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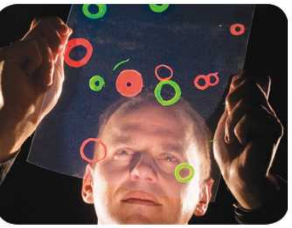

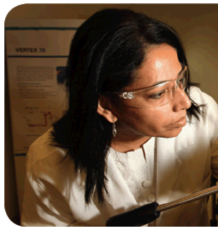

Nearest Neighbor Averaging and Its Effect on the Critical Level and Minimum Detectable Concentration for Scanning Radiological Survey Instruments for Performing Facility Release Surveys

- SAND???-

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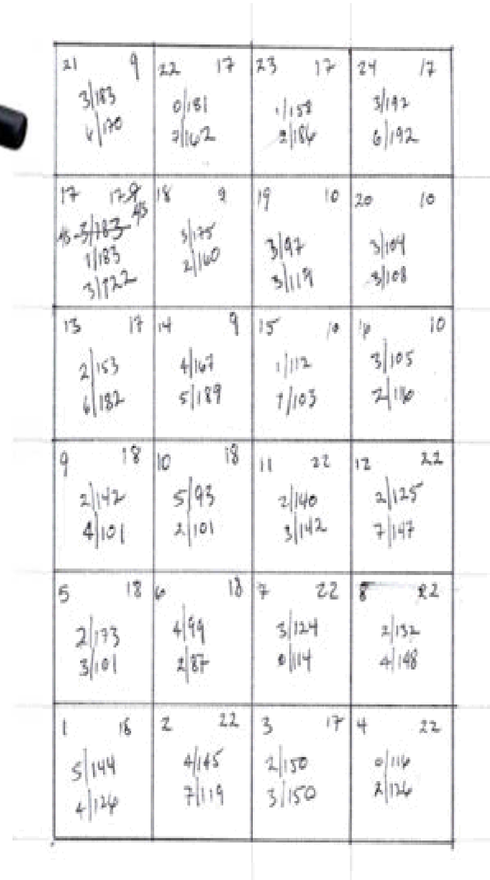
What's in it for ME? (WIFM)

Sandia National Laboratories recently worked via the SNL-New Mexico Small Business Assistance (NMSBA) program with the Environmental Restoration Group (ERG) Inc. to verify and validate a novel algorithm used to determine the scanning Critical Level (Lc) and Minimum Detectable Concentration (MDC) (or Minimum Detectable Areal Activity) for the ERG-102F scanning system. **This system employs a nearest-neighbor averaging (NNA) technique to improve the sensitivity of the instrument and reduce the variance of the data.** Through the use of Monte Carlo statistical simulations the algorithm mathematically demonstrates a reduction in the Critical Level and Minimum Detection Level when a nearest-neighbor averaging (NNA) technique was used that is proportional to the number of neighbors. The field tests also concluded that the NNA technique increases the sensitivity (decreases the Lc and MDC) for high-density data maps that are obtained by scanning radiological survey instruments. **This technique can be used to improve the cost efficiency and confidence with which Multi-Agency Radiation Survey Investigation and Release (MARSSIM)-type release surveys are conducted.**

