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# The Role of Science in Treaty Verification

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**Los Alamos National Laboratory**

On behalf of those who actually did the work…

# The Non-Proliferation Treaty (NPT)

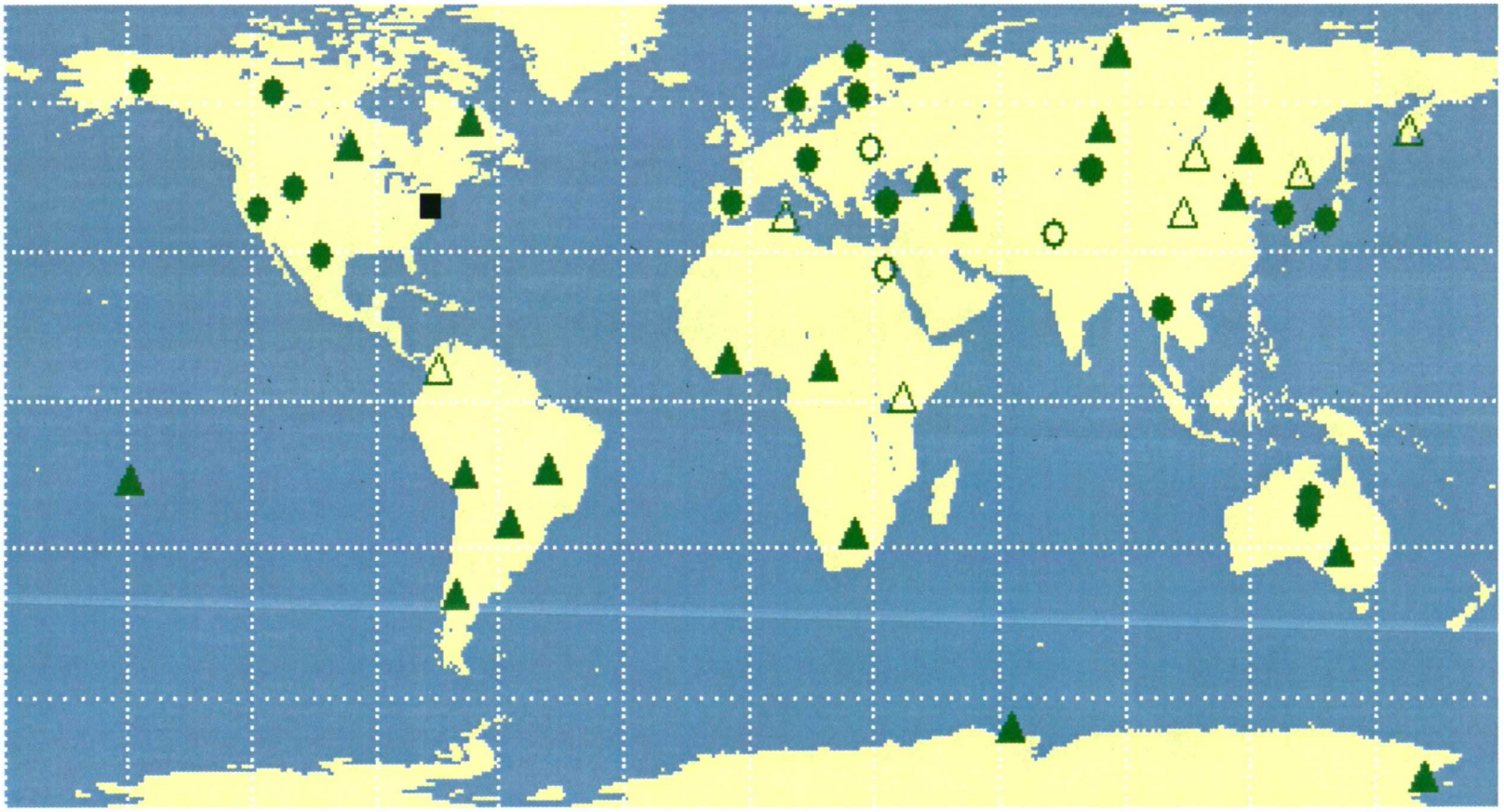
Fundamental treaty that is supposed to prevent nuclear proliferation

- IAEA responsible for safeguards monitoring of signatories
- Problems:
  - North Korea, Iran, (Libya, South Africa, Iraq)
- Non-Participants:
  - India, Israel, Pakistan

