A SYSTEMS FRAMEWORK FOR NONPROLIFERATION RESEARCH AND DEVELOPMENT*

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ABSTRACT

International safeguards and nonproliferation regimes are in a state of rapid flux. Changes in the scope of nonproliferation activities over the next few years will probably bring an overall larger fraction of the world's nuclear material under some form of international inspection. Without a commensurate increase in resources, the unintended net effect could be to reduce the overall effectiveness of international safeguards. One possible solution is to increase fiscal resources, but this may be unrealistic considering the current political climate. Alternatively, technological advances and hard political decisions can help to increase the effectiveness of nonproliferation resources. This study evaluates the many nonproliferation drivers to determine how to be proactive in a changing political environment.

I. INTRODUCTION

The nonproliferation setting has changed significantly over the past five years. In an effort to optimize investment of nonproliferation support and research and development (R&D) efforts we are examining the current nonproliferation setting from a system's perspective. In this systems framework we view the political events such as domestic restructuring, international treaties, bilateral agreements, and unilateral initiatives as establishing policy requirements. These events, in conjunction with the existing nonproliferation environment, result in global safeguards and nonproliferation requirements. Political and institutional settings establish constraints for implementing technical solutions, and enabling technologies that meet the system needs can then be identified or developed. This framework is shown schematically in Fig. 1.

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Fig. 1. Development of a systems framework for nonproliferation. The overlapping portions of the possible technical and political/institutional solutions is where effort should be directed.

II. PAST NONPROLIFERATION ENVIRONMENT

During the cold-war years an equilibrium developed under a bipolar world. Within this tense international setting, most countries had security assurances from one of the superpowers that were either implied or codified in treaties. This balance also provided a division for aid and military equipment.

Two major side effects of the bipolar world helped to prevent the spread of nuclear weapons to nonnuclear weapon states. First, countries that were reliably covered by the defense umbrella of one of the superpowers had little or no motivation to develop independent nuclear capability. Indeed, nonnuclear weapons states with superpower defense agreements risked losing this security and funding by pursuing an independent nuclear capability. Second, countries under these protective defense umbrellas also had an implicit responsibility to avoid armed conflict with mutual allies of the superpower. These responsibilities helped to keep historical regional conflicts in check, further reducing the perceived need for countries to develop a nuclear capability of their own.

The nuclear weapons material was strongly integrated into national defense and was strongly protected. Both the US and Russia had political or technical safeguards, or both, in place for the protection of the nuclear material.

III. CURRENT POLITICAL EVENTS

The recent large number of world changes have shaken up the established nonproliferation regime and have forced the international community to take a fresh look at global nonproliferation. The political changes include the breakup of the Former Soviet Union (FSU), the discovery of the Iraq nuclear program, and North Korea's limitation of International Atomic Energy Agency (IAEA) inspectors on-site. With respect to international policy, the Nonproliferation Treaty (NPT) has been renewed, the US and Russia have signed treaties that significantly reduce the number of nuclear weapons, and a Comprehensive Test Band Treaty (CTBT) is on the horizon that proposes to end nuclear weapons testing. National and international nonproliferation communities must respond effectively to fundamental changes in the political and global nuclear environment.

Reductions associated with Intermediate Nuclear Forces, Strategic Arms Reduction Treaty (START), START II, and a possible START III, with formal agreement on warhead dismantlement, will result in hundreds of tons of weapons-grade fissile material no longer needed for deterrence. Although dismantlement itself increases nuclear security by reversing the trend in vertical proliferation, implementation of international safeguards on that material further reduces the threat by ensuring that it is not diverted back into weapons. Increased potential for smuggling of this material opens a new path for proliferation against which new nonproliferation efforts must be directed.

As President Clinton stated in his May 31, 1995, commencement address to the US Air Force Academy:

> The breakup of the Soviet Union left nuclear materials scattered throughout the newly Independent States and increased the potential for the theft of those materials and for organized criminals to enter the nuclear smuggling business.

Nuclear materials resulting from disarmament inherently contain weapons design information, dissemination of which runs counter to global nonproliferation goals. If these materials are offered for IAEA inspection, then existing IAEA safeguards strategy requires that such material meet the most stringent of timeliness criteria. Safeguarding material removed from weapons under current guidelines would consume a substantial fraction of already stretched IAEA resources.

