required for the CTBT to enter into force. The Preparatory Commission for the CTBT carries out the necessary preparations for the effective implementation of the CTBT. The Provisional Technical Secretariat started its work in March 1997 in Vienna.

The basic obligation of the CTBT for each state party is "not to carry out any nuclear weapon test explosion or any other nuclear explosion" (Article I, 1). In order to verify compliance with this obligation, the IMS consisting of 321 stations is being established in order to monitor the whole globe. Subnetworks are under construction that are based on four different sensor technologies. The seismic network will consist of fifty primary and 120 auxiliary seismological stations; the hydroacoustic network comprises eleven stations to monitor all oceanic waters; sixty infrasound and eighty radionuclide stations are being set up (Hoffmann/Kebeasy/Firbas, 1999).

Seismic, hydroacoustic, and infrasound signals can be combined to detect seismoacoustic events which indicate events that released energy in waveform. The possible origin of these energies can be explosions, earthquakes, or other events. The fourth technology measures radioactivity in the atmosphere. The purpose of the four IMS sensor networks is to detect signals that are indicative of nuclear explosions, as well as to identify and to locate nuclear explosions underground, underwater, or in the atmosphere.

Seismic, hydroacoustic, and infrasound have the advantage of providing highly accurate information about the location in time and space of a seismoacoustic event. In addition, it is possible to distinguish to a high degree between natural events such as earthquakes and anthropogenic events such as explosions. However, these sensors are not able to provide any indication of what caused an explosion. The detection of relevant fission and activation products is the only way to identify the nature of an event that is caused by a nuclear explosion. This is often referred to as the detection of the smoking gun. Given a sufficient sample of radioactive debris, the information that is gained from radionuclide analysis can be very rich. Some characteristics of the original event can be reconstructed regarding the environment of an explosion and the nuclear materials involved. Concentration ratios of certain radionuclides are especially useful to distinguish between a nuclear explosion and a nuclear reactor source and to estimate the date of the release.

However, radionuclide monitoring has virtually no accurate localization capability. Detections are not prompt and could be delayed by a transport time of several days, sometimes even one or two weeks. However, given a sufficiently large release of activity, the relevant geographic area can be confined considerably with a combined evaluation of detections and non-detections by a network of stations over several days. Nevertheless, radionuclide events will most likely not prove adequate for a decision on where to conduct an onsite inspection unless the event is located with high accuracy by other elements of the IMS.

Radionuclide Signatures

Historic examples of detections

In the past, there were many incidents where a detection of radioactivity indicated a nuclear test explosion that occurred at a large distance. Up to 1998, a total of 2,041 nuclear explosions occurred (Yang/North/Romney, 2000). Most of them were detected either by seismoacoustic or radionuclide signals, or by both. Various radio-chemical and nuclear analytical methods have been successfully applied to identify and characterise the nuclear explosions. Early methods focused on total beta counting of rain samples and autoradiographs of single hot fall-out particles. Vegetation, food, and sludge samples were analyzed as well. Aerosol particles were collected on air filters at ground level as well as at high altitude with the help of airplanes. For example, the Ba-140 concentrations in the atmosphere that were reported in the literature and that were thought to indicate a nuclear test explosion at large distances range from 30 to 5 $10^5 \mu Bq/m^3$. For Xe-133, concentrations of up to 1,600 mBq/m^3 were attributed to venting from underground nuclear explosions.

For example, the Swedish national monitoring program detected twenty-two Chinese atmospheric tests (De Geer, 1996) as well as venting from eight underground explosions between 1966 and 1990 (De Geer, 1996a). The Swedish network has detected thirty different fission products and seventeen activation product isotopes in nuclear weapons test debris (De Geer, 2001).

Noble gas sampling

Though radioactive aerosols carry a lot of information, their release from underground explosions is limited to unintentional ventings. In addition, particle transport through the atmosphere can be terminated by scavenging processes like wash-out by rain or by dry deposition. In comparison, noble gases have the advantage of being the only radionuclide signature that has the potential of escaping at detectable concentrations from underground and underwater explosions. In addition, the noble gases are not affected by any deposition process. They are removed from the atmosphere only by their radioactive decay. Though noble gas monitoring has been applied since the 1940s, it took until the more recent past, before it became more generally recognized as a routine monitoring method to detect radioactive signals from nuclear explosions. Most suitable is a suite of xenon isotopes (Xe-131m, Xe-133, Xe-133m, Xe-135) which have half-lives in the range of nine hours to twelve days.

Ground-based air sampling

Already in 1958, a Geneva Conference of Experts on the Means of Detection of Nuclear Explosions considered radioactive debris as only specifically nuclear indication of an explosion that is available for analysis at large distances. Accordingly, ground-based as well as airplane mounted air filtering devices and analysis of the collected fission products were suggested as a means to detect nuclear explosions at distances of several thousand miles and at times of ten to twenty days after the event (Mark, 1959).

The most timely and most reliable collection method is based on high volume air samples taken at ground-based stations. The most comprehensive and cost-effective analysis method is high-resolution gamma spectroscopy for particulate filters and in addition beta-gamma coincidence counting for noble gas samples.

Network design

A nondiscriminatory approach that offers the most uniform sensitivity is a network of stations distributed according to meteorological conditions over the globe. Various possible designs of radionuclide station networks were discussed over the decades and many countries implemented their own stations which were considered as candidate sites. During the negotiations for the CTBT at the Conference on Disarmament, the network was optimized by atmospheric transport modelling studies undertaken by several countries (see for example Mason/Bohlin, 1995, and Schulze, 1996) with the goal to detect a 1 kilton nuclear explosion within fourteen days and with a certain detection probability (90 percent for atmospheric explosions). Basic design criteria for the network were derived from four different scenarios and related performance criteria for detection, identification, and location. These scenarios were nonevasive as well as evasive atmospheric, underwater, and underground explosions (CD 1995).

As a result, eighty radionuclide station locations were selected and listed in the Protocol to the CTBT. At that time, it was left open as to where the forty noble gas stations should be located and whether the noble gas network should be expanded to all eighty sites. As a result of further network design studies undertaken by France, Canada, and United States (see e.g. Hourdin/Issartel 2000) forty of the eighty sites were chosen by the Preparatory Commission in 1998 as a start to locate noble gas detection systems.