Alpha/Beta Surface Surveys

Traditional Methods

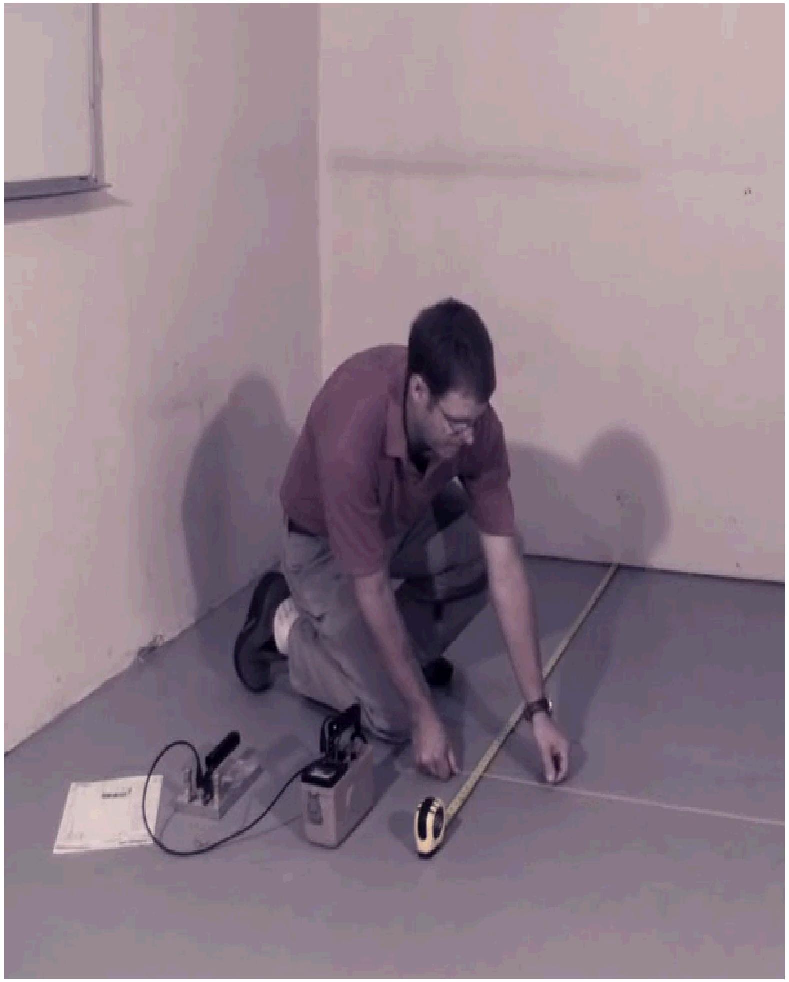
- Typically gas proportional or zinc sulfide/plastic scintillator detectors used to scan areas of interest.
- Results commonly recorded as an integrated count over some unit area.
- Detector size, type, and scanning process usually determined by release criteria, or minimum detectable concentration (MDC).



Alpha/Beta Surveys

Traditional Methods

- Short range of alpha and beta particles requires constant contact between detector and scanning surface.
- Indoor environment much more difficult to automate data collection due to lack of, or insufficient GPS signal for positioning.
- Detection capabilities are sensitive to scanning speed and decisive responsibilities of technicians.



Alpha/Beta Surveys - A New Approach

Combines high-accuracy indoor positioning with an advanced detection system for maximum survey efficiency and superior data quality.

- Eliminates most sources of error associated with traditional surveys.
- Yields very high survey efficiency from large area detector.
- No P-10! High-efficiency detector geometry provides similar detection efficiency to that of gas proportional.
- Complete automation of data collection significantly reduces processing time.

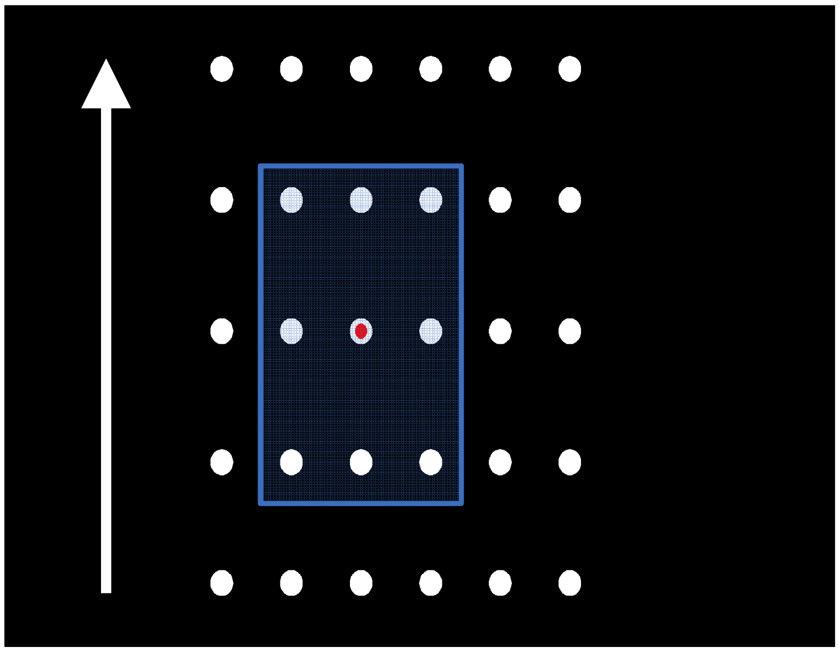
Alpha/Beta Surveys - A New Approach

Position-correlated data using scalers (rather than the traditional rate meters) allows one to apply statistics to the data. This allows one to do things like:

