

Real-Time Radionuclide Identification In Dynamic Urban Environments



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Presented to the FLC TT
September 2007

Outline

- ◆ Why do this ?
- ◆ The Post-9/11 Challenge: “How do you find a certain needle in a very large and noisy haystack”.
- ◆ Miniature Integrated Nuclear Detection System (MINDS) concept.
- ◆ MINDS Description and Function.
- ◆ MINDS Configuration.
- ◆ Peak-fitting and Support-Vector algorithms for hyper-accurate detection of weak and embedded spectra.
- ◆ Real time analysis of background conditions.
- ◆ Unaccounted Radioactive Materials.
- ◆ MINDS demonstration video.

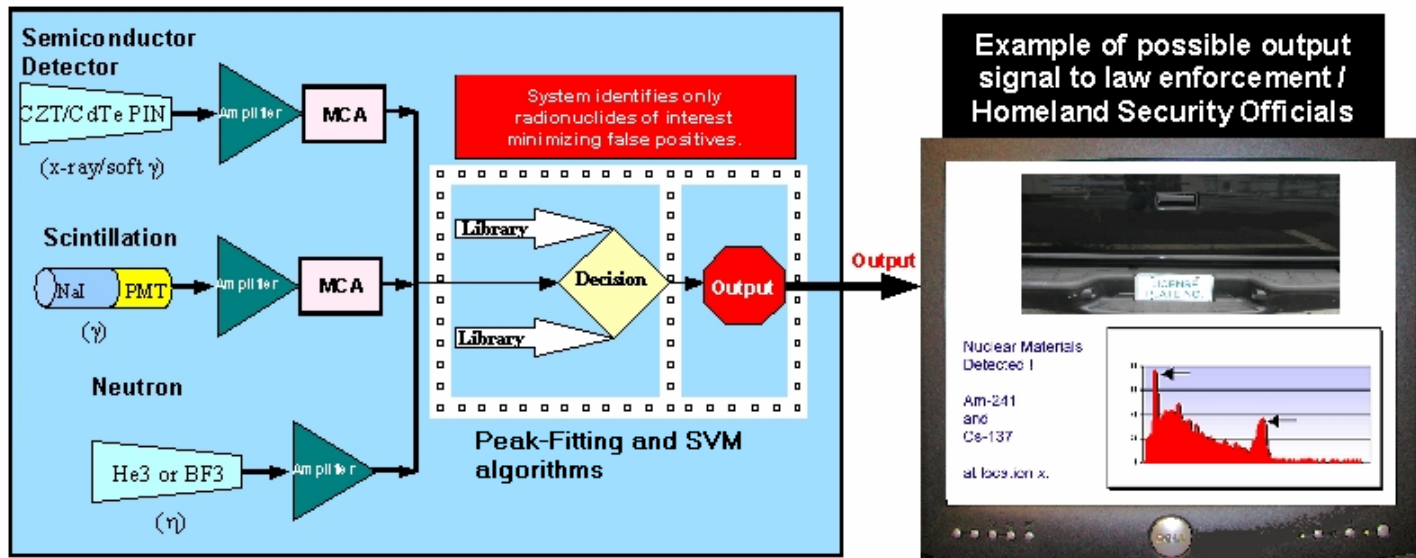
The MINDS Concept

- ◆ Rapidly differentiate radionuclides in transit (in seconds).
- ◆ Commercial Off The Shelf (COTS) hardware (keep it inexpensive) uniquely configured linked to peak fitting and artificial intelligence (A.I.) software.
- ◆ Hyper-accurate radionuclide identification.
- ◆ Several hundred radionuclide shipments a month on Northeast Corridor roads for authorized use (medical / Industrial).
- ◆ >120,000 people in USA “walking around” undergoing medical isotope treatment. (Ref: Physics Today, Nov. 2004).
- ◆ Low maintenance, highly robust available components, low energy consumption.