Possible radionuclide source terms

The largest part of radioactive debris released by an explosion in the lower atmospheric (below 10 km) will remain within the troposphere and will easily be detected by a significant fraction of the radionuclide stations on the same hemisphere. For a 1 kiloton atmospheric fission explosion, the initial source term is about 2 PBq of Ba-140 that is representative as a fission product. In an evasive scenario, the largest aerosol portion is washed out in the local area. However, the gas signatures would remain with an initial source term of 1 PBq of Xe-133.

If underwater explosions occur deep enough, the released gases will be cleaned from a large portion of the particulates before entering the atmosphere. However, the noble gases do not easily dissolve in water and could be released to the atmosphere. The noble gas source term is the same as for the atmospheric explosion.

For underground explosions there is always a risk that the containment fails and radioactivity is released unintentionally into the atmosphere. This can happen in a quick high-pressure venting or as a seeping that extends over hours, days, and longer periods. It may also happen that radioactivity is released in controlled manner, e.g. by controlled cavity purging to allow either for recovery of experimental data or reuse of part of the underground testing area. Between 1962 and 1988, nineteen U.S. underground nuclear tests inadvertently released sufficient radioactivity to be detected by ground monitoring equipment off the testing site (Allen 1971, OTA 1989). From 1971 to 1988, late-time seeps happened in four cases, controlled tunnel purgings were carried out following ten explosions, and for 108 other tests smaller operational releases were detected (OTA 1989).

The risk of venting and seeping and the possibility of controlled releases provide a significant probability for remote detection of underground test through radionuclide signatures. For the network design studies, it was assumed that 10 percent of the xenon, i.e. 0.1 PBq of Xe-133, escapes into the atmosphere over a twelve-hour period, as opposed to the instantaneous release assumed in the other scenarios.

For high-altitude test at 10 km and higher (above the tropopause) the collection of radioactive material is determined by the low mixing rate between stratosphere and troposphere.

For onsite inspection of a suspected underground explosion, twenty-one fission products were identified as relevant residuals from a nuclear explosion (Takano/Krioutchenkov, 2001). The most important radionuclides are the xenon isotopes and with calcium-rich environments Ar-37 as well. They may be sucked through geological faults by atmospheric depressions and thus can escape with some delay even from well-contained underground explosions (De Geer, 1996b, and Carrigan et al., 1996).

Radionuclide Network in the International Monitoring System

The radionuclide network

The radionuclide network consists of three components: eighty particulate stations, forty noble gas systems collocated with particulate stations, and sixteen radionuclide laboratories. Installation of the particulate stations is underway, currently six particulate stations are certified, four more are sending data.

The number of forty noble gas systems is a compromise after some delegations were hesitant during the Geneva negotiations to agree to this technique at all. A noble gas test experiment performed at the Institute of Atmospheric Radioactivity in Freiburg, Germany, convinced all interested parties of the advantage to have noble gas systems. It is up to the conference of state parties to decide after entry into force of the CTBT to increase the numbers of noble gas systems.

Sixteen radionuclide laboratories have been chosen during the Geneva negotiations to further evaluate samples from radionuclide stations. They are considered to have existing expertise in order to make an independent evaluation. These radionuclide laboratories will be certified by the PTS regarding their procedures and their quality management, but not regarding their expertise. National accreditation will be taken into account.

What do the stations look like? The design of the stations is based on the minimum requirements as required by the CTBT Preparatory Commission (CTBT/PC/II/1.Add.2, p.49) and shown in Tables 1 and 2. The station has always a particulate system, either manual or automatic. Additionally the station may host a noble gas system (Schulze, 2000).

Particulate stations

The sampler at each particulate station will draw at least 500 cubic meters per hour of air through a filter for about one day. Each particulate station will draw at least 500 cubic meters per hour of air through a filter for about one day in the sampler. Decay time for background radioactivity in this filter and, if necessary, transportation time of the filter to a laboratory should be no more than one day. By the end of the third day, the measurement on a high-resolution gamma spectrometer will be taken and reported to the IDEC. With this scheme the minimum detectable concentration (MDC) for the “typical” fission product Ba-140 should be below 30 mBq/m3. In case of a blank sample the limit is even 10 mBq/m3.

These requirements are strong and the limit of 30 mBq/m3 can be very difficult to achieve in high radon background areas.

Figure1. Radionuclide Station RN46 Chatham Islands, New Zealand

Table I. Minimum Requirements for Radionuclide Particulate Stations

	Characteristics	Minimum Requirements
System	Manual or automated	1
Air flow	500 m^3h^{-1}	2
Collection time[1]	24 h	3
Decay time[2]	24 h	4
Measurement time[3]	20 h	5
Time before reporting	£72 h	6
Reporting frequency	Daily	7
Filter	Adequate composition for compaction, dissolution, and analysis	8
Particulate collection efficiency	For filter: 80% at = 0.2 µm Global [1:] 60% at = 10 µm	9
Measurement mode	HPGe high-resolution gamma spectrometry	10
HPGe relative efficiency	40%	11
HPGe resolution	< 2.5 keV at 1,332 keV	12
Baseline sensitivity[5, 6]	10 to 30 µBq m^{-3} for ^{140}Ba	13
Calibration range	88 to 1,836 keV	14
Data format for gamma spectra and auxiliary data	RMS (Radionuclide Monitoring System) format[7]	15
State of health	Status data transmitted to IDC	16
Communication	Two-way	17
Auxiliary data	Meteorological data Flow rate measurement every 10 minutes	18
Data availability	95%	19
Down time[8]	7 consecutive days 15 days annually	20

[1] *Time specifications allow for an uncertainty of 10 percent, except for the reporting time parameter.*
[2] *This value can be reduced, down to a minimum of six hours, if a suspicious event is detected by other stations or techniques.*
[3] *This value allows for authentication measurements for manual systems.*
[4] *This global value includes the 80 percent filter efficiency and the collection efficiency of the incoming air circuitry.*
[5] *The upper limit is intended for high background areas.*
[6] *Certification procedures to be defined for baseline sensitivities (a posteriori MDCs) as well as the efficiency. Sample preparation losses should not affect base line sensitivities.*
[7] *This format should make provision for auxiliary data, authentication data and state of health data.*
[8] *Provision should be made for spare parts in particular areas where periodicity of transportation facilities is more than seven days.*

A manual station consists of air sampler and VSAT antenna outside, and the other equipment for filter pressing, decay, and analysis in an HPGe detector, station control, and data transfer inside a shelter (see Figure 1). An automatic particulate system can be one of two currently available systems, one filter band machine and one robot system.

