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Title: PANEL ON PROTECTION AND MANAGEMENT OF PLUTONIUM: SUBPANEL ON SAFEGUARDS AND SECURITY

Author(s): James W. Tape

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Panel on Protection and Management of Plutonium:
Subpanel on Safeguards and Security
J. W. Tape, Chair

Abstract

Nuclear materials safeguards and security systems are described in the context of the nuclear nonproliferation regime. Materials of interest to safeguards, threats, proposals to strengthen International Atomic Energy Agency safeguards, evolving safeguards issues and requirements, system effectiveness, and elements of a global nuclear materials management regime are discussed. Safeguards are seen as an essential element of nuclear materials management, but not a driver for decisions regarding nuclear power or the disposal of excess weapon nuclear materials.

Summary of Conclusions

- Domestic safeguards and security systems implemented by operators under the regulatory authority of stable governments are effective against the threat of subnational diversion or theft. Response elements, which are not discussed in this paper, reduce further the probability of successful malevolent actions involving nuclear materials.
- International safeguards practiced in a global nuclear materials management regime can provide credible assurance that States are complying with their safeguards agreements at a level that provides confidence the State is not diverting declared materials to a nuclear weapons program. As has been demonstrated in new facilities, modern approaches to international safeguards employing defense-in-depth concepts can meet the demands of safeguarding a growing and more complex nuclear fuel cycle, including plutonium recycle.
- Thus, in stable regions, the effectiveness of safeguards and security systems need not be a driver for decisions regarding the use of plutonium in the civil power fuel cycle or the disposition of excess weapons plutonium.
- Implementing improved nuclear materials protection systems in Russia and the other nuclear republics of the former Soviet Union is a matter of considerable urgency for the safeguards and security community.
- More needs to be done to strengthen both national and international systems for detection of potential proliferation by States using unsafeguarded facilities.

The subpanel on safeguards and security is a loosely organized group of professionals in safeguards and security who were invited to comment and contribute to this paper. I am grateful to the following individuals for taking the time to provide insightful and constructive comments on a number of drafts: Roger Howsley of BNFL, Bill Sutcliffe of Lawrence Livermore National Laboratory, and especially, Myron Kratzer, co-chair of the ANS Panel.

Jim Tape, Chair

Introduction: The Nonproliferation Context of Nuclear Materials Safeguards and Security

The role of safeguards and security in the protection and management of plutonium must be viewed in the broad context of nonproliferation. The nuclear nonproliferation regime can be divided into four major areas:

- actions that motivate states or groups to not acquire nuclear weapons,
- measures to detect nuclear proliferation or to verify compliance with commitments not to proliferate (e.g., international safeguards),
- systems to control nuclear technologies and nuclear materials (e.g., national safeguards and security, export controls), and
- proliferation response.

National (also called domestic) safeguards and security are designed to protect nuclear materials from misuse, including diversion and theft, by adversaries of the State operating at a subnational level, but possibly including terrorism sponsored by an external state. Domestic safeguards and security systems are the first line of defense in controlling and protecting nuclear materials and are a fundamental building block of international arrangements for managing and controlling nuclear materials.

International safeguards are designed to verify that States are meeting their nonproliferation commitments relating to agreements to place nuclear materials and facilities under inspection through bilateral, regional, or multilateral arrangements. Safeguards inspections carried out by the International Atomic Energy Agency (IAEA) are the most prominent example of international safeguards and the EURATOM inspectorate is noted as the largest multilateral regional safeguards organization.

This paper describes briefly the nuclear materials of interest to safeguards and security, the threats to those materials, the elements of safeguards systems, proposals to strengthen IAEA safeguards, issues and requirements for safeguards systems, defense in depth, transportation safeguards, the debate over safeguards effectiveness, policies to assist safeguards that would result in a global nuclear materials management regime, and conclusions.