MINDS Description and Function

- ◆ Integrated multiple detector system for rapid real-time detection of gamma and neutron-emitting radionuclides.
- ◆ COTS components used as much as possible for detection heads, including NaI(Tl), He-3 detectors.
- ◆ Software algorithms written in C++.
- ◆ System interfaces with a variety of CPU types (laptops, desktops, servers).
- ◆ System configured for USB or multiple Ethernet connections.
- ◆ LLD for gamma-emitting radionuclides ~ 10 micro rem/hr for one second dwell time at the face of the detector.
- ◆ HLD conforms to ANSI N42.38 (10 milli rem/hr).
- ◆ Can be used to detect unauthorized transport of specific nuclear materials with features to filter out medical isotopes for reduction of false positives.

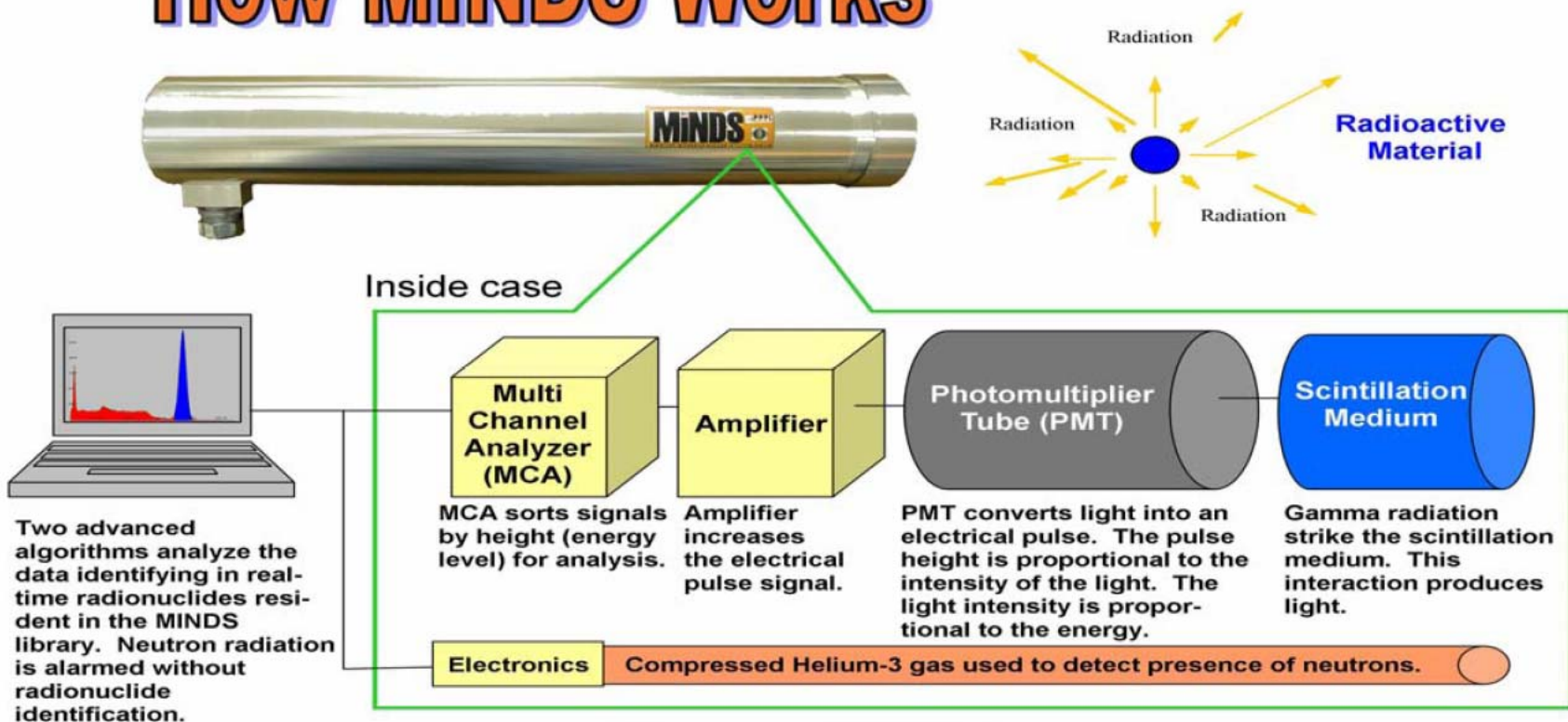
MINDS Configuration



- System is tailored to user's requirements.
- System conforms to applicable ANSI standards for physical capabilities (N42.38).
- In full configuration, three detector heads are employed for identification/detection of gamma-emitting radionuclides and neutron emitters.

