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Arms Control Treaty Verification: Neutron Radiographic Techniques

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ABSTRACT

Bilateral and multilateral arms control treaties are placing increasing demands on technical means for on-site verification. Radiation detection and imaging are important, especially when verification involves nuclear warheads. Neutron interrogation techniques are particularly useful in fissile material verification. The role of neutron radiographic imaging must be balanced between acquisition of sufficient information for effective verification and the avoidance of unneeded information that would be overly intrusive.

INTRODUCTION

Because the treaty between the United States and Soviet Union on the Elimination of Their Intermediate-Range and Shorter-Range Missiles (INF) has been in effect for nearly a year, considerable international attention has turned to this and to other arms control measures. On-site verification is an important means of ensuring compliance. Verification is also concurrently carried out by national technical means and through human intelligence gathering.

The verification that can be conducted at a given site depends on the agreed purpose: usually confirming declared inventory, eliminating missiles, witnessing allowed tests, or monitoring production of weapons. The declared inventory is part of the treaty, usually in a memorandum of understanding that specifies

items to be controlled or eliminated under the treaty. In some cases production and testing of weapons systems can continue but within restrictions. In cases where such testing or production is banned, other similar activities that cannot be easily distinguished by national technical means (e.g., satellites) must be obsered to confirm compliance with the treaty. For example, a plant that formerly produced an intermediate range missile banned under the INF treaty might now be producing an intercontinental range missile that is still permitted.

On-site verification can be carried either by on-site inspection or by on-site monitoring. The inspection is conducted by a designated team of specialists who are escorted during the inspection by the inspected party. The monitoring is carried out at a fixed installation, normally the portal of a missile production plant. Monitoring also includes the right to watch the periphery or fences of the plant. Such monitoring requires specialized instruments that provide data analyzed by inspectors stationed full-time at the portal. This team also services the equipment.

The amount of time and frequency of verification is normally spelled out in the treaty or its protocols, as it is for INF. The amount of warning time is specified (up to nine hours), the inspection duration (24 hours), and the inspection quota (initially 20/yr).

On-site verification is carried out by human observation and with instruments. Human observers can carry out many of the verification tasks in the alloted time and at minimal cost. For inspections that are limited to 24 hours and for inspection tasks where access is limited, instruments can be specified for assistance to the inspection team. In some situations instruments can be left at a site for continuous monitoring, in particular at the portal of a missile-production facility.

Some requirements that drive the choice of verification instrument are effectiveness for the purpose, lack of unnecessary resolution, ability to operate in the field, and other special capabilities. No instrument can be used unless it is acceptable to all treaty parties; this places a premium on "transparency" of the instrument in its engineered form.

Some of the authorizable instruments are very simple devices and some are of increasing complexity, ranging from measuring tapes, cameras, and radiation detection instruments. Methods for "tagging", or marking in a unique, tamper-revealing manner are also under consideration.

STRATEGIC-ARMS TREATIES

The two types of such verification in the INF treaty are short-notice inspections and continuous portal monitoring. The short-notice inspection allows the use of "radiation detection devices" and the portal monitoring permits "non-damaging image-producing equipment." Because the short-notice inspection does not explicitly allow image-producing equipment, the radiation detection will be limited to integral detection of passive radiation from warheads. The specific purpose will be to ensure that mobile missile canisters contain only the permitted one-warhead SS-25 and not the three-warhead SS-20 that is being eliminated.

The portal monitoring permitted under INF is a radiographic system "for imaging the contents of launch canisters or shipping containers declared to contain missiles or missile stages." The INF treaty inspection protocol does not further define the imaging system. Production of the permitted intercontinental missile SS-25 will be monitored at the Soviet Votkinsk facility to verify that no banned SS-20 intermediate range missiles are produced and placed in canisters that are shipped through the portal. A portal monitor system is also being established near Salt Lake City in the United States.

For the START treaty under negotiation, the December 1987 Washington summit talks indicated that warheads and missiles will be subject to limitations. This could conceivably require detection of nuclear warheads, differentiation between different sizes of rocket motors, counting nuclear reentry vehicles, and differentiation between conventional and nuclear warheads. If warheads were to be verifiably dismantled, the means to ensure compliance would be very important. Each of these applications could involve some form of radiation instrumentation or radiography, including neutron radiography.

Most nuclear-armed strategic missiles carry more than one warhead in their post-boot vehicle (MIRV bus). Some of the specific verification problems that are subject to technological assistance could involve counting the number of warheads (reentry-vehicles, RVs) in silo-based strategic missiles. Long-range aircraft can carry either nuclear gravity bombs or air-launched cruise missiles; counting the number of these on each aircraft could become a verification function. Sea-launched cruise missiles (SLCMs) can carry either nuclear or non-nuclear warheads, but some types outwardly look alike; verification could be required to distinguish between these two types. Nuclear missiles are also deployed on land-mobile carriers, usually within a canister; verifying the type of missile within a canisterized rail- or road-mobile carrier is another possible task.