The noble gas systems need a sophisticated sampling system since noble gases are inert (McKinnon 1996, DASE/CEA 1998, Dubasov 1999 and Larson 1999). After the sampling, a chemical purification process extracts the radon. Otherwise the MDC of 1 mBq/m3 could not be achieved. At the end of the purification, the amount of separated stable xenon is determined and the radioactivity is measured. From these two numbers, the concentration of the relevant xenon radionuclide in one cubic meter of air can be determined assuming that the content of stable xenon in the air is constant (ratio of xenon volume per standard volume of atmospheric air is $0.087 \bullet 10^{-6}$). The minimum requirements for noble gas systems are as follows.

For noble gas collection equipment, the specifications include capability to measure 131mXe, 133mXe, 133Xe, 135Xe at a sampling rate of 0.4m3/h, with a total volume of 10m3 after twenty-four hours. Xenon isotopes are analyzed by high-resolution γ-spectrometry or by β-γ coincidence technique with a measurement time of less than twenty-four hours, having a detection sensitivity of 1mBq/m3 for 133Xe.

Table II. Minimum Requirements for Radionuclide Noble Gas Stations

	Characteristics	Minimum requirements
Air flow	0.4 m^3 h^{-1}	21
Total volume of sample	10m3	22
Collection time	24 h	23
Measurement time	24 h	24
Time before reporting	48 h	25
Reporting frequency	Daily	26
Isotopes measured	^{131m}Xe, ^{133}Xe, ^{133m} Xe, ^{135} Xe*	27
Measurement mode[9]	beta-gamma coincidence or high-resolution gamma spectrometry	28
Minimum detectable concentration[10]	1 mBq m^{-3} for ^{133}Xe	29
State of health	status data transmitted to IDC	30
Communication	Two-way	31
Data availability	95%	32
Down time[11]	7 consecutive days 15 days annually	33

* *135 Xe is the right isotope. In the original table 135m Xe is tabled but this is wrong.*
[9] *Calibrations need to be defined.*
[10] *MDCs for the other isotopes are not defined here since they critically depend on the detection system used.*
[11] *This is a goal to be reached.*

Detection limits of the other xenon radionuclides will be in the same order of magnitude. For γ-spectrometry, either planar or coaxial type of HPGe can be used to detect 133Xe and 135Xe by their primary γ-signatures, 81keV and 250keV respectively. 131mXe and 133mXe can be detected by their 163.9keV and 233.2keV gamma lines but have relatively weak intensities of 1.96 percent and 10.3 percent due to internal conversion of 30-34keV x-rays. In β-γ coincidence technique, the spectrometer consist of a NaI detector for γ-detection and a scintillator for β-counting. The β-detector is surrounded by NaI crystal to give a maximum detection efficiency and through coincident measurement, the background of the β-gated γ-spectrum is reduced by a factor of 1,000 relative to a simple γ-spectrum.

Figures 2a, 2b, and 3 show the four currently existing high sensitive automatic noble gas systems.

Figure 4 shows a twofold exciting result from the noble gas experiment in Freiburg (Bowyer et al., 2002). Firstly all four systems show xenon peaks in the air at the same time. Secondly the xenon peaks are quite sharp because of the short sampling time down to eight hours. Until now the sampling time was usually one week and therefore the concentration was smeared out resulting in much lower peaks compared to the background.

Global Communication Infrastructure

The Global Communication Infrastructure (GCI) is operated by the Provisional Technical Secretariat for data transmission between the IDC and IMS stations as well as National Data Centers. Through the GCI, the IMS stations send spectra, state-of-health data, and meteorological data to the IDC. The data are transmitted through very small aperture terminals (VSAT) to one of five satellites. The latter send all data to a hub that is linked through a frame relay network to the IDC. The telecommunication services are provided by a private company.

Radionuclide Analysis in the International Data Center

Radionuclide data analysis

The mission of the International Data Center (IDC) is to support the verification responsibilities of state signatories by providing objective products and services necessary for effective global monitoring. Especially, the IDC shall according to the Protocol, Part I:

- Receive, collect, automatically process, interactively analyse, report on, and archive data from IMS facilities;
- Carry out special studies, provide technical assistance and technical analysis of IMS or other data on request by a state party.

Figure 2a. Noble gas system Arix (KRI, Russia)

Figure 2b. ARSA (Pacific Northwest National Laboratory, United States)

Figure 3. Noble gas system SAUNA (FOI, Sweden) and SPALAX (DASE + SFI, France)

The routine operational work of the IDC can be compared to a factory. The raw products are the data from IMS stations. Once all stations are operational, the amount of data from the four monitoring technologies received by the IDC will exceed 10 gigabyte per day, including data for at least 120 radionuclide samples (the precise number of daily noble gas samples has still to be determined). Analysis of the raw data is required to extract the relevant information, characterise it and to make the results available in daily products that are released according to a defined schedule. It is important to note that the IDC provides standard products with no prejudice to final judgments that are up to the state signatories and carried out basically at their national data centers.

The processing pipeline starts with automated processing, followed by interactive analysis (Matthews/Schulze, 2001). For each spectrum an automated radionuclide report (ARR) is released as soon as possible after the receipt of the raw data, typically within a few minutes. This contains sample information, processing parameters, calibration equations and quality tests, a list of all peak detections with their nuclide associations, nuclide quantifications, and minimum-detectable concentrations for some key nuclides where no detection has taken place.

