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Title: PROGRESS TOWARD MUTUAL RECIPROCAL INSPECTIONS OF FISSILE MATERIALS FROM DIMANTLED NUCLEAR WEAPONS

Author(s): M. W. Johnson, T. B. Gosnell

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ABSTRACT -- INMM ANNUAL MEETING 1995

PROGRESS TOWARD MUTUAL RECIPROCAL INSPECTIONS OF FISSILE MATERIALS FROM DISMANTLED NUCLEAR WEAPONS

M. W. Johnson, Los Alamos National Laboratory, Mail Stop J562, Los Alamos NM 87545, 505-667-2047, and T. B. Gosnell, Lawrence Livermore National Laboratory, Mail Stop L-366, P.O.Box 808, Livermore CA 94550, 510-422-0297

In March 1994, the United States and the Russian Federation announced their intention to conduct mutual reciprocal inspections (MRI) to confirm inventories of fissile materials from dismantled nuclear weapons. Subsequent interactions between the two countries have established the basis for an MRI regime, covering instrumentation, candidate sites for MRI, and protection of information deemed sensitive by the countries. In this paper we discuss the progress made toward MRI, stressing measurement technologies and observables, as well as prospects for MRI implementation. An analysis is presented of observables that might be exploited to provide assurance that the material being measured could have come from a dismantled weapon rather than other sources. Instrumentation to exploit these observables will also be discussed, as will joint US/Russian efforts to demonstrate such instrumentation. Progress toward a so-called "program of cooperation" between the two countries in protecting each other's sensitive information will be reviewed. All of these steps are essential components of an eventual comprehensive regime for controlling fissile materials from weapons.

INTRODUCTION

In March 1994, US Secretary of Energy Hazel O'Leary and Russian Minister of Atomic Energy Viktor Mikhailov concluded a joint statement (hereinafter the O'Leary-Mikhailov joint statement) on inspection of facilities containing fissile materials removed from dismantled nuclear weapons. This joint statement was part of a series of US/Russian moves toward transparency in nuclear disarmament; a summary of transparency measures currently being implemented or studied appears in the paper by Percival at this conference.[1]

The O'Leary-Mikhailov joint statement records the two ministries'

> ...intention to host reciprocal inspections by the end of 1994 to facilities containing plutonium removed from nuclear weapons. In preparation for these inspections, technical experts will meet to define the procedures for inspecting plutonium that has been removed from nuclear weapons. An initial meeting of technical experts will be held within two months from this date. The two sides intend to conclude an agreement on the means of confirming the plutonium and highly enriched uranium inventories from nuclear disarmament. These inspections will be an important step in the process of establishing a world-wide control regime for fissile materials.[2]

Mutual reciprocal inspections (MRI) of fissile materials from dismantled weapons pose special problems because of the sensitive nature of the materials (particularly those that remain in weapon-component form) and the facilities that store them. Classical nuclear-

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[1] C. M. Percival, T. H. Ingle, and A. J. Bieniawski, "Proposal for Broader United States-Russian Transparency of Nuclear Arms Reductions," this conference.

[2] Department of Energy, "Joint Statement on Inspection of Facilities Containing Fissile Materials Removed from Nuclear Weapons," released to press 16 March 1994.

safeguards approaches to inspections of fissile materials may not be appropriate to MRI because of their generally intrusive nature. However, some physics measurements seem essential to MRI, to provide policy makers with assurances that the fissile materials truly are from dismantled weapons, and therefore that dismantlement is indeed taking place. This conundrum stands at the heart of transparency and irreversibility and is an underlying reason for the meetings of technical experts prescribed in the O'Leary-Mikhailov joint statement.

Initial progress toward MRI was described a year ago by Percival and Ingle[3], emphasizing the overall context of MRI work. Here we describe MRI developments that have transpired since the publication of that paper, with an emphasis on the state of negotiations and on the instrumentation and procedures that the two countries have exhibited to date. The reader should recognize that the final implementation of MRI has not yet been concluded at the date of this paper's publication, and that some of the remarks made here may be overtaken by events. The present discussion reflects the state of MRI *circa* June 1995.