MINDS Configuration

How MINDS Works



MINDS Automatic Radionuclide Identification Software

- ◆ Software automatically analyzes the gamma-ray spectrum at the end of the measurement interval (0.5s/1s/2s/5s,...).
- ◆ Radionuclides found are displayed on monitor, distinguishing threat materials from non-threat materials (i.e., Cs137 from Tc99m).
- ◆ Current library includes Am-241, Ba-133, Ce-139, Cf-252, Co-57, Co-60, Cs-137, DU, Ga-67, I-131, Ir-192, K-40, Np-237, Ra-226, Tc-99m, Th-232, Tl-201, Po-210.
- ◆ Identifies multiple radionuclides in parallel, in any combination.
- ◆ A **Dual-Algorithm** approach for a new level of accuracy.

MINDS Radionuclide Identification (Algorithm I)

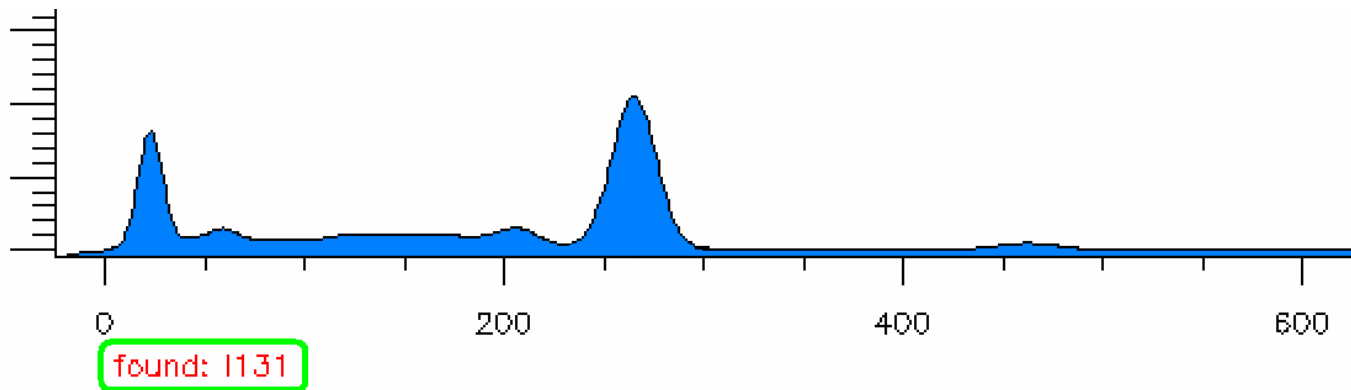
- ◆ **Peak-fitting - “Identifying the nuclear finger print”.**
- ◆ The “classical approach” to automated spectroscopy.
- ◆ Each radionuclide has characteristic peaks in the gamma-ray spectrum.
- ◆ Software performs curve-fitting to match up known peaks.
- ◆ Similar to the method the human eye employs in analyzing spectra.
- ◆ Quite reliable for radionuclides with distinct peaks (in low-noise environments) and for “clean” high resolution spectra.