Interactive analysis is performed mainly for quality control of the automated processing. Within twenty-four hours after receipt of the raw data, a reviewed radionuclide report (RRR) is published. In addition to repeating the information provided in the ARR with all required corrections, the RRR contains analyst comments, event characterization results and images from atmospheric transport modelling showing the geographic region that the sampled air had passed.

Part of the interactive analysis is to scan the spectra for peaks missed by the automated analysis (type II error) and to decide whether a small peak is a false one (type I error). The application of agreed peak definition criteria is expected to reduce this workload. Another task is to check the nuclide association especially for those peaks that might indicate the presence of a relevant anthropogenic nuclide. This may be difficult if there are interferences with natural radionuclides. A typical example is a peak close to 140 keV that can both be associated to the key energy line of Ge75m at 139.68 keV and the only energy indicative for Tc99m at 140.51 keV. Cosmic neutrons excite the germanium crystal of the detector by inelastic scattering and the related peak is in fact sometimes seen in particulate filter spectra. If the analyst decides that Tc99m is present, the sample characterisation indicates the presence of a CTBT relevant fission product and a special bulletin called SSREB (see below) is issued and serves as an alert to that fact. CTBT relevant anthropogenic radionuclides are defined by an agreed list of fission and activation products that are the best indicators for a nuclear explosion (De Geer, 2001). Currently, the categorization list for particulate samples contains eighty-three radionuclides, the list for gas samples has four xenon isotopes.

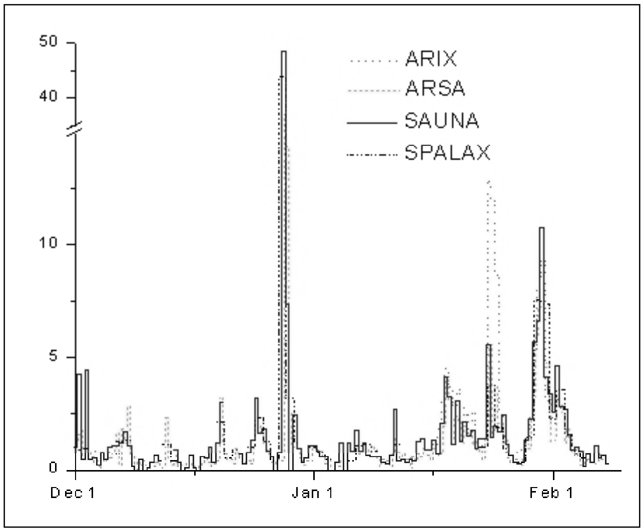

Figure4. Xe-133 concentration in the air at Freiburg during phase II of the noble gas experiment

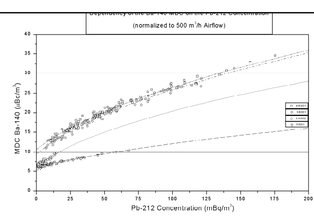

Figure5. MDC for Ba-140 as a function of Pb-212 concentration

Sample categorization
According to the current IDC event characterisation scheme, every sample is categorized by one of the following five levels:

- Level 1 = Typical Background: The spectrum contains only typical background of non-CTBT relevant radionuclides (either natural or anthropogenic).
- Level 2 = Anomalous Background: Same as Level 1 but with an abnormal concentration.
- Level 3 = Typical Anthropogenic: The spectrum contains typical measurements of CTBT relevant fission products, or activation products.
- Level 4 = Anomalous Anthropogenic: Same as Level 3 but with an abnormal concentration of one CTBT relevant nuclide.
- Level 5 = Multiple Anthropogenic: Same as Level 4 but with multiple CTBT relevant anomalous measurements.

A radionuclide event is defined as a unique occurrence of relevant anthropogenic radionuclides at abnormal concentrations and is categorized as a Level 4 or 5. For each radionuclide event a special report called standard screened radionuclide event bulletin (SSREB) is published simultaneously with the RRR. It summarizes information on the relevant nuclides including isotopic ratios, if available. This report incorporates additional information from certified laboratory analysis and special atmospheric transport modelling as well.

Radionuclide events occasionally happen when Cs-137 that is still remaining on the ground from historic releases is resuspended into the atmosphere and measured at abnormally high concentrations. What is considered abnormal is determined from the concentrations measured in the recent past at the same station and follows seasonal changes. Fission products used in radiopharmaceuticals like I-131 and Tc99m may cause radionuclide events, too.

Detection sensitivity
The IMS radionuclide stations achieve a high sensitivity. The detection limits are described as minimum detectable concentrations (MDC). They depend on the varying background of natural radionuclides, the sampled air volume, decay and acquisition time, and counting efficiency. Table 1 gives the required detection limit for Ba-140. The expected MDCs for other isotopes can be predicted from this requirement because all isotopes occur in more or less defined ratios. Table 3 lists the expected and measured detection limits for key CTBT relevant nuclides. For the iodine isotopes lower limits are given, because the fraction of particulate iodine in air varies according to the generation and transportation processes. The average MDCs are calculated for nine IMS stations over all daily spectra that were analyzed up to the time of writing. The fourth column in Table 3 gives the ranges of these average MDCs for key nuclides.

The MDC is determined by the level of Compton background from natural radionuclides. This is typically dominated by Th-232 and its decay chain. Pb-212 is a decay product of Rn-220 that emanates from the ground wherever Th-232 deposits are found. Radionuclide stations sited on oceanic islands achieve the best sensitivity, because they experience the lowest natural background. Figure 5 shows the dependence of the Ba-140 detection limit from the Pb-212 concentration. The shape of the curve is can be fitted with sqrt[a + b*conc(Pb-212)] (Denier/Toivonen, 2001). Typical Pb-212 backgrounds vary from 10 mBq/m^3 to 1 Bq/m^3. The MDC for Ba-140 in general remains below 30 $\mu Bq/m^3$.