Nuclear Materials

Nuclear materials of concern to proliferation can be divided into three categories; materials in the weapons programs of the Nuclear Weapons States (NWS--US, UK France, China, and Russia), materials used in civilian applications that are under some kind of international safeguards, and materials that have been produced or acquired by States not party to international safeguards and/or produced in violation of international safeguards agreements or the Nonproliferation Treaty (NPT).

Nuclear Weapons States materials include the special nuclear materials found in nuclear weapons, weapons reserves, excess inventories from production or dismantlement (including research materials, scrap, and residue), and those materials that might be produced in the future at weapons production sites. The management and control of these materials in the former Soviet Union and plans for the disposition of similar materials from the US weapons program have recently focused attention on weapons-related materials (ref 1).

Civil Power and research materials have been the focus of international safeguards and have also been subject to domestic safeguards and security. Quantities of materials of proliferation concern in civil programs exceed those in the NWS military programs and are expected to grow while the military reserve inventories will decrease dramatically (although materials excess to defense needs will require protection until they are disposed of as noted previously). Domestic safeguards and security and international safeguards standards are applied equally to so-called weapons plutonium and reactor plutonium (with higher plutonium 240 and 241 content). [Plutonium high in 238 is subject to less stringent safeguards.]

The third category of materials are those that are produced "outside of safeguards" by Non Nuclear Weapon States in violation of their NPT agreements or by States not party to the Treaty. Iraq provided a clear example of the former case while India, Pakistan, and Israel are widely held to be in the latter category. From an international legal perspective it is important to recognize that there is a difference between a treaty or agreement violator (Iraq) and states that do not accept full-scope safeguards and who may have "legally" produced materials outside safeguards; however, it seems appropriate to combine the two cases in the context of controlling nuclear materials to prevent proliferation. The US proposal to "prohibit the production of highly-enriched uranium or plutonium for nuclear explosive purposes or outside international safeguards." aims to stop the growth of materials in the first and third category. (ref 2)

Threats

The proliferation threats to nuclear materials are usually divided into those posed by subnational groups (although these might be directed by external states engaged in state-sponsored terrorism) and those posed by the States having jurisdiction over the materials. Domestic safeguards and security systems are designed to deal with the subnational threat while international safeguards deals with the State as the adversary. It is important to recognize that these threats are linked and that subnational terrorist groups may be sponsored by proliferant States or criminal elements may be motivated to sell stolen nuclear materials to proliferant States.

The subnational threat is further divided into outsider threats, usually defined by a number of adversaries who are intent on stealing nuclear materials by force or stealth; and insider threats, employees or otherwise authorized individuals who have access to nuclear facilities and materials. Most threat scenarios developed for safeguards design consider combinations of outsiders and insiders. Subnational groups who might be affiliated with international terrorist organizations, international criminal organizations, or political factions (as might be the case in the former Soviet Union) are of particular concern because of their potential for marshaling significant resources against the nuclear materials protection systems.

The national government of the State is the assumed adversary in the international safeguards system. The goal of the system is to verify compliance with safeguards agreements and to have a high probability of detection non-compliance.

Elements of safeguards systems

Domestic

Domestic safeguards systems are usually described in terms of three elements; physical protection, materials control, and materials accounting. Operationally, materials control and materials accounting activities are often managed as part of an overall materials control and accounting (MC&A) system.

Physical Protection systems are designed to deter, detect, and respond to threats by outsiders and also serve to limit authorized actions by insiders. Elements of these systems include detection, assessment, delay, response, entry control, communication, and data display subsystems. Fences, intrusion sensors, guards, and response teams are familiar components of the physical protection system.

Materials Control systems consisting of procedures and hardware provide timely information about the movement of nuclear materials and access to those materials. Vault monitoring systems and portal radiation monitors are example materials control components.