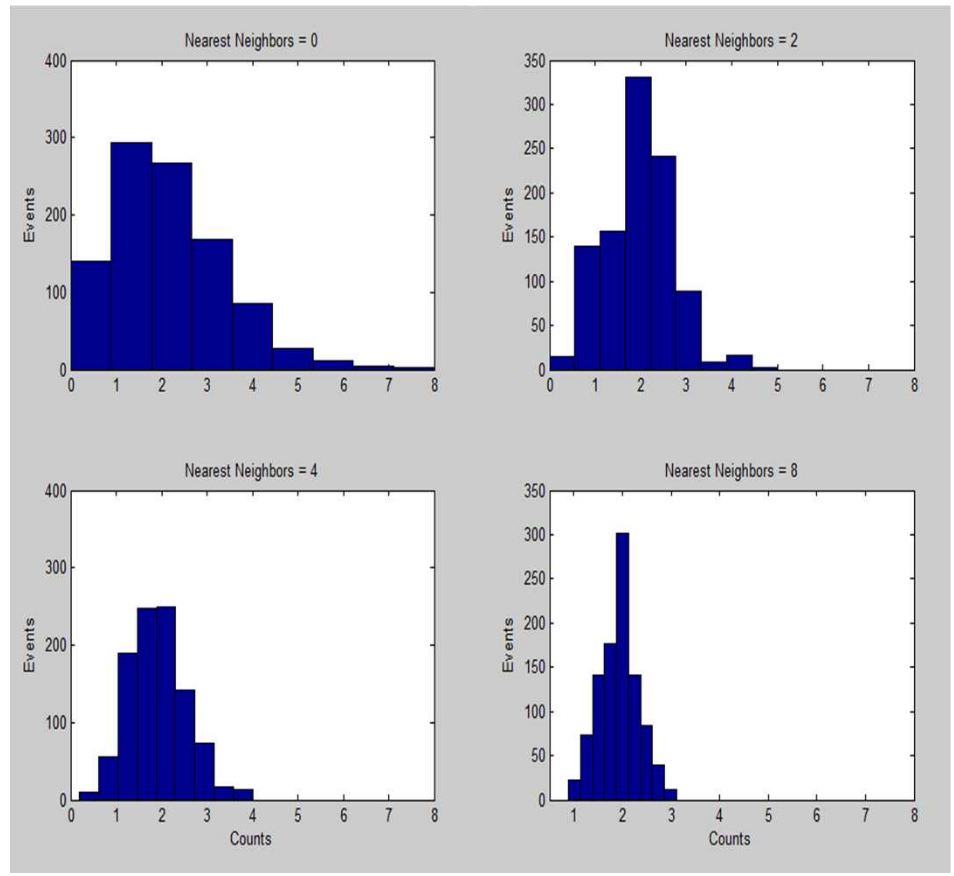
- establishing Lc levels based on acceptable false positive rates,
- accurately calculating MDC based on detector efficiency and local background rates,
- AND applying statistical methods such as NNA that reduce the variance of the data (thus reducing the false-positive rates and MDCs).