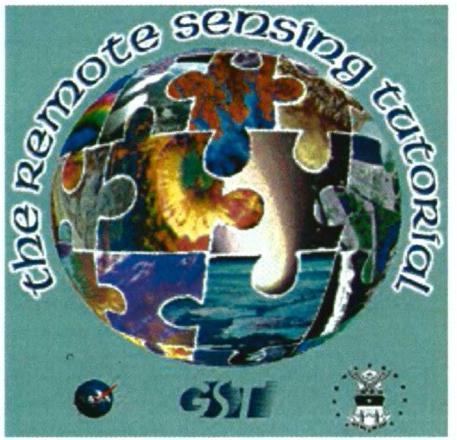
# IAEA Additional Protocol

- 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

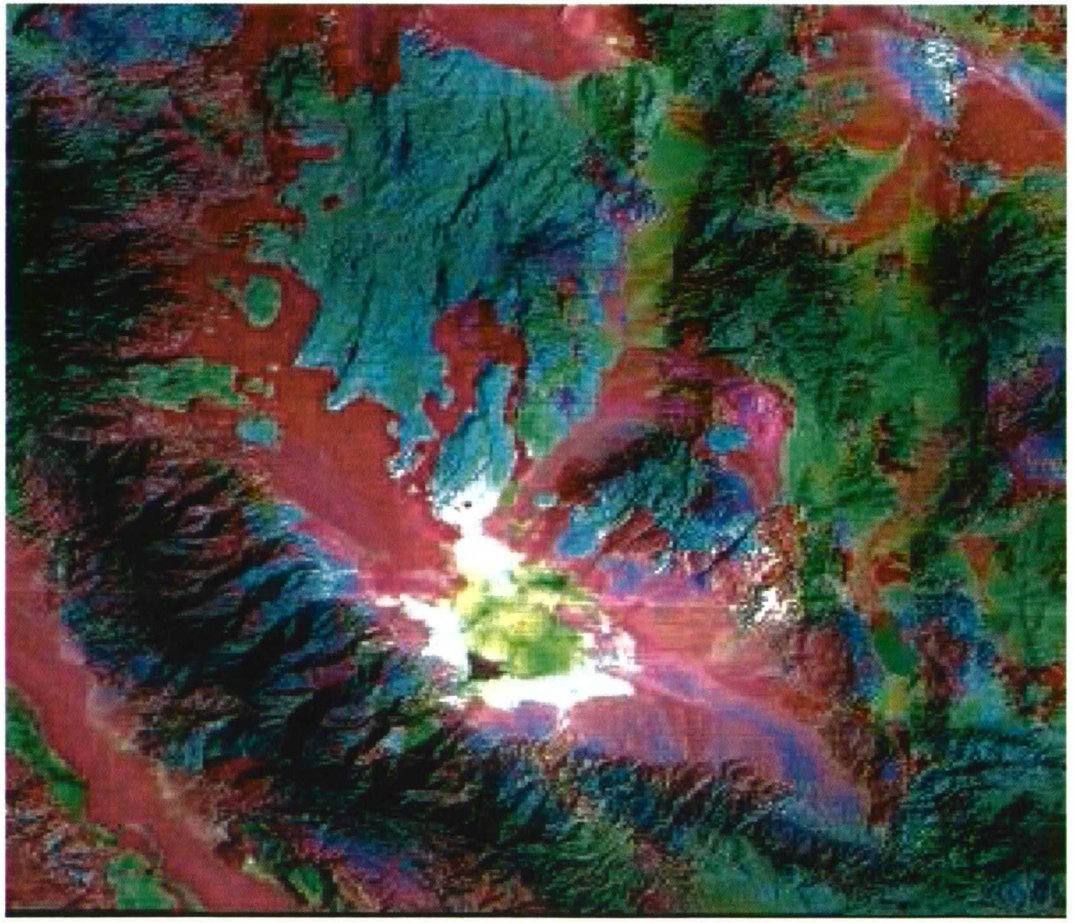
Quasi-natural color view of the 48 continental U.S landmass (Courtesy Earthsat Corp, Rockville, MD) Notice the regionally variable distribution of vegetative cover (green).