Materials Accounting systems include the "books" that reflect the records of all actions involving the nuclear materials, including receipts, inventories, transfers within the facility, and shipments. A fundamental safeguards measure is the periodic reconciliation of the book inventory with the physical inventory for a nuclear facility. Unlike other valuable assets that can be counted, nuclear materials must often be measured using chemical or physical analysis methods to determine the mass of material present. Because measurements have inherent uncertainties, the total mass of nuclear materials inventories are never known with perfect certainty. Item inventories can be determined exactly and the corresponding statement that the nuclear materials inventory is accounted for can be made with certainty, provided item integrity can be assured.

The Materials Control and Accounting systems include measurement, measurement control, radioactive decay corrections for 241 Pu, inventory, item control, evaluation (including statistical analysis of inventory difference data), record and report, and audit subsystems.

International

Materials Accounting is a fundamental element of international safeguards in which the State is expected to maintain a record of nuclear materials activities. Inspectors examine and verify independently facility records by performing measurements of quantities of materials.

Containment and Surveillance (C/S) consists of systems that provide continuity of knowledge about nuclear materials or detect unusual activities associated with the materials and includes human observation. Surveillance cameras, seals, and radiation monitors are typical C/S devices.

Nuclear facility Design Verification by the IAEA, from construction through the life of the plant, is also an essential element of international safeguards that provides assurance that the facility safeguards approach remains effective.

International safeguards performs no direct equivalent of physical protection; however, the IAEA does support the dissemination of knowledge and common standards for the protection of nuclear materials. The United States Government also provides for the transfer of physical protection technology and methods by means of bilateral discussions and technology transfer programs. It should also be noted that modern integrated systems that combine features of C/S, process monitoring, and continuous, unattended assay of materials can provide timely warning of anomalous conditions in facilities under international safeguards and thus perform some of the prompt detection functions of a physical protection system.

Changing IAEA Safeguards

International safeguards by the IAEA has been evolving and improving on a continuous basis since its inception; however, the revelations of a major clandestine nuclear weapons materials production program in Iraq, an NPT signatory under Agency safeguards, has provided new impetus for strengthened IAEA safeguards. In the period before 1992 Agency safeguards were focused almost entirely on diversion of declared materials from declared facilities. Undeclared facilities were considered only indirectly in designing safeguards approaches for declared facilities. For example, spent fuel safeguards are required because there is a possibility of clandestine reprocessing. · Following the discoveries in Iraq there has been a major shift in thinking to look beyond declared materials and facilities and to develop means to detect undeclared materials and facilities. Two primary areas of improvement have been identified; improved access to information about a State's nuclear activities, including for example information provided by member states (intelligence information) and the use of environmental monitoring by the agency; and improved access to sites (special inspections and expanded access). In addition, there is continuing interest in improving the efficiency, effectiveness, and cost-performance of safeguards to include, for example, more use of regional offices and greater utilization of unattended remote readout of monitoring equipment.

Key to these new approaches is to go "beyond materials accountancy," including the goal of improving the Agency's ability to detect undeclared activities, materials, or facilities(refs 3,4,5).

- Environmental monitoring provides the possibility of detecting activities or materials that should have been declared by the State in the context of international safeguards agreements. Regional and wide-area monitoring are currently under consideration for use by the IAEA in routine and special inspections. (ref 6)
- Special Inspections by the IAEA are called for "(a)...to verify the information contained in special reports; or (b) if the Agency considers that information made available by the State, including explanations from the State and information obtained from routine inspections, is not adequate for the Agency to fulfill its responsibilities under the

Agreement." (ref 7) Thus access is permitted to declared facilities, at nuclear sites, and elsewhere in the state.