TIMELINE FOR MRI ACTIVITIES

The O'Leary-Mikhailov joint statement, quoted above, calls for reciprocal inspections to "facilities containing plutonium removed from nuclear weapons" -- not necessarily operational dismantlement facilities -- to occur by the end of calendar 1994. To meet this objective, the United States agreed to host a Russian delegation at the Rocky Flats ETS facility outside Denver, Colorado, and Russia in turn agreed to host an American

[3] C. Mark Percival and Timothy H. Ingle, "Overview of Joint Statement on Reciprocal Inspection of Fissile Material Removed from Nuclear Weapons," INMM Journal of Nuclear Materials Management, July 1994, Vol. XXII, pp.19-21.

delegation at the Siberian Chemical Combine at Seversk (Tomsk-7). These visits had the dual technical purpose of giving an overview of the two countries' procedures and capabilities for storing the material, and allowing each country to demonstrate instruments that might be used in MRI. Details of the instrumentation used in the Rocky Flats demonstration are given in the next section of this paper.

The visit to Rocky Flats occurred in July 1994, and the return Seversk visit followed in August. In each case, the visitors were escorted through a section of the host facility used for storing plutonium, to gain some familiarity with the general layout of the facility. The delegations, in each case, then moved to a nearby location suitable for handling (but not opening) containers bearing weapon components. The instrumentation demonstrations proceeded at this second location, to which a few storage containers bearing "pits" (American usage for the components of a nuclear assembly system located within the inner boundary of the high explosive, but not including safing materials or stress cushions) had been brought.

For reasons described in the next section, it was thought necessary to explore measurement options going beyond those in the initial Rocky Flats and Seversk demonstrations. Panels of US and Russian technical experts met in Moscow during September and October 1994 to "define the procedures for inspecting plutonium" as mandated by the O'Leary-Mikhailov statement, with the result that a joint US/Russian program of measurements with enhanced instrumentation occurred in November 1994 at Lawrence Livermore National Laboratory. These measurements in turn have supplied the basis of further consultations by technical experts that continue at this time.

PROBLEMS IN MRI MEASUREMENTS

As discussions of MRI measurements have proceeded, there has been a subtle yet significant elaboration of the language in the joint statement regarding "procedures for inspecting plutonium that has been removed from nuclear weapons," namely that it is important to verify that the plutonium being measured *is* from dismantled nuclear weapons. Mere exhibition of quantities of plutonium does not necessarily suffice to "[confirm] the plutonium and highly enriched uranium inventories from nuclear disarmament" (from the O'Leary-Mikhailov joint statement), because both countries possess plutonium in forms other than weapon components that predate the onset of large-scale weapons dismantlements by the two countries. This is a particular problem for Russian plutonium. Unlike the United States' plutonium production reactors at Hanford, Russian reactors that produce plutonium for weapons applications are also key components of the country's power-generation infrastructure. The continuing operation of these reactors to meet the power-generation needs has the side effect of producing additional plutonium that obviously is not tied to nuclear disarmament, and indeed poses significant safeguards/proliferation problems (which however will not be discussed here).

This posture leads inevitably to the usual transparency problem of resolving conflicting national-security needs: on the one hand, the need to provide evidence (via MRI among other cooperative programs) that dismantlement is proceeding and, on the other hand, the importance of protecting sensitive information about the weapon components. Two parallel and complementary approaches to this problem are being pursued. First, a so-called Program of Cooperation (or Agreement for Cooperation) is being negotiated by the two countries that covers exchange of sensitive information, not merely in the context of MRI but also as required for implementing other bilateral cooperative measures (for example, agreements on stockpile declarations). Second, delegations from the two countries continue to discuss measurements that provide *confidence* -- not absolute proof

-- that the plutonium being inspected is from dismantled weapons, without revealing more sensitive information than is necessary.

The initial Rocky Flats/Seversk demonstrations were conducted, with one exception, under the assumption that no classified information could be exchanged during MRI measurements; that is, that the MRI program would have to proceed independent of the Program of Cooperation. Consequently it was necessary to limit the demonstrations to measurements showing simply that a large but unspecified quantity of plutonium was present within the storage container represented as containing a pit. The United States demonstration at Rocky Flats addressed this with two types of measurements:

a. Low-resolution gamma-ray spectroscopy, with analysis routines embedded in the instrument (so that only the results of the analysis were shown to the operator and observers), to detect the complex of gamma rays with energies near 400 keV that are characteristic of ^{239}Pu; and

b. "Threshold" measurements of neutron count rates that did not reveal the actual count rate (which was regarded as sensitive) but merely showed that the rate *exceeded* some nominal value corresponding to ~100 grams of plutonium containing 6% ^{240}Pu by weight.

