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The role of science in treaty verification

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Abstract

Technologically advanced nations are currently applying more science to treaty verification than ever before. Satellites gather a multitude of information relating to proliferation concerns using thermal imaging analysis, nuclear radiation measurements, and optical and radio frequency signals detection. Ground stations gather complementary signals such as seismic events and radioactive emissions. Export controls in many countries attempt to intercept materials and technical means that could be used for nuclear proliferation. Nevertheless, we have witnessed a plethora of nuclear proliferation episodes, that were undetected (or were belatedly detected) by these technologies—the Indian nuclear tests in 1998, the Libyan nuclear buildup, the Iranian enrichment program and the North Korea nuclear weapons program are some prime examples. In this talk, we will discuss some of the technologies used for proliferation detection. In particular, we will note some of the issues relating to nuclear materials control agreements that epitomize political difficulties as they impact the implementation of science and technology.

Keywords: Treaty; Transparency; Verification; IAEA; NPT; CTBT

1. Introduction

There is no question that science plays a major role in verifying many treaties. At the previous Crete meeting I gave a talk on how a variety of nuclear measurement technologies were applied to the detection and measurement of nuclear materials. This is in direct support of article III of the Non-Proliferation Treaty (NPT), that says "Each non-nuclear weapon State Party to the Treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency in accordance with the Statute of the International Atomic Energy Agency and the Agency's safeguards system, for the exclusive purpose of verification of the fulfillment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices."

The discovery of Iraq's nuclear program (utilizing undeclared facilities not covered by existing safeguards inspections) in 1991 led to the realization that "we are looking for the keys under the lamp, not necessarily where they were lost". As a result, an enhanced approach, initially dubbed "93+2" was initiated in 1993. The name "93+2" referred to the initial goal of implementing a plan of action in 2 years ("+2"), in time for the 1995 NPT Review and Extension Conference. The new implementation included new monitoring techniques (e.g., environmental sampling, no advance-notice inspections at points within declared nuclear facilities) that did not require any new legal permission.

Subsequently, the International Atomic Energy Agency (IAEA) decided that an "Additional Protocol" (AP), that goes further would be required to provide better confidence of non-proliferation. The AP would require that

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1. Countries would provide declarations concerning all nuclear-*related* activities and report all trade in items on the Nuclear Suppliers Group trigger list.
2. The IAEA would be able to access "on short notice" all locations it wishes to inspect.
3. There would be in place a streamlined process for visas for inspectors, that will be valid for multiple entries for 1 year.
4. The IAEA could use environmental sampling techniques throughout its activities.

This requires that countries sign the AP agreement and ratify it before it can be implemented there. As of December 2003, 83 countries have approved, 79 have signed, and 38 states have ratified their participation in the AP. This is a partial forward step—

1. It would be highly desirable that all countries ratify.
2. It is recognized that the AP is not a panacea that will resolve all the non-proliferation problems.

When we discuss the role of science in nuclear proliferation, we need to distinguish between two different issues

1. Detection of nuclear explosions (monitoring of the comprehensive test ban treaty, CTBT and prior to that, the limited test ban treaty, LTBT).
2. Detection of proliferation activities that could lead to the production of nuclear weapons (NPT).

2. CTBT monitoring

With seismic signals, it is possible both to estimate the location of an explosion or earthquake, and to discriminate between nuclear explosions and earthquakes. Discrimination methods include an interpretation of the location (including depth, a good indicator of feasibility of a nuclear test) or an analysis of the mixture of different types of recorded waves. In the 1960s, work at the Lamont Geological Observatory demonstrated that explosions are very inefficient at generating seismic surface waves. This serves as an important discriminator against earthquakes. Data around the world is collected by approximately 85 International Monitoring Systems (IMS) and relayed to the International Data Center (IDC) in Vienna. This part of the IMS will be able to detect an explosion of 1 kiloton, and determine its location within about 40 km, anywhere on the globe. The US contributes 25% of the funding needed by the IMS and IDC—whose total cost may reach $200 million for installation of all stations and all IMS/IDC operations for the first few years. The US also operates its own Prototype International Data Center (PIDC). These data will be supplemented by data from global networks of hydroacoustic, infrasound, and radionuclide sensors whose installation has barely begun.

These ground-based means are complemented by satellite-based means. The original US VELA program for nuclear explosion detection in space and in the atmosphere (that included X-ray, gamma-ray, and neutron detection) achieved notoriety when it detected very intense gamma-ray bursts coming from outer space. The US DOE web site (http://www.nnsa.doe.gov/na-20/monitor.shtml) lists the Array of Low Energy X-ray Imaging Sensors (ALEXIS) satellite and the Fast On-orbit Recording of Transient Events (FORTÉ) satellite as part of the current monitoring program. Quoting from that site "The ALEXIS satellite sensors provide near-real-time information on transient, ultrasoft X-rays, while also offering unique astrophysical monitoring capabilities. The ALEXIS satellite was launched in 1993, only three and a half years after preliminary design review", and "NNSA's FORTÉ satellite, launched in 1997, features an electromagnetic pulse sensor. This type of sensor requires wide-band radio frequency signal detection, which the FORTÉ integrates with related technology to help discriminate between natural (e.g., lightening) and man-made signals." Indeed FORTÉ has provided considerable insight into atmospheric lightening phenomenology. Another system, the Nuclear Detonation (NUDET) Detection System (NDS) consists of space, control, and user equipment segments. The space segment consists of NUDET detection sensors on the GPS satellites. The Department of Defense and DOE now have a full constellation of 24 GPS satellites in 10,900-nautical-mile orbits capable of detecting and locating nuclear detonations worldwide, 24 h a day.

3. NPT and proliferation detection—hardware

We now come to the hard problem—detection of *attempts* to develop nuclear weapons. The IAEA Additional Protocol was a result of an initial failure to detect Iraq's weapons program. In more recent times, we are all well aware of proliferation issues concerning Iran, DPRK (North Korea), and Libya, all of whom initiated clandestine programs to construct nuclear weapons, aided by a world-wide network that seems to be centered in Pakistan. Some of these programs were suspected, but their extent may only be partially known even today. Certainly, many crucial details were not initially known to the IAEA or to the existing nuclear powers. In light of these failures, we need to understand what it is we can and cannot determine using remote sensing. Obviously, I will not be able to get into significant technical details because of security issues, but I will attempt to provide an overview based on readily available information.