Practical Limitations of Peak-fitting algorithms

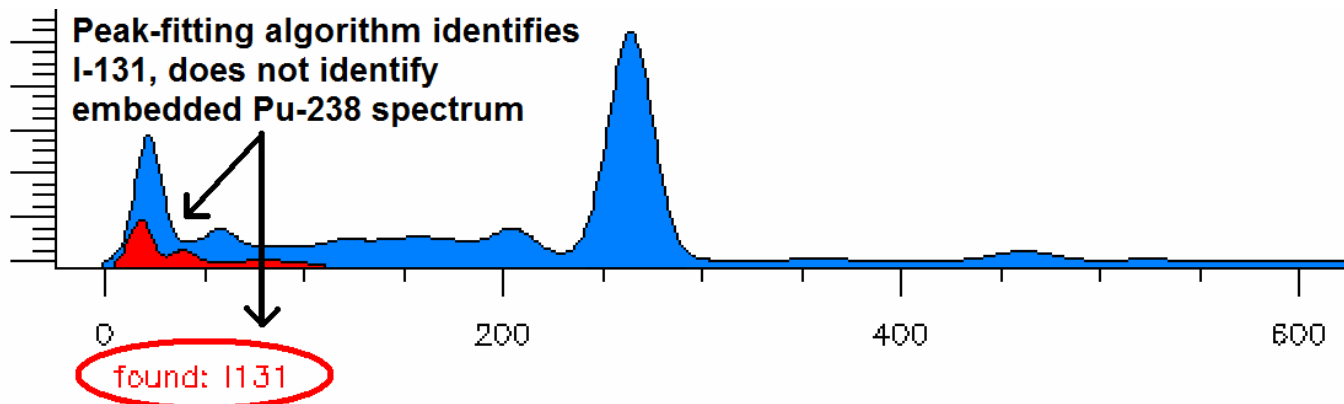
- ◆ Some Radionuclides have peaks in the same region or closely overlapping (peak masking).
- ◆ Some issues associated with Compton Scattering (for gamma ray energies of 0.5 MeV to 1.5 MeV) within the scintillating material.
- ◆ Peak masking may be exploited to disguise threat materials by obscuring them with legitimate sources of radiation (i.e., medical isotopes, naturally occurring radionuclides).

Example of Peak Masking

Iodine-131: Common medical isotope...



Could be used to mask Plutonium-238.

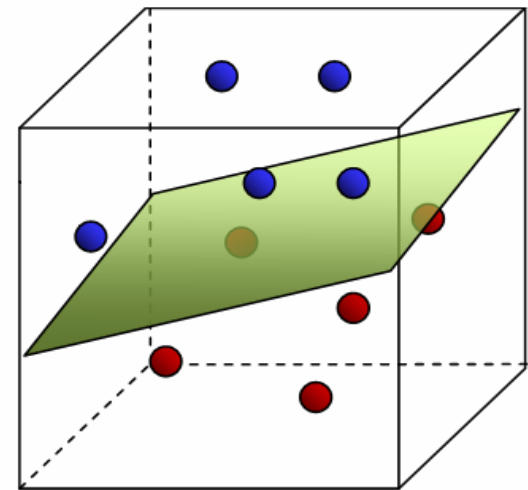


MINDS Radionuclide Identification (Algorithm II)

- ◆ **Support-Vector Machines (SVMs)**
- ◆ State-of-the art machine learning (A.I., pattern-matching) algorithm.
- ◆ **Trained** with thousands of real-world spectra.
- ◆ After models are trained, identification algorithms evaluate spectra in a fraction of a second.