All of this leads to a potential dilemma. Should weapons states volunteer nuclear material from dismantled weapons for international safeguards, with the possible risk of reducing the IAEA's effectiveness by (1) increasing the strain on international resources, and (2) possibly transferring weapons design information to nonnuclear weapons states; or would international safeguards be better served if these countries submitted material to regimes (bilateral or multilateral) outside of traditional IAEA safeguards? We are challenged to identify the solution that best solves the problem of ensuring strong safeguards on the nuclear material while being both cost effective and politically fair.

In addition to policy codified in treaties, less formal unilateral and bilateral policy decisions also provide essential background to developing needs in safeguards and nonproliferation. As an example, President Clinton's September 27, 1993, speech at the United Nations laid the groundwork for offering fissile material from retired nuclear weapons to international safeguards, initiated discussions to eliminate fissile material production outside of safeguards, and suggested moving uranium resulting from dismantlement into the civilian fuel cycle.

Superimposed on new needs to safeguard former weapons-related fissile material, expanding world demand for energy and environmental concerns with burning of fossil fuels may increase demand for nuclear energy. Safeguards approaches for multiple disposition options will require further development and integration with the existing structure.

IV. DEVELOPING SAFEGUARDS AND NONPROLIFERATION NEEDS

Current disarmament and nuclear fuel cycle policy, in conjunction with the changing nonproliferation environment, result in changing needs for safeguards. We classify these below as conventional safeguards approaches, enhanced safeguards needs, and requirements for new proliferation pathways.

A. Conventional Safeguards

Additional requirements in the civilian fuel cycle will further burden international safeguards. Increasing demand for nuclear energy, safeguarding of large reprocessing facilities, and facilities that may be used to convert retired weapons material to low-enriched uranium or mixed-oxide (MOX) fuel; long-term geologic disposal (and any processing steps associated with a particular geologic storage option); or accelerator transmutation will all place new challenges on the existing safeguards regime. Medium-term storage of separated plutonium under international authority may also become important if reprocessing outpaces short-term needs for MOX fuel.

National means to detect nuclear weapons testing on land, in the sea, and in space have provided an important deterrence to potential proliferant states. Under a comprehensive test ban treaty, further international cooperation and improved detection capability will be even more critical, both for monitoring weapons states and for deterring even small tests by rogue states.

B. Enhanced Safeguards

In 1995 we have seen many significant changes in nonproliferation. On May 11, 1995, the NPT was extended indefinitely. Included in this indefinite extension were numerous responsibilities including a commitment to progress toward nuclear disarmament, safeguarding of fissile materials resulting from weapons dismantlement, movement toward a universal ban on production of fissile material for nuclear weapons, and a ban on nuclear weapons testing.

Driven partly by the Iraq experience and partly by a continually increasing global nuclear infrastructure, the IAEA has been examining new safeguards approaches in its 93+2 program. Several additional safeguards methods are being proposed through this project including environmental monitoring to detect undeclared nuclear activities and to monitor declared activities, enhancements in declarations from states regarding their nuclear infrastructures, improved information analysis, and improved access to nuclear facilities. Freedom of travel and expanded environmental sampling rights for inspectors would further improve the capability to ensure the absence of undeclared facilities.

Based upon the negotiations of the CTBT, additional environmental monitoring is being proposed to detect and deter future nuclear weapons tests. The difficulty in selecting the technology is balancing cost with detection requirements and balancing international detection capability with national capability.

These positive steps all have strong potential for increasing confidence in international safeguards. However, significant increases in the quantity and quality of material, the increased number of facilities to be safeguarded, the requirement to be able to locate undeclared facilities (as demonstrated by Iraq) and the ability to respond to smuggling and nuclear threats will also increase the financial and political strain on the current system.

C. Additional Proliferation Pathways

Reported attempts at nuclear material smuggling raise the specter of subnational groups developing a nuclear terrorist capability. Although this possibility is not new, the threat has changed both qualitatively and quantitatively. No longer is it necessary for a rogue country or terrorist group to enrich uranium or produce and process spent fuel and expose itself to the associated hazards and observables. They may be able to gain access to weapons-usable material (or even weapons themselves) diverted from facilities not subject to a high standard of safeguards.