Data fusion
One task that is unique to the International Data Center (IDC) is the physics-based fusion of data and products from the four monitoring technologies using information about propagation of signals through the earth, oceans and atmosphere. Events can be associated, if they have a high correlation in space and time. Waveform signals detected by seismic, infrasound, or hydroacoustic sensors, can be fused to so-called seismoacoustic events, if they can be traced back to the same origin in space and time. At least three phases are required to identify an event. The seismoacoustic events can be located very accurately in space and time. It is required that the area of the related error ellipse remains below 1,000 km^2 because, according to the Protocol to the Treaty, this is the maximum size to which an onsite inspection would be limited.

In contrast to this accuracy requirement, the origin in space and time of radionuclide events is determined with significantly larger uncertainties for the following reasons. The origin time of the radionuclide release remains undetermined unless plume age information can be derived from the measured isotopes. The location inaccuracy is due to the air transport over long distances, the mixing of air in all three dimensions, and changes in wind direction. A plume can travel around the globe with a transport time of one to two weeks. In addition, there are significant uncertainties involved in atmospheric transport modelling. As a result, the area from where the air originates that arrives at the sampling site during the collection period (scheduled to last for twenty-four hours for particulate samples and eight, twelve, or twenty-four hours for noble gas samples) is typically very large. Allowing for seventy-two hours travel time, it has a size of 1 to 5 million km^2.

Due to the uncertainty in time and space of the release that caused a radionuclide event, fusion with a seismoacoustic event is very difficult. However, data fusion between seismoacoustic and radionuclide events is essential for two reasons. First, a seismoacoustic event that is caused by an explosion can only be characterized as a nuclear explosion, if it is shown to be related to at least one radionuclide event.

Table III. Minimum Detectable Concentrations (MDC) for Key Nuclides

Nuclide	Half-life	MDC Expected (?Bq/m³)	Average MDCs Achieved (?Bq/m³)
Ba-140	12.8 d	10-30	5-23
Ce-143	1.4 d	15-50	6-25
Cs-134	2.1 y	3-10	1.5-5.3
Cs-136	13.2 d	3-10	1.5-6.1
Cs-137	30.1 y	3-10	1.5-6.5
I-131	8.0 d	>5	1.4-6.9
I-133	20.8 h	>30	5.5-27
Mo-99	2.7 d	20-60	17-69
Nb-95	35.0 d	5-15	1.5-6.6
Ru-103	39.3 d	3-10	1.1-5.3
Te-132	3.2 d	5-15	1.4-6.7
Zr-95	64.0 d	3-10	2.5-10
Zr-97	16.9 h	20-60	9.0-34

Second, the location capability associated with radionuclide events can be improved by relating it to a seismoacoustic event.

Therefore, a capability is needed to fuse seismoacoustic events with detections of relevant radionuclides in the atmosphere. Since event fusion depends on co-location in space and time, atmospheric transport, and dispersion modelling is applied to get indications for the possible source location of radionuclides detected at one of the eighty sampling sites. To put it another way, the geographic area associated with a radionuclide event can be used to exclude most of the seismoacoustic events because they are outside the relevant field of regard. This reduces significantly the number of potentially relevant seismoacoustic events.

Atmospheric transport modelling to get indications for the possible radionuclide source area

Atmospheric transport modelling is applied to get indications for locating the origin of the relevant radionuclides. Single sample modelling is applied routinely for each single sample and—in the absence of event time information—does not allow for a meaningful source location. In case of radionuclide events, multi-sample and network modelling can significantly improve location capabilities. Various possible products can be generated with atmospheric transport modelling by the IDC (Kalinowski, 2001).

In order to account for the inherent uncertainties of modelling atmospheric processes, the standard presentation of results considered for CTBT purposes is the so-called field of regard (FOR). This will say that the shown geographical area is only indicative for a possible source region and, therefore, is a field that can be taken into regard for further investigation. The FOR is defined as the geographic area indicating possible sources of air that may have contributed to the radionuclide measurement at a specific station within a specific sample collection period. In estimating this area certain assumptions have to be made (e.g. source at ground level). The FOR is a function of certain parameters, especially the transport time and dilution ratios. Especially, the geographic area depends on time and is the larger the longer the radioactive plume travel time is assumed to last. The origin time of a radionuclide event can be determined only, if suitable isotopic ratios can be calculated. Plume age information would confine the FOR area to be meaningful for source location. If the origin time is not known, standard FORs are shown, e.g., for twenty-four-hour, forty-eight-hour, and seventy-two-hour periods before the collection stop time.

An enhanced version of the standard FOR could quantify for each region and point in time the maximum release concentration that is consistent with the collected sample. This value can be derived either from the measured concentration at the detector site or—if this is not available—from the minimum detectable concentration by accounting for the dilution caused by turbulent mixing, scavenging, and other processes along the transport path.

A significant reduction of the possible source area as well as a determination of the origin time can be achieved by inverse multi-sample modelling, i.e. by combining FORs that are related to different detector sites (network analysis) and to more than one collection period (consecutive sample analysis). This can be compared to seismoacoustic analysis that requires at least three defining phases from three different stations in order to form an event and determine its origin time and location. Under favorable meteorological conditions, the achievable accuracy is in the order of the model resolution. The IDC software is currently planned to have a resolution of three hours and 1°x1° for longitude and latitude. The possible source region of a particular event can be confined by rejecting and confirming areas that are covered by FORs related to other samples. The confirmed region can be defined by the union of all geographic areas that are matching in travel time estimate for all sites that detect the same event (positive indication). The region can be further confined by cutting off those areas that have matching travel times and are related to samples in which the relevant radionuclide is not detected (negative indication).

The method of choice for calculating FORs and combining them is to calculate the source-receptor sensitivity matrix that contains the transfer functions between all possible regions for a radioactive release (sources) and all detector sites (receptors). The source-receptor matrix can be calculated by dispersion models operating in backward mode to calculate the retro-plume from the detector sites. Depending on the conditions, the inverse modelling with multiple samples may be solvable only with so-called regularization, i.e. the input of *a priori* knowledge that may especially be either the origin time or the location (Seibert, 2001). This could be applied in expert technical analysis as hypothesis testing related to seismoacoustic events.