# Use of NASA Remote Sensing

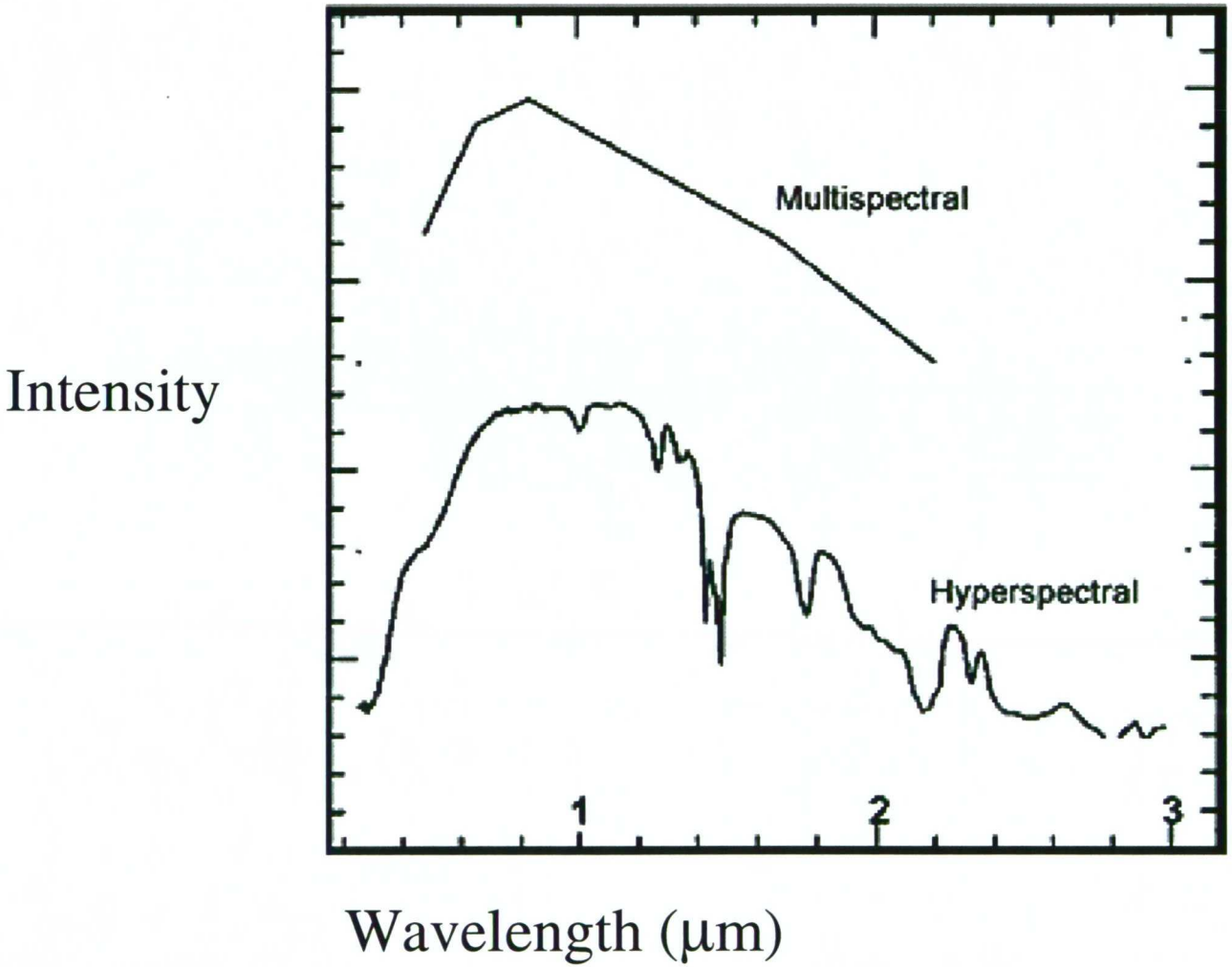
- Agriculture, forestry and range resources
- Land use and mapping
- Geology
- Water resources
- Oceanography and Marine resources
- Environment

