The Role of Science in Treaty Verification

Author(s):
Avigdor Gavron

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Avigdor Gavron

U.S. Department of State & Los Alamos National Laboratory

On behalf of those who actually did the work...
The Non-Proliferation Treaty (NPT)

Fundamental treaty that is supposed to prevent nuclear proliferation

- IAEA responsible for safeguards monitoring of signatories

- Problems:
  - North Korea, Iran, (Libya, South Africa, Iraq)

- Non-Participants:
  - India, Israel, Pakistan
IAEA Additional Protocol

- Provide declarations concerning all nuclear related activities and report all trade in items on the Nuclear Suppliers Group trigger list.
- The IAEA can access "on short notice" all locations it wishes to inspect.
- There will be a streamlined process for visas for inspectors, that will be valid for multiple entries for one year.
- The IAEA can use environmental sampling techniques throughout its activities.
CTBT - Seismic Monitoring Stations
CTBT - Remote Sensing from Space

- Large area coverage
- Repetitive coverage
- Worldwide coverage
- Use new parts of the EM spectrum
- Use several parts of the spectrum simultaneously
- Use advanced computerized data processing
Example of Satellite Coverage and Mapping

Quasi-natural color view of the 48 continental U.S landmass (Courtesy Earthsat Corp, Rockville, MD) Notice the regionally variable distribution of vegetative cover (green).
Use of NASA Remote Sensing

- Agriculture, forestry and range resources
- Land use and mapping
- Geology
- Water resources
- Oceanography and Marine resources
- Environment
Satellite Monitoring – Material Identification

Multispectral color composite of three bands in the 8-10 µm range. The area shown is the Saline Valley of eastern California (near Death Valley); most of the colors in this image can be related to rock types (silicates, carbonates, etc.).
HS Leap Forward: the upper spectrum - a spectral signature of a specific substance made with the 4 MSS bands on Landsat; the lower the hyperspectral equivalent signature:
The influence of iron is evident in this next spectral plot, through parts of the Visible-Near-IR and Short-Wave-IR ranges of two pyroxenes. Diopside (CaMgSi2O6) contains almost no iron. Bronzite ([Mg,Fe]SiO3) has Fe but no Ca. The presence of Fe2+ causes two absorption bands, near 1 and 2 µm, to deepen and shift notably towards lower wavelengths.
GENIE identifies the smoke plume and the chemical signature of the dispersed dust in the debris field across Manhattan after 9/11.
Verification and Transparency

The Problem:

Making sure ("verification") or providing some degree of confidence ("transparency") that the object being dismantled is a warhead without disclosing classified information!
Secret "Restricted Data"

- Gamma spectra and intensity
- Neutron spectra and intensity
- Pit shape, size, mass, position in warhead

❖ Russian classification – Isotopic composition of Pu
Examples of "Issues"

- Mutually supervised warhead dismantlement (START III)
- Uranium down-blending
- MOX disposition of weapons-grade Pu
- Fissile Materials Cutoff Treaty
Suggestion Sample

- Fission Product Tagging
  - Induce $10^{12}$ fissions
  - Up to a day or two, fission gamma spectrum will dominate

- Problem
  - Setting up intense neutron source, or using high-energy proton beam
Information Barrier

Attributes Of Material in a Classified Form

- Heat/relative temperature
- Fissile Mass (above a threshold value)
- Gross container mass
- Multiplication
- Not another radiation source (Cf, Am...)
- Presence of plutonium
- Radioactivity
- Weapons-grade plutonium
Protecting Sensitive Information

- Radiation Detectors and Electronics
- "Information Barrier"
- Unclassified Interface
- Yes
- No

Sensitive Information
Non-Sensitive Information
Information Barriers: A Defense-in-Depth Approach

- Physical protection, *by the inspected party*, of instruments/computers containing sensitive information.

- Physical tamper indication, *applied by the inspectorate*, to ensure instruments/computers have not been altered.

- Data and software protection to ensure that sensitive data are not revealed to the inspectorate and to ensure that analysis software has not been altered.

- Unclassified Interface ("Yes / No")
Summary of Attributes Approach

● Multiple unclassified attributes can be declared and verified to provide confidence in a declaration while protecting sensitive information.

● Attributes can be measured or monitored to provide continuity of knowledge of the inventory in a non-intrusive (unclassified) manner.

● Both the attribute verification approach and the example technologies presented require extensive testing and evaluation.
Multiplicity Fingerprint System

The Problem:
- Measurement of the gamma ray flux or of the neutron flux from a pit is classified
- Can one use radiation measurements to provide certainty that object is "pit" of type X, without divulging classified information?

The Answer:
- Maybe, if the n and γ information is scrambled together
Multiplicity Fingerprint System

- Intentionally scrambles $n$ and $\gamma$ signal
- Technique is applicable to both plutonium and uranium components
- Develop fast multiplicity system, piggybacking on fingerprint system
- Prototype detector has been built and successfully tested at Los Alamos

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BC454 - B Loaded Plastic Scintillator

\[ n + ^{10}\text{B} \rightarrow ^{7}\text{Li} + \alpha + \gamma \]
\[ n + ^{1}\text{H} \rightarrow n + ^{1}\text{H} \]

478 KeV \(\gamma\)

93 KeV
Multiplicity Fingerprint System

- Array of boron-loaded plastic scintillators (BC454) optically coupled to BGO that detects neutrons and gamma rays simultaneously.
- System is sensitive to the parameter of primary interest => fissile material.
Combined neutron and gamma-ray response of the detector array is converted into a generic logic pulse train and input into a multiplicity shift register for time correlation analysis.
Generic Multiplicity Fingerprint Results

GENERIC MULTIPLICITY FINGERPRINT RESULTS

- Components
- Metal
- PuO2 + HEU
- Impure PuO2
- Pure PuO2
- Alpha, n
- Gamma Ray
- Cf-252
Summary

- Science can play a major role in the verification of international treaties.
- Although there have been problems associated with treaty verification using current technology, we should accept this as a challenge to invent and implement improved and more robust technologies.