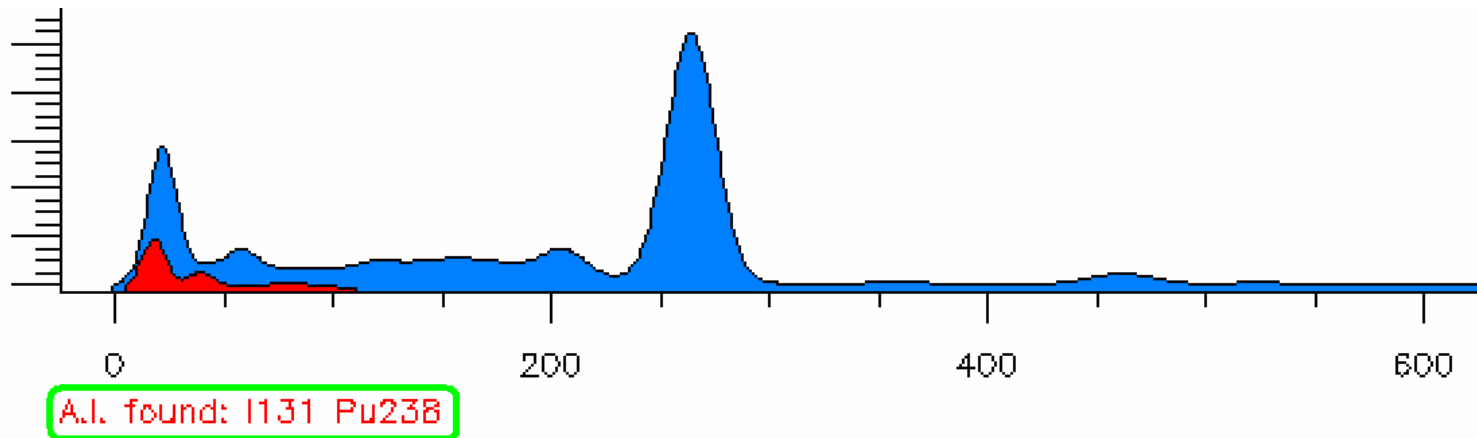
Support Vector Machine Algorithms

- ◆ A geometric framework: SVMs view each spectrum as a point in a high-dimensional feature space.
- ◆ Search for the separating hyperplane that produces the largest “margin” between the positive and negative training examples.
- ◆ This produces the weighted sum of global features which **most reliably distinguishes** between spectra
- ◆ Train one SVM for each radionuclide, with a range of data in various combinations.



Feature Space

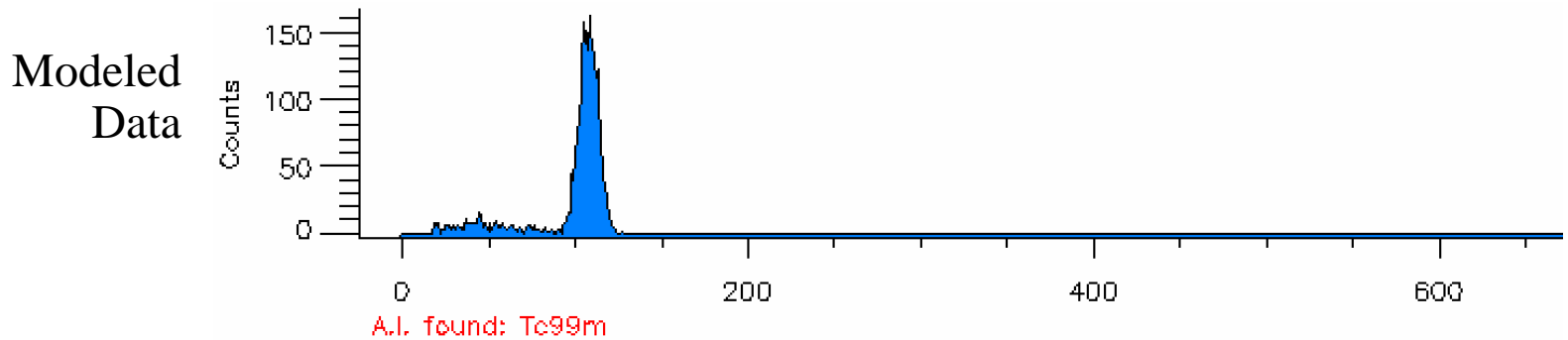
Masked Peaks FOUND with SVM Algorithm



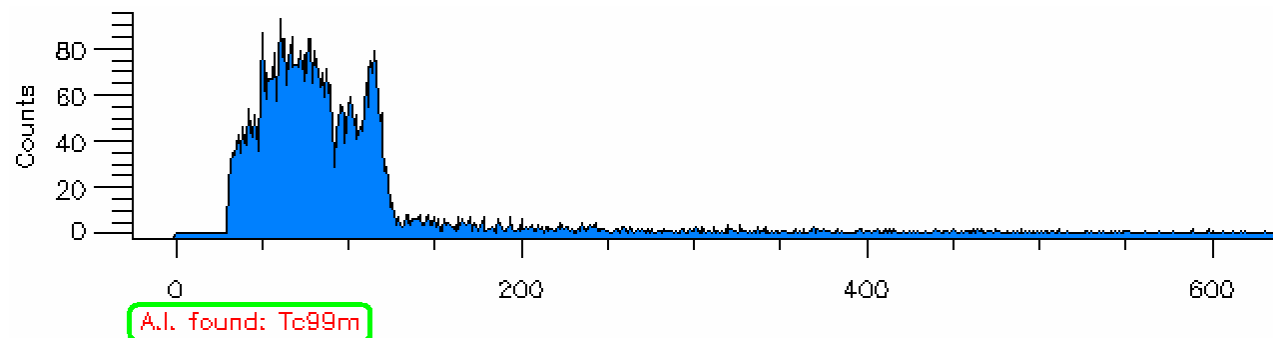
- ◆ Support Vector Machine distinguishes correctly through training to differentiate by means of variations in spectra not obvious to the human eye (and in most cases unable to be resolved by peak-fitting algorithms.)