# Satellite Monitoring – Material Identification

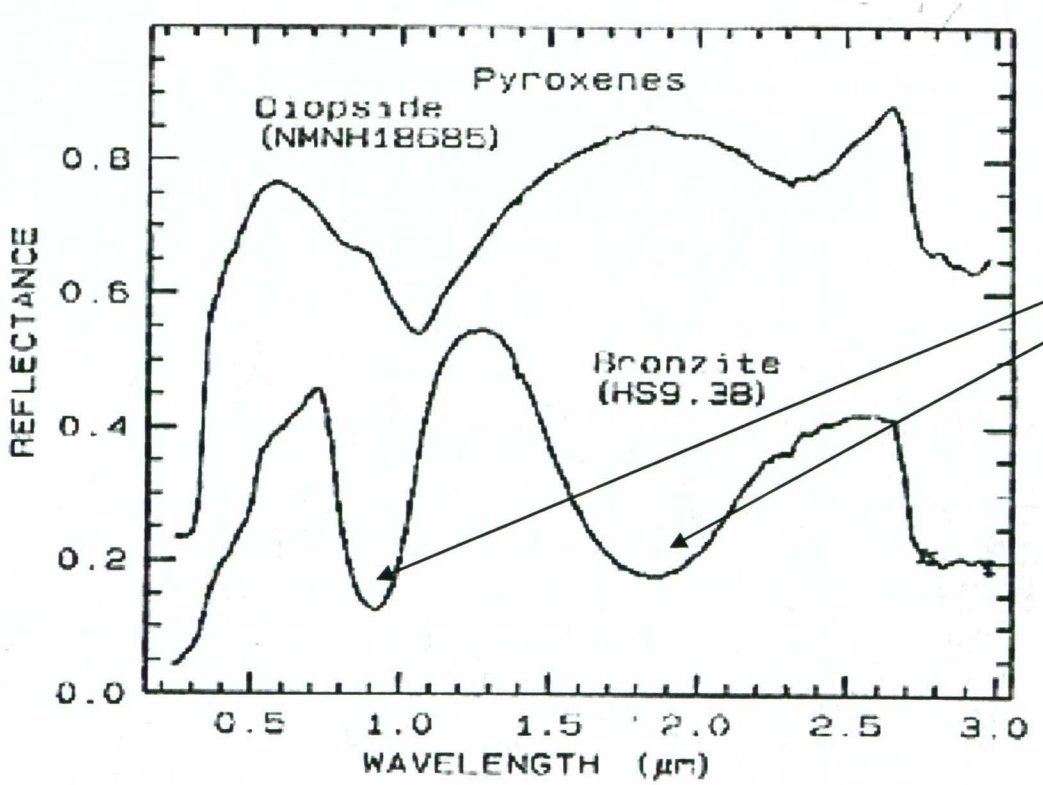
Multispectral color composite of three bands in the 8-10 $\mu$m range. The area shown is the Saline Valley of eastern California (near Death Valley); most of the colors in this image can be related to rock types (silicates, carbonates, etc.).



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 ($CaMgSi_2O_6$) contains almost no iron. Bronzite ($[Mg,Fe]SiO_3$) has Fe but no Ca. The presence of $Fe^{2+}$ causes two absorption bands, near 1 and 2 $\mu$m , to deepen and shift notably towards lower wavelengths.




Effect of Fe

# GENIE

GENIE identifies the smoke plume and the chemical signature of the dispersed dust in the debris field across Manhattan after 9/11.

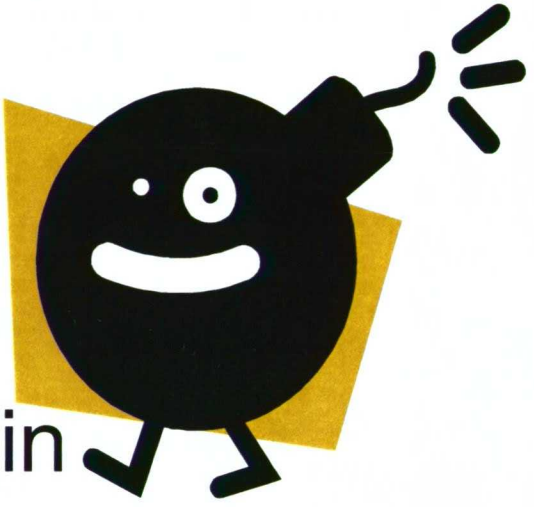
# Verification and Transparency

- 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 (STARTIII)
- Uranium down-blending
- MOX disposition of weapons-grade Pu
- Fissile Materials Cutoff Treaty