The Russian demonstration at Seversk was similar, except that Russian guidelines regarding classified/sensitive information apparently permit the exhibition of actual neutron count rates associated with pits; therefore, the Russian neutron measurement displayed actual numbers of counts seen by the detector in a preset time interval.

One other demonstration was conducted at Rocky Flats, with an eye toward the eventual Program of Cooperation: radiography of a storage container containing an unclassified sphere of tantalum. The resulting radiograph was presented to the Russian delegation as an example of what might be done to show the "shape" of the material within the container, should the Program of Cooperation allow such an exchange of information. No such radiography demonstration was conducted by the Russians, and subsequent discussions have presumed other approaches to measuring shape.

In consultations following the Rocky Flats/Seversk demonstrations, both sides opined that the measurements shown during the demonstrations were inadequate to confirm the presence of a pit inside a storage container. Discussions therefore turned to types of measurements that might be possible under a Program of Cooperation but which would still minimize the amount of sensitive information that would have to be exchanged. The US delegation suggested a program consisting of three types of measurements:

1. Measurements, via γ-ray spectroscopy, of the isotopic composition of the plutonium (specifically the ratio {mass ^{240}Pu}/{mass ^{239}Pu}), useful in confirming that the plutonium is weapons-grade and assisting in the analysis of the other measurements;
2. Measurements of gross neutron count rate, which is roughly correlated (ignoring neutron multiplication and neutrons from (α,n) reactions) with the amount of ^{240}Pu present so that total plutonium mass can be inferred in conjunction with the isotopics measurements; and
3. Measurements to exhibit the "shape" of the plutonium piece(s), to distinguish between pits and scrap pieces of plutonium whose shape would presumably be irregular or at least non-pitlike.

The basis of this measurement scheme is the contention that, while it might be impossible to *prove* that a plutonium piece is a pit via such measurements, a piece of weapons-grade plutonium of sufficient mass and appropriate shape might as well be considered a pit. All three types of measurements could reveal information considered sensitive by one or both parties, requiring the Program of Cooperation before implementation occurs.

At the present time, the two sides have not yet agreed on the details of all of these measurements. The primary outstanding issue is the "shape" measurement, where different technical approaches have been proposed, as has the possibility of foregoing shape measurements altogether.

PROPOSED MRI INSTRUMENTATION

The technical experts' consultations achieved consensus on the desirability of using a common set of instrumentation (or at least types of instrumentation) for measurements in both countries. To emphasize the reciprocal, cooperative nature of the MRI activities, it was held desirable -- and achievable -- that both countries contribute to the instrumentation pool that will be used for the measurements. Current plans, which are subject to formal ratification by the governments of the two countries, call for the United States to contribute instrumentation for the isotopic-composition measurements, Russia to supply instrumentation for the neutron count rate measurements, and the source of instrumentation (if any) for shape measurements to be resolved during future consultations.

The initial Rocky Flats demonstration used the NAVI-2 system developed at Los Alamos National Laboratory for general-purpose arms-control applications. This instrument has not yet been described in the literature, but it is based on a similar, earlier instrument also intended for arms-control use.[4] The NAVI-2 consists of a NaI low-resolution γ-ray spectrometer and two lightly moderated ^{3}He neutron detectors, packaged integrally with signal-processing electronics and a microprocessor for data analysis and operator control. The entire package weighs about 4 kg, including batteries, and is ruggedized for use over

[4] K. B. Butterfield, W. S. Murray, D. R. Millegan, and L. E. Ussery, "Portable Gamma-Radiation Analyzer for Treaty Verification," IEEE 1991 Nuclear Science Symposium, November 1991, Santa Fe.

a wide range of temperatures. The NAVI-2 was also demonstrated as a candidate for the shape-determination measurements, using a collimator on the NaI crystal and without using data from the neutron tubes.

The system for isotopic analysis is described elsewhere at this conference.[5] It uses a HPGe high-resolution γ-ray spectrometer and commercially available multichannel analyzer, running the PU-600 computer code, derived from the widely used MGA package[6] and written at Lawrence Livermore National Laboratory for the express purpose of use in MRI. In contrast to MGA, PU-600 treats only the part of the γ-ray energy spectrum near 640 keV, which is of secondary value in most safeguards measurements[7] but is useful in MRI because lower-energy lines may either raise sensitivity/classification concerns or be difficult to measure in an MRI setting.