A further significant reduction in possible source area can be achieved, if the origin time of the detected radionuclides can be estimated. Given the presence of certain isotope pairs with suitable half-lives in the sample, isotopic ratios could be utilized to determine the age of the sampled plume. Useful isotope pairs are Ba-140/La-140, Nb-95/Zr-95, and with more uncertainties Xe-133/Xe-131m, Xe-133m/Xe-133, and Xe-135/Xe-133. A plume age probability distribution can be derived from the error associated with the isotopic concentration ratios. Since the elements of the source-receptor-matrix are a function of the travel times they can be multiplied by the plume age distribution to get the source probability matrix as a function of space and time.

The source probability could be even further improved, if information about the release scenario, especially the source strength probability distribution, is available.

The IDC will not be left alone with the task of atmospheric transport modelling. It has been decided that the CTBTO PrepCom will cooperate with the World Meteorological Organization (WMO). In 1997, the WMO set up a task group on WMO/CTBTO matters to explore areas of possible future collaboration. Its findings were presented in a final report (Draxler/Bourdette, 1998). A framework agreement between the CTBTO PrepCom and the WMO has been prepared in 2000 and is now being put in operation. Under this agreement the WMO Regional Specialized Meteorological Centers will run their models to determine potential source regions for radionuclide events of interest and the IDC will receive meteorological analysis data to drive its atmospheric transport models.

Summary

The measurement of atmospheric radioactivity is one out of four sensor technologies used in the IMS for the verification of the CTBT. Only radionuclide signatures can be applied to distinguish between nuclear and chemical explosions. The particulate and noble gas sensors at the eighty radionuclide stations will take daily samples that are analyzed by the International Data Centre (IDC). A high sensitivity can be achieved: 30 μBq/m³ for Ba-140 and 1 mBq/m³ for Xe-133. Atmospheric transport modelling is applied to get indications for a possible origin in time and space for radionuclide events. The goal is to enable the fusion of radionuclide and seismoacoustic events by determining their correlation in time and space.

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References

1. Allen, R. E. 1971. Summary information on accidental releases of radioactive effluent to the atmosphere from underground nuclear detonations designed for containment, 5 August 1963 – 30 June 1971. U.S. Atomic Energy Commission Report, WASH-1183.
2. Bowyer, T. W., C. Schlosser, K. H. Abel, M. Auer, J. C. Hayes, T. R. Heimbigner, J. I. McIntyre, M. E. Panisko, P. L. Reeder, H. Sartorius, J. Schulze, and W. Weiss. 2002. Detection and analysis of xenon isotopes for the Comprehensive Nuclear Test Ban Treaty international monitoring system. Journal of Environmental Radioactivity, 59, 139-151.
3. Carrigan, C. R., R. A. Heinle, G. B. Hudson, J. J. Nitao, and J. J. Zucca. 1996. Trace gas emissions on geological faults as indicators of underground nuclear testing. Nature, 382, 528-531.
4. CD. 1995. International Monitoring System Expert Group Report based on Technical Discussions held from 6 February to 3 March 1995. Conference on Disarmament, Document CD/NTB/WP.224.

5. DASE/CEA. 1998. The radioxenon automatic sampler and detector developed by DASE. Bruyères-le-Châtel, France.
6. De Geer, L.-E. 1996. Chinese Atmospheric Nuclear Explosions from a Swedish Horizon. FOA paper prepared for the Scope-Radtest Workshop in Beijing, China, October 19-21, 1996.
7. De Geer, L.-E. 1996a. "Atmospheric radionuclide monitoring: A Swedish perspective." In: Huseby, E. S. and A. M. Dainty (eds.), Monitoring a Comprehensive Test Ban Treaty, Kluwer Academic Publishers.
8. De Geer, L.-E. 1996b. Sniffing out clandestine tests. Nature, 382, 491-492.
9. De Geer, L.-E. 2001. Comprehensive Nuclear Test Ban Treaty: relevant radionuclides. Kerntechnik 66/3, 113-120.
10. Dernier, P., and H. Toivonen. 2001. Evaluation of the International Monitoring System and International Data Centre of the Comprehensive Nuclear Test Ban Treaty Organization. Kerntechnik 66/3, 147-151.
11. Draxler, R., and J. P. Bourdette. 1998. Final Report of the WMO/CBS/WGDP Task Group on WMO/CTBTO Matters. World Meteorological Organization, Commission for Basic Systems, Working Group on Data-Processing, Task Group on WMO/CTBTO Matters, Geneva, July 15-17, 1998.
12. Dubasov, Y., and Y. Popov. 1999. Private correspondence, Khlopin Radium Institute, St. Petersburg, Russian Federation.
13. Hoffmann, W., R. Kebeasy, and P. Firbas. 1999. Introduction to the verification regime of the Comprehensive Nuclear Test Ban Treaty. Physics of the Earth and Planetary Interiors, 113, 5-9.
14. Hourdin, F., and J.-P. Issartel. 2000. Sub-surface nuclear tests monitoring through the CTBT xenon network. Geophysical Research Letters, 27, 2245-2248.
15. Kalinowski, M.B. 2001. Atmospheric transport modelling related to radionuclide monitoring in support of Comprehensive Nuclear Test Ban Treaty verification. Kerntechnik 66/3, 129-133.
16. Larson, T., and A. Ringbom. 1999. The Swedish Xenon Autosampler, A Room Temperature Sampler-Analyzer. Defense Research Establishment (FOA), Stockholm, Sweden.
17. Mark, C. 1959. The Detection of Nuclear Explosions. Nucleonics 17, No. 8, 64-73.
18. Mason, R., and J. B. Bohlin. 1995. Optimization of an Atmospheric Radionuclide Monitoring Network for Verification of the Comprehensive Nuclear Test Ban Treaty. PSR Report 2585, Pacific-Sierra Research Corp., Arlington, Virginia, U.S.A.
19. Matthews, M., and J. Schulze. 2001. The radionuclide monitoring system of the Comprehensive Nuclear Test Ban Treaty: from sample to product. Kerntechnik 66/3, 102-112.
20. McKinnon, A. D., M. W. Panisko, R. W. Perkins, P. L. Reeder, R. C. Thompson, and R. A. Perkins. 1996. Automatic Radioxenon Analyzer for CTBT Monitoring, PNNL 11424. Pacific Northwest National Laboratory, Richland, Washington, U.S.A.
21. OTA. 1989. The Containment of Underground Nuclear Explosion. Congress of the United States, Office of Technology Assessment, Report OTA-ISC-414.
22. Schulze, J. 1996. Verification for CTBT Compliance: Developments during 1995 Negotiations. In: Poole, J. B., and R. Guthrie, Verification, Westview Press.
23. Schulze, J., M. Auer, and R. Werzi. 2000. Low-level radioactivity measurement in support of the CTBTO, Applied Radiation and Isotopes 53, 23-30.
24. Seibert, P. 2001. Inverse modelling with a Lagrangian particle dispersion model: Application to point releases over limited time intervals. In: Gryning and Schiermeier (eds.), Air Pollution Modelling and Its Application XIV. Kluwer Academic/Plenum Publishers, New York.
25. Takano, M., and V. Krioutchenkov. 2001. Technical methods employed for the On-Site Inspection. Kerntechnik 66/3, 143-146.
26. Yang, X., R. North, and C. Romney. 2000. CMR Nuclear Explosion Database (Revision 3). Center for Monitoring Research Technical Report CMR-00/sixteen.