# Suggestion Sample

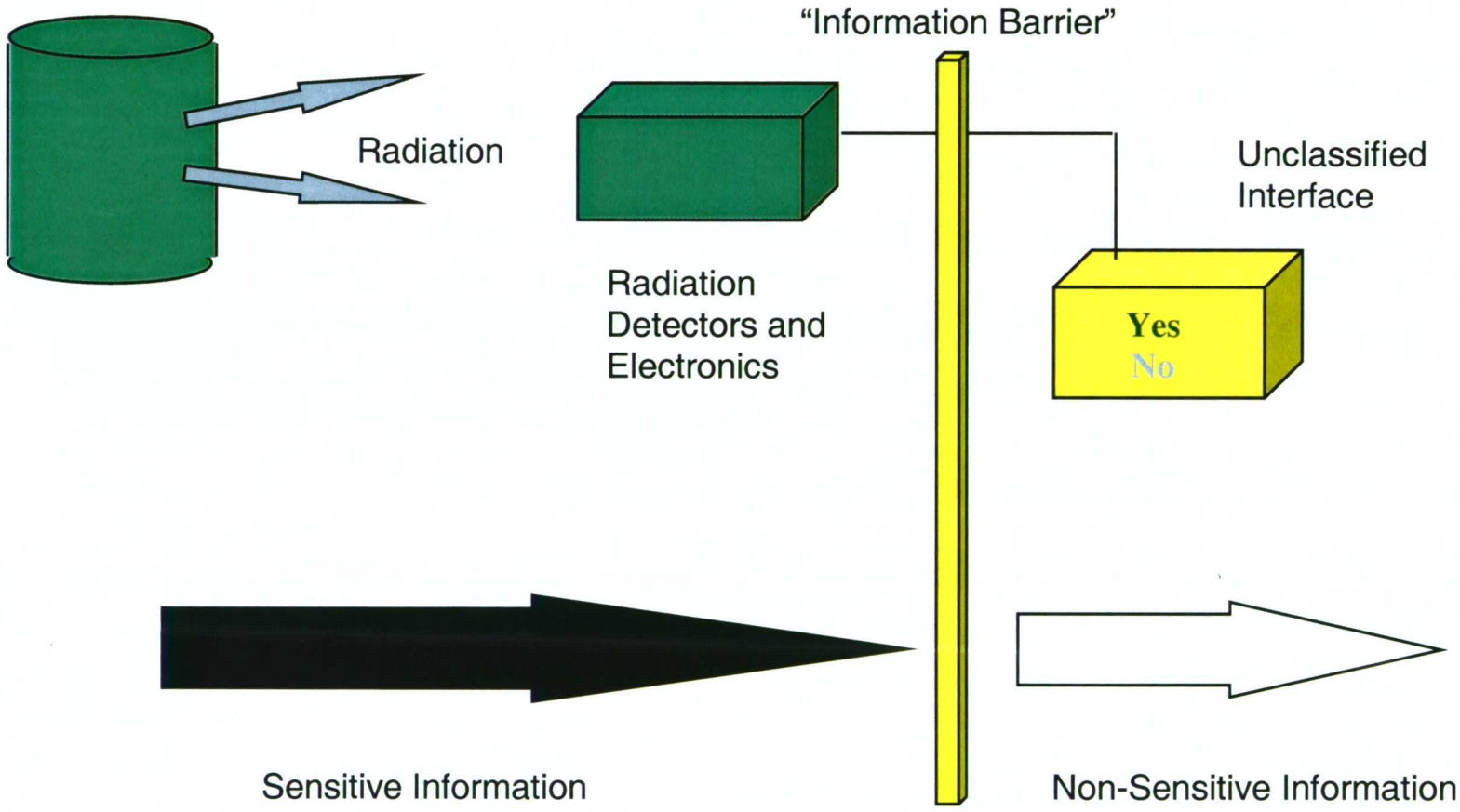
- Fission Product Tagging
  - Induce $10^{12}$ fissions
  - Up to a day or two, fission gamma spectrum will dominate
- Problem
  - Setting up intense neutron source, or using high-energy proton beam