Potential availability of weapons-usable material places a new burden on the ability to assess threats by subnational organizations or rogue states. Moreover, information on nuclear weapons design is becoming more available, strains on morale of nuclear workers are increasing the plausibility of individual cooperation with rogue states, sophisticated computing power (software and hardware) is readily available, and many high-technology components that could support a weapons program are more available than in the past. The increase in international trade places additional burdens on export controls. Under this situation, sufficient nuclear material, parts, and expertise could be acquired with few observables. In the worst case, an operable nuclear device might be purchased. The mere plausibility of such a scenario increases the threat represented by terrorist organizations and rogue nations.

This concern is amplified in countries where nuclear material controls depend on societal constraints rather than technical safeguards. The breakup of the Soviet Union, the insurrection at the Russian parliament, and the uncertain future in China and other countries with nuclear infrastructures outside of international safeguards raise the possibility of nuclear weapons falling into hostile hands. Technical, political, and diplomatic methods of improving domestic safeguards, as well as detecting and responding to diversion of nuclear materials or weapons, are becoming increasingly important.

Beyond the availability of nuclear material, rogue states developing an independent nuclear capability remain a concern. These can be either signatories or nonsignatories of the NPT. Iraq and North Korea demonstrate the need for techniques to identify and locate undeclared nuclear facilities within a country.

V. PATH FORWARD

New approaches to international safeguards may be required to alleviate some of the strain on the current nonproliferation regime. In particular, improved cooperation on and transparency of nuclear operations within each country might be used as a guide to reducing intrusiveness of international inspections at the facility level. However, significant improvements in transparency will require advances in technology, integration of existing technologies, and improved cooperation from each state.

Important advances in cooperation and transparency have begun. Strong examples in international cooperation are the US-FSU government-to-government programs, the US-Russian lab-to-lab program, the international science and technology center (ISTC), and many other bilateral assistance programs designed to improve domestic and international safeguards. Most of these have been directed toward detecting, deterring, and preventing diversion of nuclear material within the FSU. The strength of these international support programs is their ability to provide funding and technological solutions for specific problems. A weakness is the lack of international coordination to ensure that the technical solutions provided by each country can be integrated between institutes and government agencies. In addition, the governments need to continue to establish stronger controls over the nuclear materials within their countries.

An additional step of importance is the establishment of an international capability to respond to the tracking of smuggled nuclear material. This will require improved international communication and activities such as cooperative exercises, advance contingency planning, and improved customs procedures to help detect unauthorized transport of nuclear material and technology between international borders.

A. Technological Solutions

Environmental monitoring will continue to play a critical role in proliferation detection. The infrastructure to support this is being developed under the Network of Analytical Laboratories.[1] As environmental sampling and analysis techniques are developed, the system must be continuously exercised for this approach to be effective at detecting and deterring undeclared nuclear activities. This will require support from governments that have participating laboratories for developing new techniques as well as maintaining a state of readiness and excellence in existing analytical techniques. Maintaining facilities and expertise will require a reliable base of support. This implies routine analysis of blind quality control samples and actual field samples to ensure that the highest analytical standards are maintained.

Remote, unattended monitoring technologies must be developed, particularly in long-term storage environments where material access is infrequent and in dismantlement activities where access is limited by national security and nonproliferation considerations.

This will include integration of diverse sensor arrays that are appropriate to the safeguards regime into information management systems, data authentication, encryption, secure data transmission, anomaly detection, and other automated methods to screen and review data. Many components exist, and a few prototypes are being examined, but many system architectures will ultimately be needed to address the diverse range of activities that require safeguarding. These technologies will be critical to minimizing strain on the international safeguards system as well as minimizing exposure of personnel. The integration of sensor data can be used to safeguard nuclear weapons material and to support the CTBT.

Locating diverted materials may become increasingly important in the future. Components to address this issue include radiation portal monitors for personnel and material arriving from countries known or suspected of having loose material. An international nuclear emergency response team that is exercised as a team could also provide needed capability to locate fissile material or terrorist-type weapons.

Improved sharing of information, in conjunction with advanced information management and analysis, can aid in transparency as well as detecting proliferation and optimizing inspection efforts. Openness of the weapons states will help in assessing threats or detecting diversion of nuclear materials. Critical information such as materials unaccounted for and detected diversion from nuclear facilities will be increasingly important for the international community. Armed with knowledge on missing or potentially missing material, the international community will be able to fine tune its response capability. Response options include detection of material entering the country as well as assessment of potential observables associated with converting missing material to weapons use. To use such information, we will need advanced communication and information analysis systems.