Common “Noisy” Medical Isotopes Correctly Identified

- ◆ Technetium-99m: Used in medical procedures



Empirical Data
(scattering
occurs in
real life)

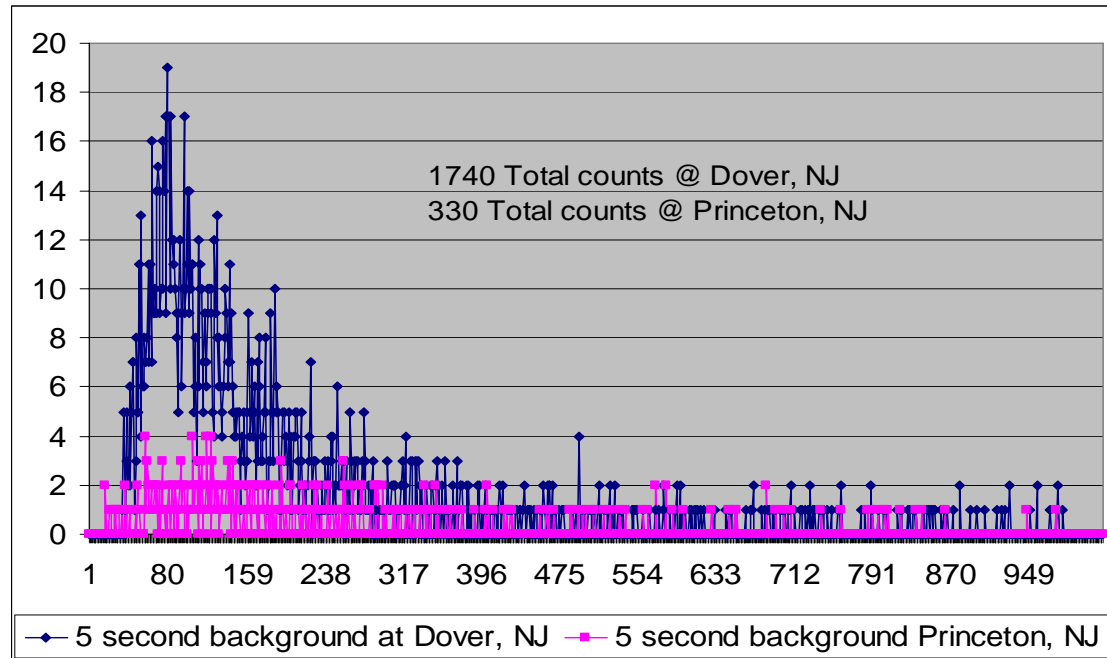


- ◆ Significant reduction of false positives

MINDS Synthesis of the Two Identification Algorithms Running in Tandem

- ◆ Results of peak-fitting and SVM algorithms are compared.
- ◆ Each algorithm performs optimally in different scenarios.
- ◆ In the case of disagreement, hand-tuned heuristic logic determines the most likely scenario.
- ◆ **RESULT:** Hyper-accurate real-time radiological threat assessment.
- ◆ **RESULT:** Fully exploits the capabilities of NaI(Tl)-based detection; more expensive scintillating materials or semiconductor materials not necessarily needed for this application.

Real-Time Analysis of Background Conditions



- ◆ Algorithms analyze real-time background to locate acute shifts either up or down for cps. This also helps in alerting for radionuclides that may not be in the library.

Unaccounted-for Radioactive Materials

WAR ON TERROR

'NUKES' MISSING



'Dirty bombs' lost in ex-Soviet region

CHISINAU, Moldova — Dozens of rockets outfitted with so-called "dirty bombs" are missing in a breakaway region of the former Soviet republic of Moldova, an expert said yesterday.

Oanu Nantoi, a political analyst at the nongovernmental Institute for Policy Studies in Chisinau, said he had seen photographs of Russian military documents that revealed at least 38 dirty-bomb warheads had disappeared from a storage depot near the Trans-Dniester Tiraspol military airport.

Dirty bombs do not make a nuclear explosion, but include radioactive material that is dispersed by the bomb's explosion.

The warheads were designed to be carried on a small, thin rocket, known as the Alazan, which was originally created to destroy hill clouds.