- Information management, including all sources of information about the fuel cycle of a State, is an essential element of strengthened safeguards. The information includes declarations by the State about its fuel cycle, facility design information, inspection reports, open source information, and any information provided by Member States to the Agency (intelligence information).
- Continuous, unattended monitoring of declared facilities, either operating, in standby, shutdown, or decommissioned, can be provided by the use of C/S and materials accounting measurement instrumentation that is operated continuously without inspector presence. Data from such instruments can be transmitted to remote locations for analysis. Continuous unattended monitoring technologies hold the promise of extending limited inspector resources, of providing more timely information, and freeing inspectors for duties well-suited to humans. (ref 8)

Defense-in-Depth

Integrated systems are the key to successful safeguards for either domestic or international applications. Defense-in-depth is a fundamental principal of design that is often misunderstood by those who attempt the very difficult task of assessing the effectiveness of safeguards system. Timely detection of diversion might be, for example, the result of surveillance (by humans or sensors), near-real-time accounting systems, process monitoring, portal monitors, access control systems, or intrusion detectors. Deterrence of diversion is provided by all these elements plus an effective accounting system that can provide an audit trail confirming that materials are in fact missing from a facility or process. No one element is the "most important," they must work together for good materials safeguards (ref 9).

Transportation Safeguards and Security

The protection of nuclear materials during transportation relies primarily on physical protection measures such as armed escort, armed response teams available along the route, barriers surrounding the materials, surveillance measures, and stealth. Materials accounting is used to confirm that the quantity declared by the shipper is received at the destination. Like facility safeguards and security, the effectiveness of protection of materials in transit is a function of defense-in-depth.

Issues and Requirements for Safeguards and Security Systems

Effectiveness

Global comparability of nuclear materials protection systems (e.g., the US vs. Russia) has become a significant safeguards issue with the breakup of the Soviet Union. Large quantities of very attractive nuclear materials that were under strict controls in the Soviet Union are now subject to a wide range of threats that were not present under the old system or were deterred by tight security measures. Improving domestic safeguards and security in Russia and the other republics (primarily Belorus, Kazakhstan, and Ukraine) is arguably the highest priority for the international safeguards community.

The ability to "adequately" safeguard plutonium in large bulk handling plants (MOX and reprocessing) has been the subject of considerable discussion. Missing from this debate has been an approach to quantitatively measure the effectiveness of all the elements of the safeguards systems (defense-in-depth) for either domestic or international applications. Assessment of defense-in-depth involves understanding the value of all the elements of the system working together. Because it is easily quantifiable, materials accounting performance measures ("timely detection" of "significant quantities") have received an inappropriate role as the sole measure of safeguards systems performance. This is particularly true in international safeguards where materials accounting is described as a measure of fundamental importance (ref 10). A performance measure that has a quantitative, nonpolitical basis is desirable in the international environment; however, as the safeguards approach adopted by EURATOM for THORP (Thermal Oxide Reprocessing Plant) shows, it is possible to go far beyond a periodic determination of material unaccounted for (MUF) in the design of modern safeguards systems. Additional information, including operations and internal materials flow data, coupled with authentication and verification measures, provides a powerful set of controls yielding a high degree of assurance concerning the declared operations of the plant. (ref 11)

Detection of undeclared materials in declared facilities or undeclared facilities is fundamental to effective international safeguards. As described previously, significant efforts are currently underway at the IAEA to strengthen the safeguards system's ability to detect undeclared materials through improved access to information and sites, but, like defense-in-depth, the effectiveness of these measures will be very difficult to assess in quantitative terms.

Efficiency

The growth of the quantity of materials under safeguards, and perhaps more importantly the number of geographic locations to be safeguarded, makes the efficiency of safeguards important to the nuclear industry and the larger international nuclear materials management community. Although safeguards costs are small relative to the security (prevention of proliferation) and the energy benefits provided by the use of nuclear materials, it is still worthwhile to minimize them where ever possible. The control of the costs of implementing safeguards, whether domestic or international often reduces to questions of risk management, and the use of people vs. technology.

Graded safeguards, providing more protection for and inspection of those materials most attractive for use in nuclear explosive devices, is key to efficient allocation of resources.

Personnel costs are high and ongoing, whereas technology requires large up-front investments and minimal operating costs. Reducing operator and inspectorate personnel reduces the insider threat; however, there is probably no substitute for the curious inspector. Overall the goal should be to use technology to permit humans to perform functions they are still best suited for. In international inspections, the use of regional offices and resident inspectors permits the inspectorates to complete more inspection days in safeguarded facilities with the same staff by reducing travel time.