B. Political Solutions

In addition to the identified technical solutions, some hard political decisions can help facilitate international safeguards. These might expedite submission of defense materials by weapons states to international safeguards while minimizing the impact on the existing regime.

One option to minimize the impact of weapons material on international safeguards is a regime where weapons states perform baseline inventories on nuclear material from dismantlement activities that other weapons states submit to international safeguards. This has the advantage of limiting the spread of weapons design information to nonnuclear weapons states, while still permitting detailed measurements (if issues on sharing nuclear weapons design information with other weapons states can be resolved). After the baseline is established, the IAEA could then monitor containment and surveillance data to ensure material is not diverted from storage.

Another option is to change the timeliness and significant quantity criteria for material from dismantled weapons placed under IAEA safeguards until the weapons states achieve complete nuclear disarmament. The criteria could be scaled with the overall international uncertainty in the fissile material stockpiles of the weapons states. These changes would have the dual benefit of making it more palatable for the nuclear weapons states to submit retired defense-related material to international safeguards while minimizing the strain of the international system that was designed to prevent proliferation to nonnuclear weapons states.

One method for indirectly changing the timeliness criteria would be to implement random, no-notice inspections.[2] This might involve pre-approving inspectors for that activity and supplying them with multiple-entry visas.

Random, no-notice inspections might also be a useful cost-savings tool in states that have submitted themselves to broad environmental sampling to demonstrate the absence of undeclared nuclear facilities. Random inspections in conjunction with environmental sampling could be particularly effective in states that have no enrichment or reprocessing capability because the background environmental signatures should be low.

A significant increase in efficiency and efficacy of IAEA safeguards might be realized as states cooperatively adopt some of the recommendations found in the IAEA's 93+2 program and related studies.[3,4] To improve confidence in the nonproliferation goals, states could provide more detailed information regarding their nuclear infrastructure; subject themselves to broad environmental sampling ranging from swipe samples taken anywhere in a facility to collection of air, water, soil, or biological samples anywhere in the country; volunteer facilities for detailed continuous unattended monitoring; and establish preapproved lists of inspectors with multiple-entry visas from which inspectors could be selected for any future inspections in that country. To improve efficiency and make it palatable for the host countries, these inspections involving increased intrusiveness could be balanced by a reduction in inspection frequency. Policy decisions such as these must be closely coupled with technical capability and R&D efforts.

In addition, an international response to NPT signatures who are acting outside of the agreement by limiting IAEA inspections should be developed. This could limit the uncertainty of countries testing the NPT boundaries by establishing a rapid and strong response.

VI. SUMMARY

The changing nonproliferation environment is offering important opportunities to place nuclear material that was previously safeguarded only by domestic programs under international safeguards and to improve safeguards that already exist. New materials to be safeguarded include those coming from dismantlement activities and possibly material passing through reprocessing plants that are in weapons states and nonsignatories to the NPT. Superimposed on this is a continually increasing stockpile of irradiated fuel, large reprocessing plants coming onstream, and a need for safeguarding the long-term disposition of nuclear materials. Each state must develop long-term plans for the disposition of spent nuclear fuel, and weapons states must address disposition of retired nuclear weapons material.

The opportunity to place additional retired defense material under international safeguards must be balanced with the need to maintain strong nonproliferation goals with respect to nonnuclear weapons states. To avoid undermining the global nonproliferation regime, care must be taken to ensure that the additional strains these initiatives place on the IAEA will not reduce the effectiveness in its traditional safeguards responsibilities.

Advancements in technology can also improve the efficiency and efficacy of IAEA safeguards. These include advanced environmental monitoring techniques, continuous remote unattended monitoring, random inspections, and new anomaly detection and information management techniques. Directing R&D efforts in these areas will help to optimize investment in international safeguards.

Nuclear materials smuggling has become a new path for potential proliferation countries or subnational groups. Therefore there should be a concerted international effort to respond to this new threat. This must include international cooperation, declaration of diverted material, and environmental monitors that detect the passage of nuclear materials at borders and other choke points.

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