Because fissile masses are essential components of nuclear weapons, both spontaneous and induced fission are important signatures in their detection and characterization. Such imaging as would be allowed would be restricted to that which is sufficient to meet the agreed verification requirements -- but no better. In addition to fundamental restraints on the imaging concept and resolution, controls will be exercised over design, fabrication, and operation of the instrument system and the data.

Other possible strategic treaty regimes that require technology for verification include nuclear defense systems, space-borne craft, and nuclear underground test bans.

NON-STRATEGIC-ARMS TREATIES

Considerable international attention is now being paid to a Chemical Weapons Convention. It is widely understood that verification is one of the key stumbling blocks. Any measures that can reduce the scope and intrusiveness of on-site inspection and monitoring would be extremely valuable.

Conventional armed forces in Europe are subject to accelerated discussion, coupled in part to progress in START. Theater nuclear weapons, the smaller tactical nuclear weapons widely dispersed in Europe, are not officially part of current negotiations, but they might become an issue for verification in the future.

NEUTRON RADIOGRAPHIC TECHNIQUES

Narrowly defined, verification is an act of confirming the validity of a specific item of treaty-declared information. Gathering any extraneous information is unnecessarily intrusive, which all sides guard against. Only that information needed to verify the treaty is authorized to be collected during verification. The possibility of collecting collateral information is recognized, but measures are usually taken to reduce that risk.

Nuclear warheads are commonly understood (1) to contain at least a fission component, and in the case of thermonuclear weapons to have a secondary fusion component. Both U-235 and Pu-239 are fissile materials that can be used in the fission triggers. Detailed designs of these weapon components are closely guarded secrets; nations that have tested nuclear weapons do not in general share their design information. As a result, a verification method that would reveal anything beyond that which is necessary for the purpose would not be acceptable. For example, imaging a nuclear warhead sufficiently to determine the size of the key components or their internal separations would not be negotiated.

Consequently, because of the narrow verification requirements agreed to in treaties, radiography in its broadest sense is likely to be too intrusive. The type of radiography that can be used in a treaty environment is likely to be constrained in some manner in terms of spatial and energy resolution, penetration, area coverage, irradiation time, radiation form, dose, and other parameters.

Interrogation and imaging by neutrons is particularly relevant to treaty verification because of the selective response neutrons provide from fissile materials. This specificity makes neutron radiography in some form with controlled parameters potentially useful in nuclear-arms treaties.

The neutron radiographic systems likely to meet treaty requirements would have to be fieldable under a wide range of environmental and operating conditions. They would have to perform reliably in the field, with minimal maintenance, for many years (perhaps one or two decades), and not involve the transfer of any sensitive technology. Radiation doses to sensitive components must be controlled.

A neutron radiographic system is most likely to require fast neutrons to gain sufficient penetration, to obtain the characteristic fissionable material signatures, and to minimize collateral informtion. Spontaneous fission neutrons and gammas from plutonium can act as a source for autoradiography.

The gamma radiographic system that has been chosen to carry out the portal monitoring at Votkinsk in the Soviet Union is a 6-8 MeV LINAC with a large array of detectors for real-time imaging of selected portions of rocket-motor diameters. Bremstrahlung transmission through the cargo containers will be detected. The diameters of the SS-20 and SS-25 differ sufficiently to permit that difference to be detectable by gamma transmission radiography.

Radioactive source gamma transmission radiography might be an alternative to an accelerator-based system. A gamma-transmission hodoscope (2) has been examined for a similar role in START and future treaties. Using a 100 mCi Co-60 source, rocket-motor differentiation can take place with a relatively inexpensive, proven system.

For detection that must be more specific to nuclear materials, neutron methods become prominent. In particular, the fast-neutron hodoscope (3) can be used to detect nuclear warheads in SLCMs and to count RVs (2,4). In these applications, the degree of radiographic resolution must be made deliberately coarse in order to avoid obtaining weapons-design information. If the SLCM warhead were non-nuclear, no fission radiation would be expected to emerge on neutron bombardment. For RV counting, the matter of interest is to count the number of nuclear warheads actually deployed. If they deployment is in an underground silo or aboard a submarine, severe practical difficulties arise for the measurements. When the missiles are out of their deployed tubes or are in mobile carriers, they are more accessible.

SUMMARY AND ACKNOWLEDGEMENTS

The potential for neutron radiography to contribute to arms control treaty verification can now be better understood in light of INF implementation and START negotiation. It is important to factor these lessons into consideration for future applications in arms control. The actual location where such measurements are to be made strongly affects the practicality of using an single instrument system.

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