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INMM Membership Directory Now Online

As I hope you already know, the INMM Membership Directory is now available online. After many requests to make the directory available electronically, we launched this new member benefit with the 2002 edition of the directory. The membership directory is available by password access, and is intended for member use only. Please do not abuse this service; the membership listing is not to be used as a marketing list, but has been made available to make the directory available to you even when you are away from the office. The 2002 Membership Directory was also produced in hard copy format, and was mailed to you this spring.

One of the best features of the electronic version is the ability for you to ensure that your information is always up to date. If your contact information changes, please edit your information so that other members can keep up with you. When you log on and confirm your information, you will also have the opportunity to see the other great improvements that have been made to the INMM Web site. Our thanks to INMM Communications Chair James Griggs and his team for all of their hard work.

Write On

Two of our members have co-authored books that recently have been published. Frank Jones was a co-author of *The Handbook of Mass Measurement,* and Steve Dupree was a co-author of A *Monte Carlo Primer: A Practical Approach to Radiation Transport.* Our congratulations go out to them. These works are further evidence that our membership includes individuals who are in the forefront of their respective fields related to the management of nuclear materials.

A Note on New Members

We again welcome our newest members, listed on page 68 of this issue. I encourage all new members to get involved with a technical division that is of interest to you and your regional chapter. Those new members attending this year's INMM Annual Meeting will find that this is the best opportunity each year to obtain current information on all aspects of nuclear materials management and to interact with world leaders in our field. For those who have joined since the last annual meeting, it is also the opportunity for you to attend a special welcoming reception in your honor that provides you with the opportunity to interact one-on-one with the current INMM officers. I hope that you will take advantage of it.

A Short Reminder

As always, if you have any news about an INMM member, including yourself, be sure to keep your colleagues informed by contacting either me at scott.vance@shawpittman.com or our *JNMM* Managing Editor Patricia Sullivan at psullivan@inmm.org. Please include photographs when possible.

Scott Vance
Chair, INMM Membership Committee
Shaw Pittman
Washington, D.C. U.S.A.

New Member Corrections

Please note: In the Winter 2002 issue of *JNMM,* some of the listings in our New Member section were incorrect. The corrected listings are published below. We apologize for any inconvenience this may have caused.

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In Memoriam
John William Arendt (1921-2002)

The Institute of Nuclear Materials Management and the nuclear community lost a valued member and friend with the death of John Arendt from a heart attack at his home on April 21, 2002. He was 80.

Mr. Arendt was the voice and promoter of consensus technical standards in the Institute of Nuclear Materials Management. He served as the chair of the INMM's American Nuclear Standards Institute (ANSI) N14 Technical Standards Committee (Packaging and Transportation of Radioactive Materials) from 1985 through 2001, and was INMM's representative on ANSI's Nuclear Standards Board, vice chair of the Nuclear Standards Board Planning Committee, and a member of the International Standards Organization Development Board. He participated in the drafting of the original N14.1 standard on "Uranium Hexafluoride Packaging for Transport" and was active in the development of standards for more than thirty years. Mr. Arendt was one of the first to propose that INMM's scope be expanded to include the packaging and transportation of nuclear materials. He received the 1994 INMM Meritorious Service Award for his contributions to INMM's technical standards programs. Mr. Arendt was one of INMM's earliest members, having joined on July 10, 1959. He became a Fellow of the Institute in 2000.

Mr. Arendt was born in 1921, in Fredonia, Wisconsin. His parents owned a cheese factory. After graduating from Marquette University in 1943 with a degree in chemical engineering, Mr. Arendt went to work for the University of Chicago on the Manhattan Project. In 1945, he moved to Oak Ridge, Tennessee, to work for the Union Carbide Corp.-Nuclear Division at the Oak Ridge Gaseous Diffusion Plant (ORGDP). There he was a production supervisor for handling, measuring, storing, packaging, and shipping of nuclear materials, ORGDP coordinator for civilian applications of nuclear materials, superintendent for inspection, metallurgical and nuclear engineering; superintendent for physical measurements, inspection, and nuclear technology, project manager for the U.S. National Uranium Resource Evaluation Program, and superintendent for planning in the gas centrifuge program. He also served on the ORGDP Nuclear Safety Committee.

In 1983, Mr. Arendt was appointed to the Y-12 Mercury Task Force on which he chaired the Environmental Impact Committee. While at ORGDP, Mr. Arendt participated on the team to design, test, and build the 30A cylinder and overpack for the transportation of uranium hexafluoride, as well as other containers for the transport of nuclear materials. Before the 30A (30-inch diameter) cylinder was approved, uranium hexafluoride was packaged only in 6- and 12-inch diameter cylinders. The 30A cylinder facilitated reactor fuel fabrication and growth of the U.S. commercial nuclear industry. Mr. Arendt prepared the first manual on handling of uranium hexafluoride, ORO-651, revisions of which still serve as the basic source of information on the subject. Beginning in 1965, Mr. Arendt represented the United States in international symposia on packaging and transportation of radioactive materials. Mr. Arendt "retired" from Union Carbide Corp. in 1984.