Alpha/Beta Surveys - **A New Approach**

Spatial Processing Allows Quantification of Detection Capability



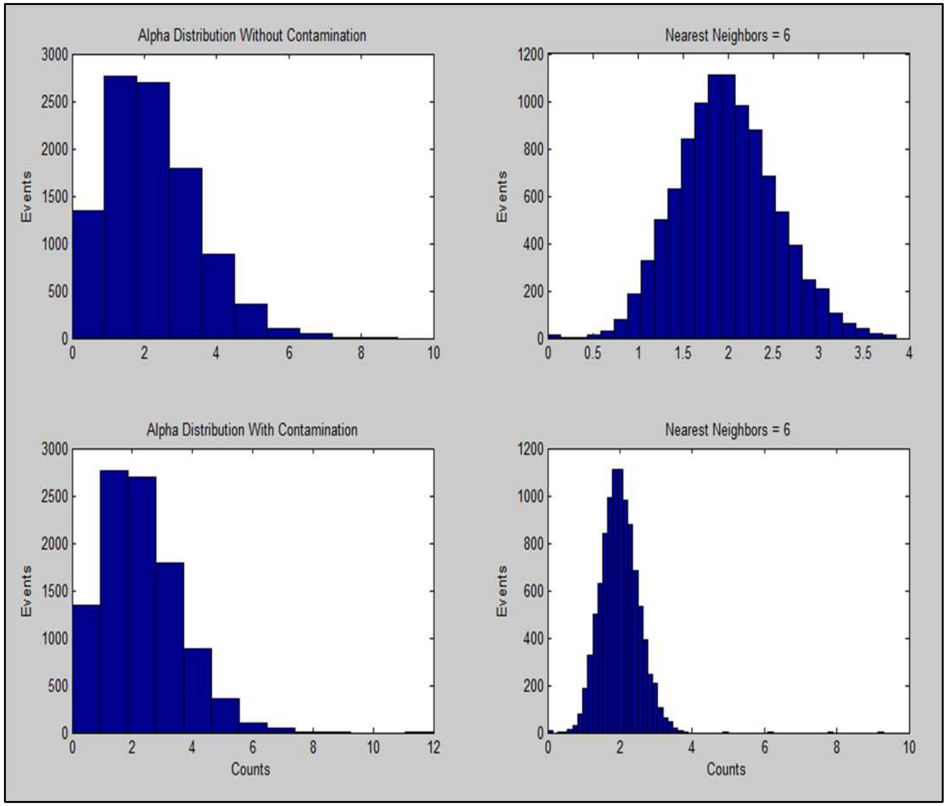
$$\mu_{\bar{x}} = \mu \qquad \sigma_{\bar{x}} = \frac{\vartheta}{\sqrt{n}}$$



Alpha/Beta Surveys **A New Approach**

$$MDC = \frac{2.71 + 3.29\sqrt{R_B t\,(N+1)}}{(N+1)\epsilon\, t\, k}$$

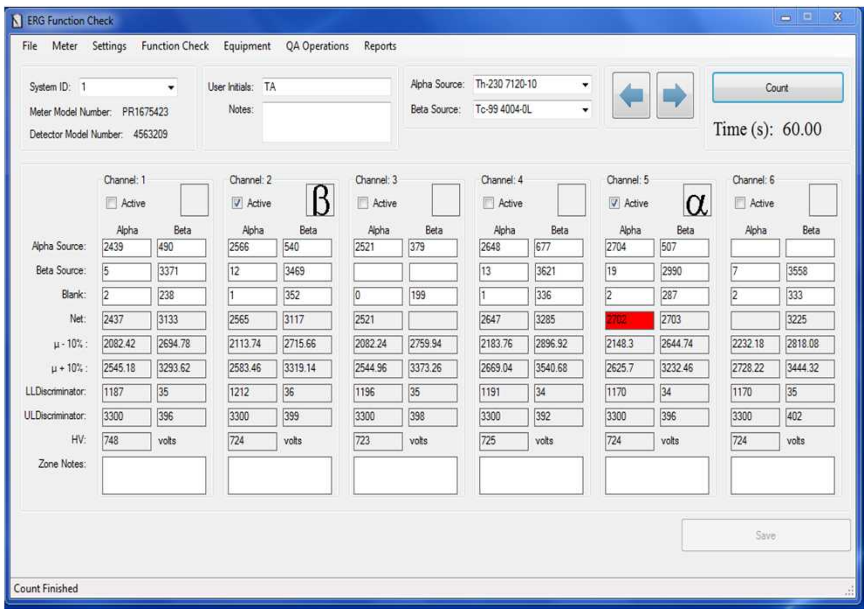
MDC = minimum detectable concentration in dpm/100 cm^2.
K = detector area factor (unitless) for conversion to 100 cm^2
ε = total detector efficiency in counts per disintegration.
t = counting time in minutes.
R_b = background count rate in cpm.
N = number of neighbors averaged.