Completeness

Growing inventories of materials outside safeguards, such as those produced by non-NPT States, must be considered when evaluating the overall global nuclear materials management and control regime. Although this paper is about safeguards, it is important to keep in mind that it is unsafeguarded materials in rogue States that pose perhaps the greatest threat to international security. There must be a balanced allocation of resources, world-wide, to reduce the risks posed by inadequate controls over nuclear materials. It is essential that we strengthen our ability to detect the production of weapons usable materials and respond appropriately to the threat presented by production outside safeguards.

The Debate

Safeguards Can Never Be Good Enough

Given the high consequences of the diversion of the relatively small quantities of nuclear materials required to fabricate a single nuclear explosive device, safeguards systems can never be made "good enough" to reduce risks to acceptable levels. The risk is seen as proportional to the amounts of weapons-usable materials in the world and the number of States possessing these materials. For those holding this view the preferred solution is to apply strong safeguards to existing materials while working for the reduction and eventual elimination of all nuclear materials and their means of production from the entire world.

Safeguards Can Reduce The Risk to Acceptable Levels

Safeguards systems designed with a defense-in-depth approach can reduce the risk of diversion or theft from declared fuel cycles to acceptable levels for reasonable costs. Modern domestic safeguards and security systems employed by facilities under regulation by strong, stable governments, when coupled with strong response elements, are commonly viewed as providing adequate protection against the subnational threats. Concern remains for the protection of nuclear materials in unstable parts of the world and for protecting against the determined State proliferator.

International Safeguards Must Be Viewed in the Context of the Threat of Unsafeguarded Production

International safeguards must consider the production of materials outside safeguards either by non-NPT signatories or treaty violators. Nuclear technology and expertise is widespread, and safeguards systems need only be good enough to motivate the determined proliferator to produce materials directly rather than diverting from safeguarded facilities. In this context, debates about the performance of accounting systems at the significant quantity level, or indeed what the significant quantity should be, add little value when the most likely long-term threat to international security is unsafeguarded production. The efforts by the IAEA to strengthen safeguards through enhanced ability to detect undeclared activities is more important than small improvements in accounting system performance.

Safeguards must be an integral part of the nonproliferation regime that considers the motives of States or terrorist groups, their capabilities, the number and kinds of nuclear devices they desire, and the global availability of all weapons-useable nuclear materials, not just plutonium. A balanced approach that considers all these factors will provide guidance as to the required performance and cost of safeguards systems. Proposals to eliminate commercial nuclear power, restrict the use of plutonium, and/or to dispose of nuclear materials must be evaluated in this broader context.

Policies to Assist Safeguards—Global Nuclear Materials Management

Proliferation Resistant Measures

Making nuclear materials inherently less useful for rapid or simple fabrication into a nuclear explosive device can be effective in reducing the terrorist or insider threat. It is not very important for reducing the risk of diversion by the State in the international safeguards context although it may delay the time from diversion to fabrication. Concepts such as the integral fast reactor in which fission products are never completely separated from plutonium during reprocessing that is integral to the reactor, protecting materials through the use of "natural" barriers such as high radiation fields (for example the National Academy of Science recommendation on the "spent fuel standard" ref 12), and coprocessing of mixed oxide materials are examples of proliferation resistant measures.

Minimizing Amounts of Separated Materials

Storage of large quantities of direct-use materials for long times can be avoided by sizing the elements of the fuel cycle to separate only those amounts of attractive materials that are needed and minimizing the time that those materials are in a direct-use form. For example, MOX as fuel is less attractive than MOX powder, which is less attractive than plutonium oxide. It is important to note however, that spent fuel still must be safeguarded against diversion by the State (and sabotage by terrorist groups), and that spent fuel becomes more attractive with time as the fission products that provide the radiation barrier decay. It has been noted that geologic repositories for spent fuel are plutonium mines that increase in quality and attractiveness with time (ref 13). Balancing materials supply with demand is made more complex by the economics of scale of building and operating reprocessing plants. however, the recent decisions by the Japanese to defer the construction of a second large-scale reprocessing plant indicate a sensitivity to slowing the accumulation of separated plutonium before it is required for fuel fabrication. (ref 14) Reprocessing plants that are part of the international nuclear fuel cycle, such as those in the UK and France, must also be prepared to deal with the uncertainties of the flows of materials to and from their facilities through the use of safeguarded and secure interim storage arrangements.