In his retirement, Mr. Arendt worked as a senior engineer for JBF Associates for two years and then started his own consulting company, John W. Arendt Associates, Inc., which he ran until his death. In 1985, he became chair of the "moribund" ANSI N14 Technical Standards Committee and quickly converted it into an "active, energetic" program. In the early 1990s, Mr. Arendt supported improving the safety of operations at Department of Energy (DOE) facilities through participation on eight Technical Safety Appraisal Tiger Teams and a Chemical Safety Appraisal Team. In 1995, Mr. Arendt was appointed by President Clinton to the U.S. Nuclear Waste Technical Review Board. Mr. Arendt was a registered professional engineer in the state of Tennessee and an INMM-Certified Nuclear Materials Manager. In addition to his work in INMM, Mr. Arendt was also active in the American Chemical Society, American Nuclear Society, American Society of Mechanical Engineers, American Society of Quality Control, American Society for Non-Destructive Testing, the National Society of Professional Engineers, the Tennessee Society of Professional Engineers, the Standards Engineering Society, and the American Nuclear Standards Institute. He was a life member of the American Defense Preparedness Association.

In addition to the nearly sixty years of service Mr. Arendt gave to the field of nuclear materials management, Mr. Arendt also served his community as chair of the Anderson County United Way Campaign, as president of the Anderson County Unit of the American Cancer Society, on the Tennessee Board of Directors of the American Cancer Society, and as Exalted Ruler of the Benevolent Protective Order of Elks.

Mr. Arendt is survived by his wife, Avanell Beatty Arendt, his sons, Steve Arendt and his wife, Susan, and Philip Arendt; two grandsons, a granddaughter, and a sister.

Calendar

June 23-27, 2002
43rd INMM Annual Meeting, Renaissance Orlando Resort, Orlando, Florida, U.S.A. Sponsor: Institute of Nuclear Materials Management. Contact: INMM, 60 Revere Drive, Suite 500, Northbrook, IL 60062; phone, 847/480-9573; fax, 847/480-9282; E-mail, inmm@inmm.org; Web site, http://www.inmm.org.

August 11-16, 2002
International Nuclear Atlantic Conference 2002, Hotel Sofitel Rio de Janiero, Rio de Janiero, Brazil. Sponsor: Associação Brasileira de Energia Nuclear. Contact: INAC2002, Web site; www.inac2002.com.br.

September 8-13, 2002
EU-High Level Scientific Conference—Strengthening Global Practices for Protecting Nuclear Material, Institute for Physics and Biophysics, University of Salzburg, Salzburg, Austria. Sponsors: European Commission, Lawrence Livermore National Laboratory, European Forum, Institute for International Studies—Stanford University, Austrian Institute for European Security Policy. Contact: Claudia Heissl, NUMAT-Conference Secretariat Office, Institute of Physics and Biophysics, University of Salzburg, Hellbrunner Strasse 34, A-5020 Salzburg, Austria; phone, +43-662-8044-5700; fax: +43-662-8044-150, E-mail, physik@sbg.ac.at; Web site, http://www.numat.at.

October 14-18, 2002
Safe Decommissioning for Nuclear Activities: Assuring the Safe Termination of Practices Involving Radioactive Materials; Pro Arte Hotel Berlin, Berlin, Germany. Sponsor: International Atomic Energy Agency. Contact: IAEA, IAEA-CN-93, Vienna International Centre, Wagramer Strasse 5, P.O. Box 100, A-1400 Vienna, Austria; E-mail, official.mail@iaea.org; Web site, http://www.iaea.org.

October 16-18, 2002
America's Nuclear Energy Symposium (ANES 2002), The Biltmore Hotel, Miami, Florida, U.S.A. Sponsors: The U.S. Department of Energy and the American Nuclear Society. Contact: Caroline Raffington; phone, 305/348-5016; E-mail, anes2002@hcet.fiu.edu; Web site, http://www.anes2002.org.

November 4-8, 2002
International Symposium on Nuclear Power Plant Life Management, Budapest, Hungary. Sponsors: International Atomic Energy Agency. Hosts: the government of Hungary through the Hungarian Nuclear Society. Contact: K. Morrison, Conference Service Section, Division of Conference and Document Services, IAEA, Vienna International Centre, Wagramer Strasse 5, P.O. Box 100, A-1400 Vienna, Austria; E-mail, K.Morrison@iaea.org. Web site, http://www.iaea.org.

December 2-6, 2002
International Conference on Safety Culture in Nuclear Installations, Rio de Janeiro, Brazil. Sponsor: International Atomic Energy Agency. Host: the government of Brazil in cooperation with Eletrobras Termonuclear S.A. - Eletronuclear and Industrias Nucleares Brasileiras. Contact: Hildegard Schmid, Conference Service Section, MTCD, International Atomic Energy Agency, IAEA-CN-97, P.O. Box 100, Wagramer Strasse 5, A-1400 Vienna, Austria; phone, (+43) 1-2600-21316; fax, (+43) 1-26007; E-mail, Hildegard.Schmid@iaea.org; Web site, http://www.iaea.org.

January 15-17, 2003
INMM Spent Fuel Management Seminar XX, the Loews L'Enfant Plaza Hotel, Washington, D.C. U.S.A. Sponsor: Institute of Nuclear Materials Management. Contact: INMM, 60 Revere Drive, Suite 500, Northbrook, IL 60062; phone, 847/480-9573; fax, 847/480-9282; E-mail, inmm@inmm.org.

July 13-17, 2003
44th INMM Annual Meeting, JW Marriott Desert Ridge Resort, Phoenix, Arizona U.S.A. Sponsor: Institute of Nuclear Materials Management. Contact: INMM, 60 Revere Drive, Suite 500, Northbrook, IL 60062; phone, 847/480-9573; fax: 847/480-9282; E-mail: inmm@inmm.org.

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