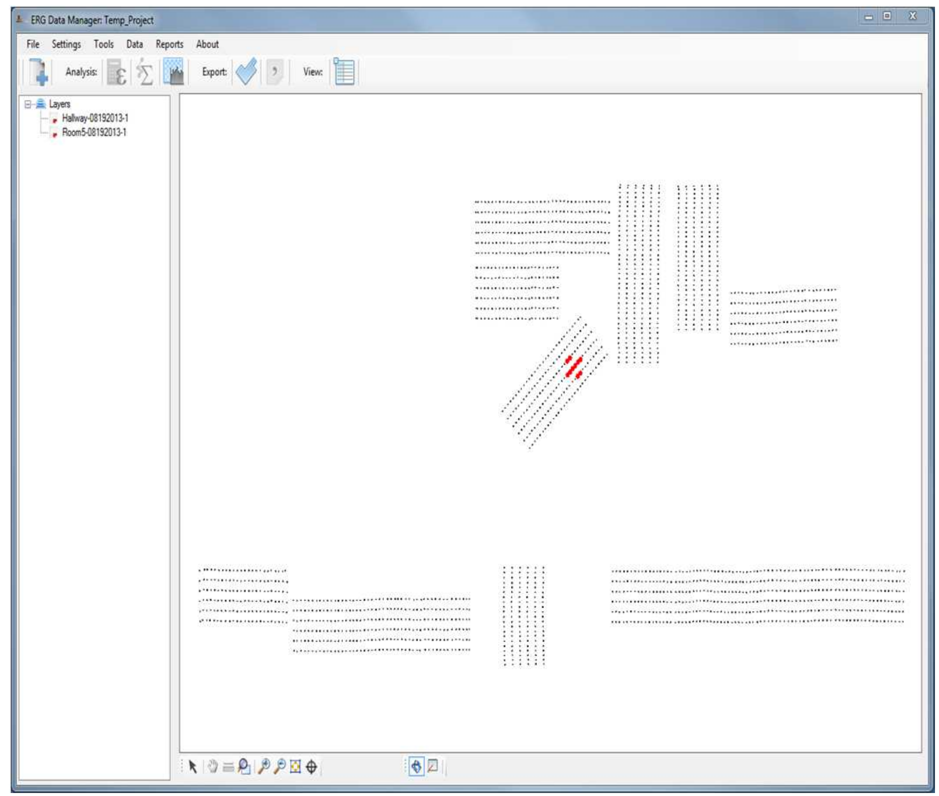


Alpha/Beta Surveys - **A New Approach**

Fully software driven to eliminate transcription errors and processing time

Calculate activity (dpm/100 cm^2), find exceeding locations, and view data statistics prior to leaving the survey area.





NEAREST NEIGHBOR AVERAGING

Nearest-neighbor averaging (NNA) is a technique used to <u>improve the sensitivity and reduce the variance</u> of spatially-correlated data maps. The raw number of counts in a given map is replaced by a new map of values that represent the average of the "N" nearest neighbors of the data.

Raw Data

1	0	1	1
1	0	0	0
0	1	0	1
0	0	0	0
0	0	1	0

The raw data matrix represents a sample from a large map of count data. The cells that are shaded were averaged using NNA to yield the cell in the top left corner of the NNA matrix below

NNA (N = 8)

NNA (N=8)

x	x	x	x
x	0.44	0.44	x
x	0.22	0.22	x
x	0.22	0.33	x
x	x	x	x

The data in this map represents the NNA of the raw data matrix. For example, the cell in the top left corner (0.44) is the average of the shaded cells in the raw data matrix. Cells marked with an "x" are ignored here since their neighbors are not included in the raw data.

WHY do Nearest Neighbor Averaging?