Materials from nuclear weapons dismantlement, which are attractive to begin with and exist in large quantities, can be dealt with in a variety of ways including special, highly secure storage; timely utilization in forms that are more proliferation resistant; disposition through reactor or accelerator burning; mixing with high-level waste; or direct deep burial disposal. The near-term drivers for dealing with materials from weapons dismantlement are first to protect them during dismantlement, storage, and ultimate disposition; and then to ensure irreversible arms reduction. The nonproliferation benefits accrue from minimizing the terrorist or insider threat to the materials, and more intangible aspects of nonproliferation leadership by demonstrating reduced reliance on nuclear weapons.

International (dual key) Control on Sovereign Territory

Stocks of attractive nuclear materials not needed for immediate processing could be placed under dual access controls of the State and the IAEA. The State would declare its requirements for withdrawals from the store, which would be made under observation of State and IAEA inspectors. The control exercised by the IAEA would not include the right to veto a materials movement, rather it would serve to provide an additional layer of containment and surveillance. Although the materials would be stored on the State's territory and would obviously be under the ultimate control of the State, dual controls would provide an important confidence building function regarding the State's nonproliferation commitments.

Transparency

Transparency measures are not well defined by the international safeguards community, but can include more openness about the purposes of nuclear activities, plans, and inventories of a State and more access by inpsectorates to facilities, declared and nondeclared, in the State. Transparency builds confidence and provides information that can be used to more effectively allocate safeguards resources. A summary of four discussions on transparency in the international safeguards context can be found in reference 11.

Intelligence Sharing

Although the IAEA can go a long way to improving its ability to detect undeclared activities and materials, it cannot hope to acquire the resources for detecting these activities that are utilized by many nations. Furthermore, the Agency has no authority to find non-compliance in regard to activities of State's not covered by safeguards agreements. Careful intelligence sharing among nations and international organizations, including the IAEA, is an essential element of the nonproliferation regime. Integral to this effort is improving the intelligence communities' ability to detect proliferation, and in particular, the production, theft, or smuggling of nuclear materials. (ref 16)

Improved States' Systems and Regional Safeguards

Global nuclear materials management begins with the development and implementation of protection and control systems by those with responsibility for the materials: facility operators and the State. Improvements in these systems can make significant contributions to international safeguards. Regional approaches such as EURATOM or ABACC (the joint Brazil/Argentine control commission) also facilitate global controls and serve as important confidence building measures for nonproliferation.

Strengthened Physical Protection

Physical protection for nuclear materials must be balanced to meet the local threat on a global basis. The international safeguards community has made major strides to disseminate physical protection standards, but more can and should be done, possibly including a role for the IAEA as an invited (by the state) independent auditor or assessor of physical protection systems. As noted in previous sections, advanced monitoring technologies can also play a physical protection function by providing timely warning of diversion even in the international safeguards context.

Supporting the IAEA

The IAEA and the international safeguards community are only a part of the nonproliferation regime; however, the Agency plays a central role in enhancing international security and the national security of all nations. As such, the Agency's costs are a bargain. It is important that the IAEA be provided the resources, financial, technical, and personnel, to meet the challenges of a post-cold war world with growing reliance on nuclear power. It is worth asking whether some of the funds being spent on studying weapons plutonium disposition options might not be better used to strengthen the overall nonproliferation regime by increasing support to the institutions that help to manage and protect all the world's plutonium.