The neutron detector supplied by Russian scientists for the neutron-count task is a conventional assembly of ^{3}He tubes encased in a polyethylene moderator. Count rate is displayed using an SRPS-7 radiation monitor operating in scaler mode. For the threshold-count-rate demonstration performed at Rocky Flats, the neutron detectors in the NAVI-2 proved sufficient.

All of these systems were used in joint US/Russian demonstration measurements at Lawrence Livermore National Laboratory in November 1994, using pieces of plutonium drawn from non-weapons inventories to assess the function of the instruments. Tests

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[5] Zachary M. Koenig, Joseph B. Carlson, DeLynn Clark, and Thomas B. Gosnell, "Plutonium Gamma-Ray Measurements for Mutual Reciprocal Inspections of Dismantled Nuclear Weapons," this conference.

[6] R. Gunnink, "MGA: A Gamma-Ray Spectrum Analysis Code for Determining Plutonium Isotopic Abundances," Lawrence Livermore National Laboratory report UCRL-LR-103220, April 1990.

[7] T. E. Sampson, "Plutonium Isotopic Composition by Gamma-Ray Spectroscopy," in D. Reilly, N. Ensslin, H. Smith, Jr., and S. Kreiner, *Passive Nondestructive Assay of Nuclear Materials* (Washington, DC, U. S. Govt. Printing Office, 1991).

showed that the isotopic analysis deduced $^{240}Pu/^{239}Pu$ ratios that were within about 10% of the true values known from prior analyses of the plutonium. Simple neutron-counting measurements, in conjunction with the isotopic analyses, provided mass estimates generally within a factor of 2 of the true masses, even without allowing for neutron multiplication or the presence of (α,n) neutrons. On the basis of these measurements, the two teams of scientists concluded that the technologies demonstrated at Livermore constitute technically adequate instrumentation for the isotopic-analysis and mass-estimation tasks. Shape measurements were also demonstrated at Livermore, but no bilateral consensus yet exists on the adequacy and appropriateness of these measurements.

SUMMARY: FUTURE MRI DIRECTIONS

At this time, further progress in plutonium MRI hinges upon resolution of sensitivity issues connected to the Program of Cooperation. The measurements shown at Livermore in November cannot be conducted reciprocally on actual pits until some arrangement for exchanging classified information is in hand; indeed, it appears that even the measurements demonstrated by Russian scientists at Seversk could not be applied to US weapon components under current classification guidance. The Rocky Flats demonstration (excluding radiography) could be repeated reciprocally without the Program of Cooperation, as the information displayed to instrument operators was all unclassified/nonsensitive, but both sides have expressed a preference for the later, more intrusive measurement scheme as being more conducive to confidence building.

The O'Leary-Mikhailov joint statement also addresses "means of confirming the plutonium *and highly enriched uranium* [HEU] inventories from nuclear disarmament" (emphasis added). Bilateral discussions of HEU MRI are still in a very preliminary stage, pending progress on plutonium MRI and a more complete formulation of the US government's own views on HEU MRI. HEU MRI is in general a more difficult problem than plutonium MRI, for several reasons. HEU weapon components are more difficult to measure, from a physics standpoint, than plutonium-bearing weapon components. Furthermore, both countries store plutonium pits long-term *as* pits, while HEU from dismantled weapons is mutable: HEU from weapons is useful for applications other than weapons, so physical alteration of weapons HEU to other forms is both desirable and achievable (HEU poses much less difficult processing problems than plutonium), and therefore proceeds apace. Meeting the O'Leary-Mikhailov objectives thus may require HEU MRI to deal not only with intact weapon components, but also with recast HEU, or even with HEU in some intermediate state encountered during an inspection of an operating disassembly facility.

A final unresolved issue is the location of the eventual full-scale MRI inspection program. Demonstrations to date have been held at secondary or interim storage sites rather than the primary sites where weapons are dismantled or pits are stored (Pantex in the United States and, according to reference 5, Nizhnaya Tura, Yuryuzan, Penza and Arzamas for Russian disassembly work, and unspecified sites for Russian storage). Full implementation of MRI will require negotiations to fix the sites where the inspections occur. However, the instrumentation demonstrated to date appears to be useful in any of the potential locations.