# 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



# 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 $\gamma$ information is scrambled together

# Multiplicity Fingerprint System

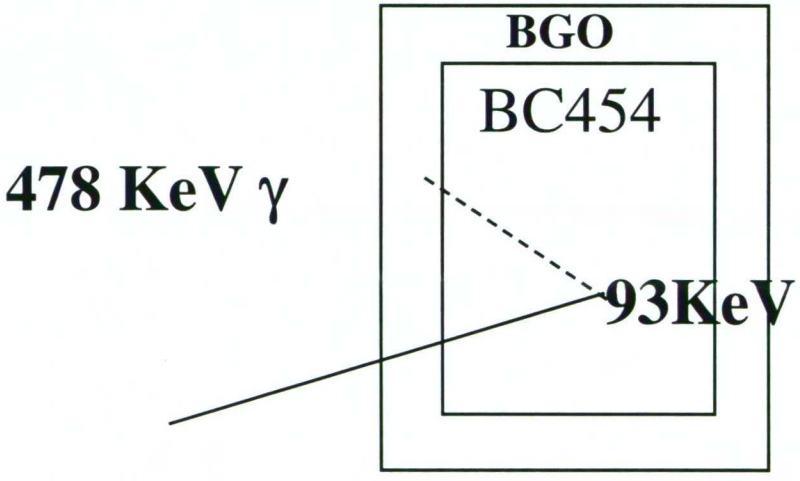
- Intentionally scrambles *n* and γ signal
- Technique is applicable to both plutonium and uranium components
- Develop fast multiplicity system, piggybacking on fingerprint system
- Prototype detector has been built and successfully tested at Los Alamos