Conclusions

Safeguards and security systems have evolved along with the evolution in the uses of nuclear materials to meet changing threats and changing levels of public risk acceptance. These systems will have to continue to improve, making use of new approaches and technologies, to meet the safeguards and security challenges of the future. Based on demonstrated performance, a strong case can be made that today we know how to design and implement cost-effective safeguards systems, both domestic and international, that reduce the risk of diversion or theft of nuclear materials from declared activities to acceptable levels. In particular:

- Domestic safeguards and security systems implemented by operators under the regulatory authority of stable governments are effective against the threat of subnational diversion or theft. Response elements, which are not discussed in this paper, reduce further the probability of successful malevolent actions involving nuclear materials.
- International safeguards practiced in a global nuclear materials management regime can provide credible assurance that States are complying with their safeguards agreements at a level that provides confidence the State is not diverting declared materials to a nuclear weapons program. As has been demonstrated in new facilities, modern, evolving approaches to international safeguards employing defense-in-depth concepts, can meet the demands of safeguarding a growing and more complex nuclear fuel cycle, including plutonium recycle.
- Thus, in stable regions, the effectiveness of safeguards and security systems need not be a driver for decisions regarding the use of plutonium in the civil power fuel cycle or the disposition of excess weapons plutonium.

- Implementing improved nuclear materials protection systems in Russia and the other nuclear republics of the former Soviet Union is a matter of considerable urgency for the safeguards and security community.
- More needs to be done to strengthen national and international systems for detection of proliferation by the determined State proliferator using unsafeguarded facilities.

References

1. "Management and Disposition of Excess Plutonium," Committee on International Security and Arms Control, National Academy of Sciences, National Academy Press, Washington, DC 1994
2. "Nonproliferation and Export Control Policy," Fact Sheet, Office of the Press Secretary, The White House, Washington, D.C., September 27, 1993
3. "IAEA Safeguards: Going Beyond Material Accountancy.....," Bruno Pellaud, 35th Annual Meeting Proceedings of the Institute of Nuclear Materials Management, *Nuclear Materials Management* XXIII, July, 1994
4. "Safeguards in Transition: Status, Challenges, and Opportunities," Bruno Pellaud, *IAEA Bulletin*, vol.36, No. 3, 1994 pp 2-7
5. "New Dimensions in Nonproliferation--An IAEA View," Bruno Pellaud, JNMM vol XXIII, No. 1, October 1994.
6. "Environmental Monitoring and Safeguards: Reinforcing Analytical Capabilities," David Donohue, Stein Deron, Erwin Kuhn, *IAEA Bulletin* vol 3, 1994 pp20-23
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" IAEA INFCIRC 153 para. 73
8. Pellaud, *IAEA Bulletin* vol 3
9. "Defence in Depth and Resource Optimization for Safeguards," A. Zardecki and J. T. Markin, 32nd Annual Meeting of the Insitute for Nuclear Materials Management, *Nuclear Materials Management* XX (Proceedings Issue), 426-431 (1991)
10. IAEA INFCIRC 153 paragraph 29
11. "THORP: Authentication, Transparency and Independence," S. Kaiser, H. Nackaerts, R. Schenkel, P. J. Chare, H. G. Wagner, R. Howsley, and E. Williams, Volume 2 of the Proceedings of the Symposium on International Safeguards, Vienna, March 14-18, 1994. IAEA-SM-333/166
12. NAS Pu study
13. "Dose Rate Estemates for Irradiated Light-Water-Reactor Fuel Assemblies in Air," W. R. Lloyd, M. K. Sheaffer, W. G. Sutcliffe, UCRL-ID-115199, January 31, 1995
14. Japanese announcement to delay reprocessing--newspapers?
15. "Four Discussions on Transparency from the INMM International Safeguards Division Meeting," JNMM Vol XXII number IV, July 1994
16. "Nonproliferation Boom Gives a Lift to the National Labs," Christopher Anderson, *Science*, vol.263, February 1994 .