But the military records show that the warheads were packed with radioactive material — making them the world's first surface-to-surface dirty-bomb weapons.

Fourteen of the warheads were dismantled according to the records — but the other 24 were ready to use.

Alazans are unlike other dirty bombs because they come with their own delivery system and could hit a target within eight miles, unaided, he said.

Nantoi said the documents came from a disgruntled Russian military official who claimed he had not received compensation for being exposed to radioactive material.

Nantoi is a respected expert on the region of Trans-Dniester, a separatist enclave populated by ethnic Slavs that broke away from Moldova 12 years ago as the Soviet Union was collapsing.

Since the Soviet army pulled out of the area, Trans-Dniester has attracted the world's black-market arms dealers.

Al Qaeda and other terrorist groups have tried to acquire a dirty bomb, but investigators said it was unknown how successful they were.

The Washington Post reported Sunday that the Alazan warheads were left in a huge arsenal, along with 50,000 tons of old artillery shells, mines and rockets.

But now the warheads are missing — and "I could not discover what had happened to them," Nantoi said yesterday.

"We tried to work with Moldovan officials, but there wasn't a clear investigation, because the territory is not controlled by Moldova," he said.

Moldova's government declined comment yesterday, while an official of the Trans-Dniester Defense Ministry in Tiraspol called the claims "propaganda."

The Organization for Security and Cooperation in Europe said it was investigating the missing Alazans but did not give details.

The possibility of terrorists acquiring dirty bombs is a main concern of the International Atomic Energy Agency in Vienna, Austria.

IAEA Director-General Mohamed ElBaradei said last week that his agency, which tries to cap the spread of nuclear weapons, is now "pending a great deal of time working on this threat."

Post Wire Services

17
New York Post, Tuesday, December 9, 2003
nypost.com

New York Post
November 11, 2003

WAR ON TERROR

'Dirty-bomb alarm over lost nuke gear

WASHINGTON — Sealed radioactive material has been lost, stolen or misplaced more than 1,300 times in the United States over the last five years — and federal investigators concluded terrorists could cobble enough together to create a dirty bomb.

But closing the gaps in security could take years, the Energy Department's Los Alamos Laboratory and the General Accounting Office found.

The studies cited examples such as how a North Carolina hospital discovered in March 1998 that 19 sealed sources of radiological material, including the highly dispersible cesium-137, were missing from a locked safe.

They have not been found.

The congressional investigators found that many of the 114 universities that possess plutonium-239 were missing unsuccessfully to return it to the government.

The Energy Department doesn't have enough secure storage space, the investigators said.

The Los Alamos report concludes that the threat of a so-called dirty bomb that could disperse radiological materials across a wide area "appears to be very significant, and there is no shortage of radioactive materials that could be used."

Security improvements under way "are unlikely to significantly alter the global risk picture for a few years," it added.

Regulatory Commission spokeswoman Beth Hayden said the agency recognizes the potential dangers of such materials and al Qaeda's interest in them — "There are millions of sources," she said.

But the added most of the 1,300 lost radiological sources were subsequently recovered.

The Los Alamos analysis specifically cited concerns about the transportation of radioactive cobalt from industrial sites, as well as lax security at hospitals that use radiological devices to treat and diagnose patients.

The GAO detailed how terrorists could abuse the legal method for obtaining radiological sources because the NRC takes as long as a year to inspect facilities after it mails them a license for such materials.

"Because the process assumes that the applicant is acting in good faith and it can take the NRC as long as 12 months before conducting an inspection, it is possible that sealed sources can be obtained for malicious intent," the GAO told the Senate recently.

NRC Commissioner Edward McGuffigan Jr. said his agency has been taking steps for months to more securely ship and store high-risk sources.

"We honestly think we are doing a very aggressive and excellent job in this area, but we have obviously more to do," McGuffigan said in an interview.

He said the government was undertaking a first-ever inventory of who possesses radioactive materials and how much they possess.

Post Wire Services

Radioactive reaction



Los Alamos scientists are calling the threat of dirty bombs, which could affect large areas with radiological contaminants, very significant.

I am alarmed at the government's inadequate response to this very real threat.

—Rep. Jim Turner (left), D-Texas

Recent trouble-shooting, AP