**Work supported by DOE NN-20, Office of Research and Development**

# BC454 - B Loaded Plastic Scintillator

$n + {}^{10}B \rightarrow {}^{7}Li + \alpha + \gamma$

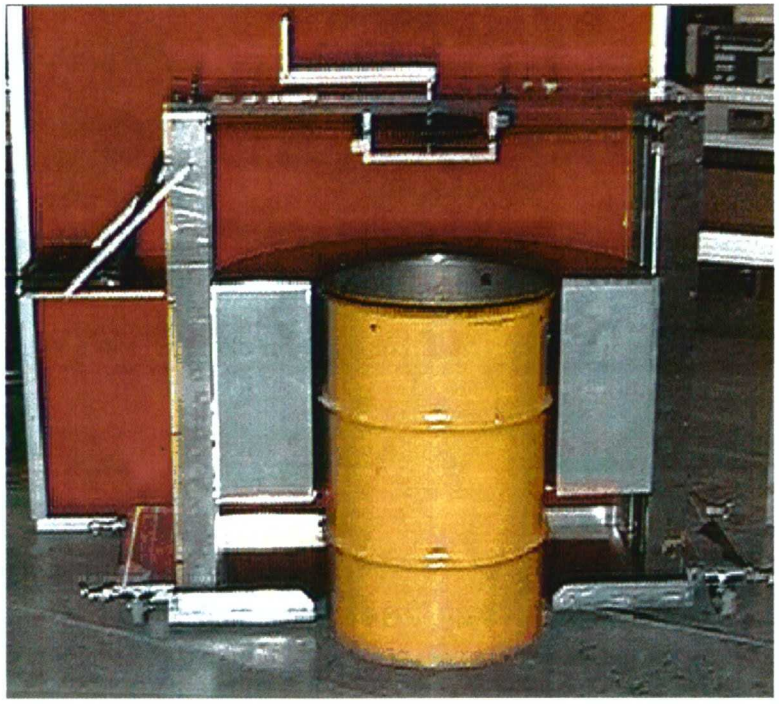
$n + {}^{1}H \rightarrow n + {}^{1}H$

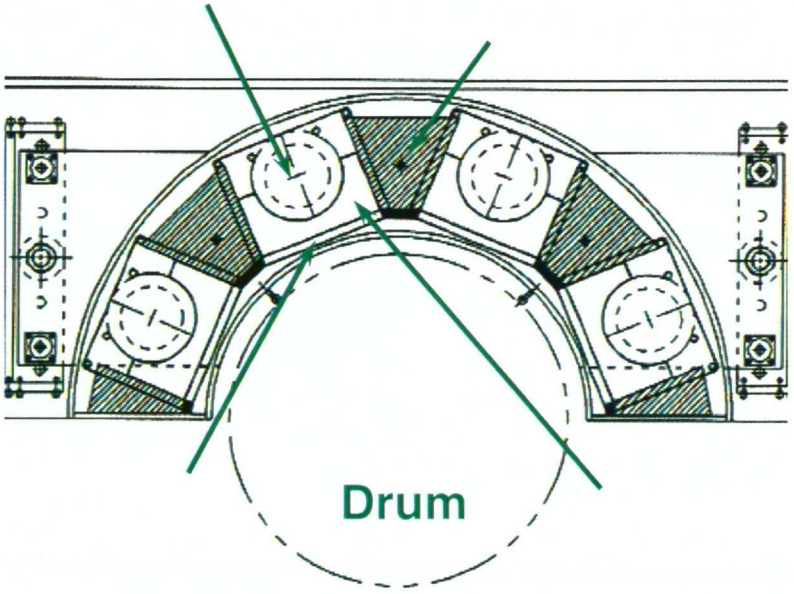


# Multiplicity Fingerprint System

- 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

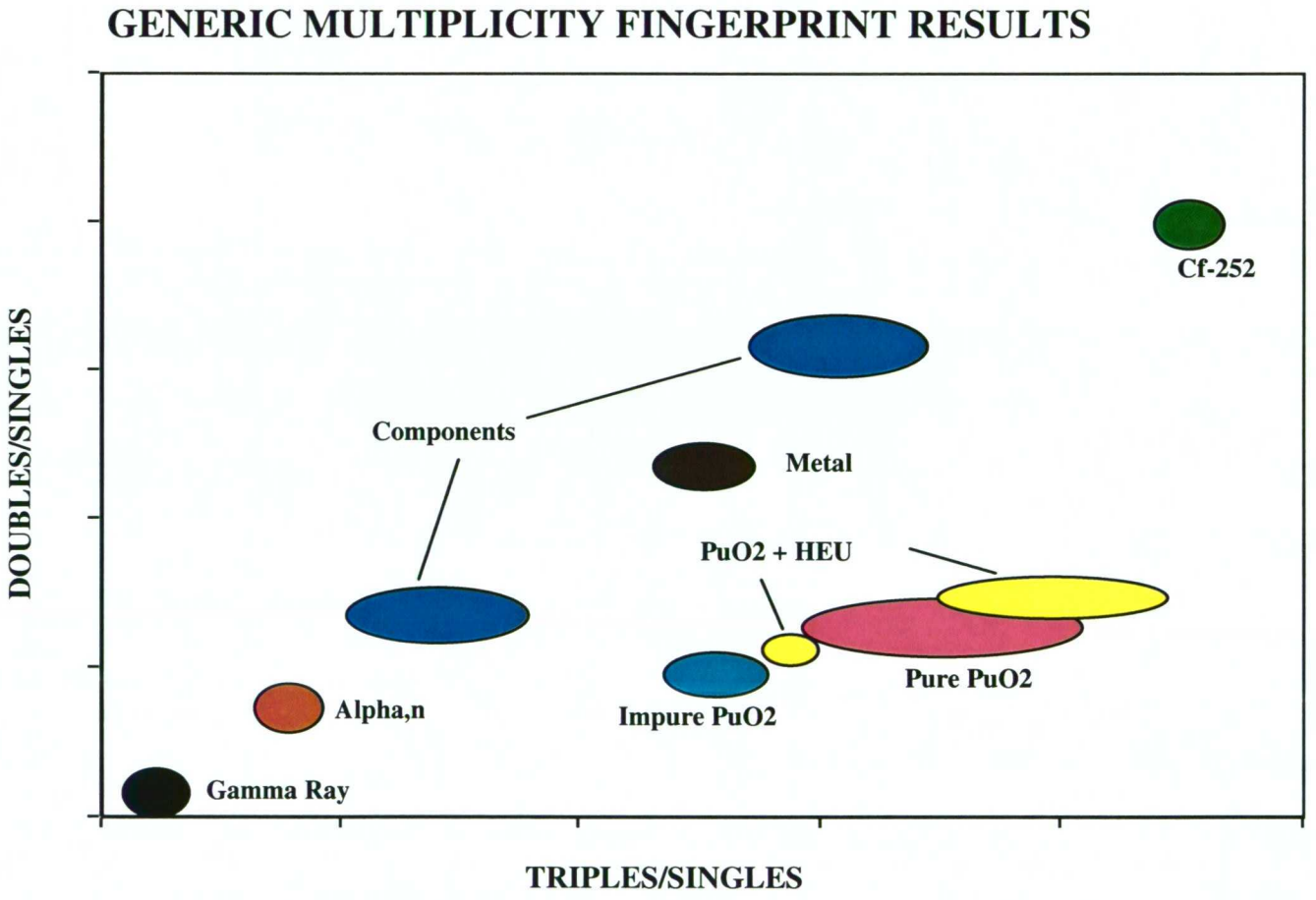
# Multiplicity Fingerprint System






**<u>Combined</u> 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



# 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