By reducing the variance by a factor of N + 1 (The number of neighbors plus the cell itself), the uncertainty in any given measurement is reduced by a factor of square root of (N+1). This reduced uncertainty is desirable when counting statistics are poor (such as measurements very near background). Also, by shifting the Poisson distribution to be more normal, conventional statistics are more applicable and intuitive for the data reviewers and decision makers.

"Critical Level" Improvement

Since data obtained with nearest-neighbor averaging has a reduced variance, the critical level is reduced by the same factor. The novel concept of this algorithm is that the NNA L_c is calculated with the following equation:

$$\boldsymbol{L_C = \frac{k s_B}{\sqrt{N+1}}}$$

Where:

N - the number of nearest neighbors

"MDC" Equation Improvement

The MDC equation becomes:

$$L_D = \frac{k^2 + 2kS_B\sqrt{(N+1)}}{(N+1)}$$

To convert L_D to a meaningful value of activity, the following equation is used:

$$MDC = \frac{L_D}{\epsilon\, t\, A}$$

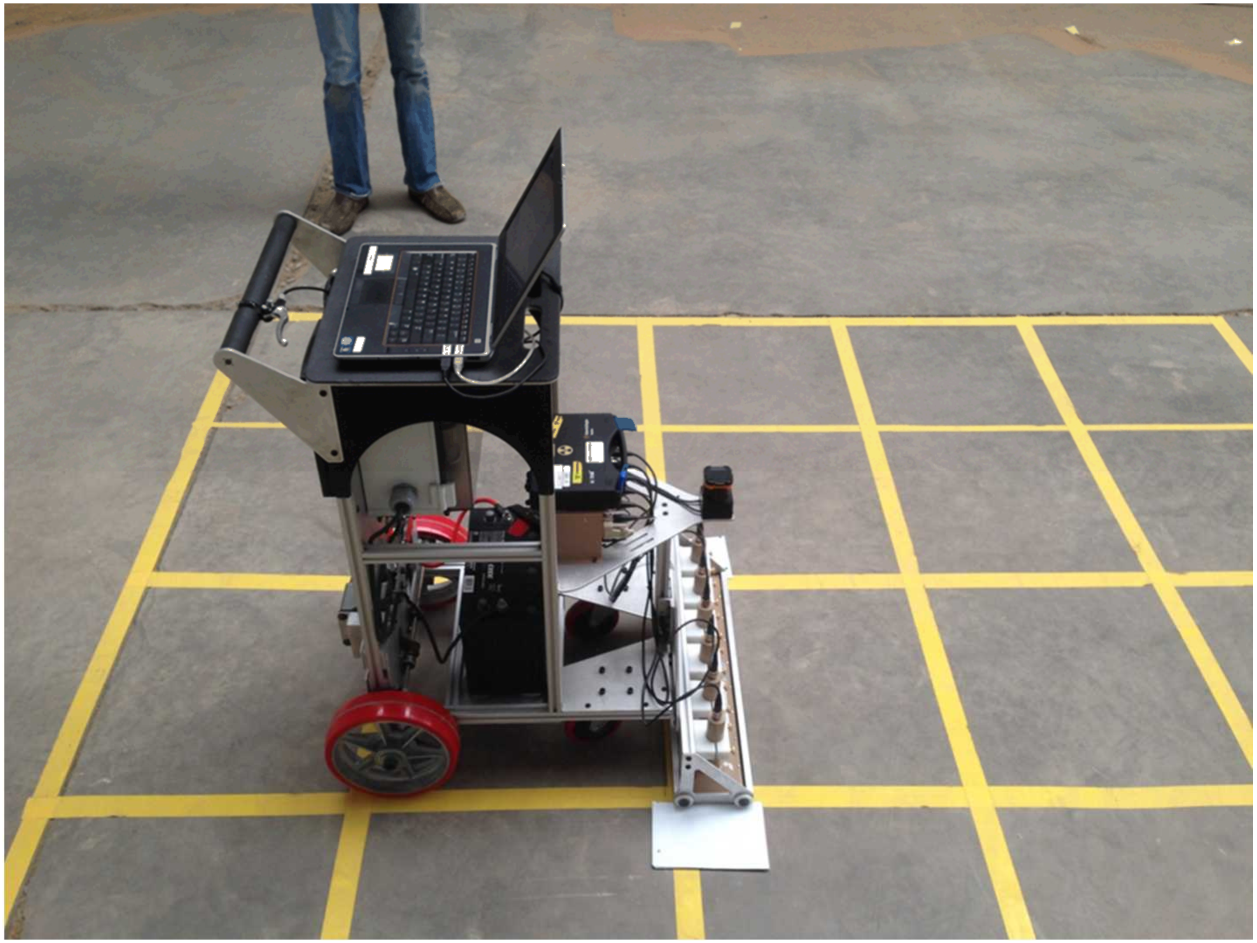
Where,

A = detector area factor (unitless) for conversion to 100cm^2

ε = total detector efficiency in counts per disintegration. This is equal to the detector efficiency multiplied by the surface efficiency

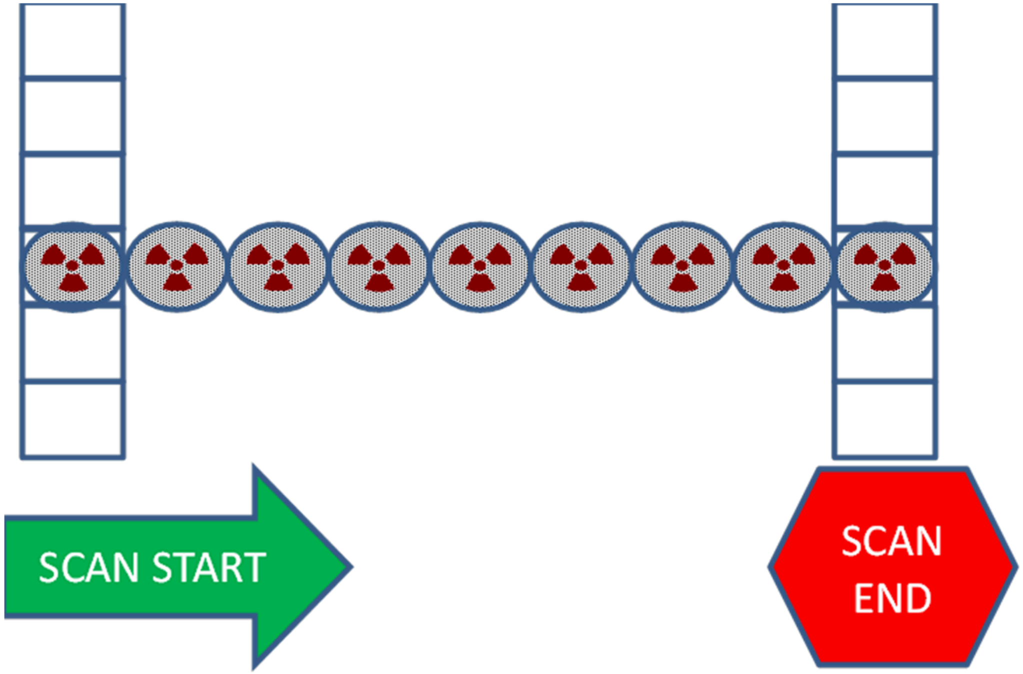
t = counting time in minutes.

Field Test Setup

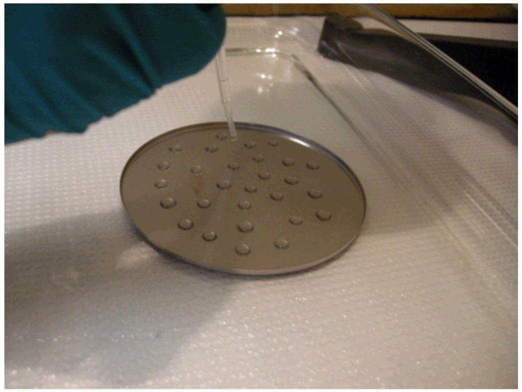


A not-so-obvious benefit of NNA is that 1 + NN=6 results in an area averaged over 0.175 m^2 (< 1/5 m^2), much smaller than 1m^2, more the size of a hot spot!

Field Test Approach



Field Scan Approach



Test DU Source Preparation

…and for Gamma Surveys…

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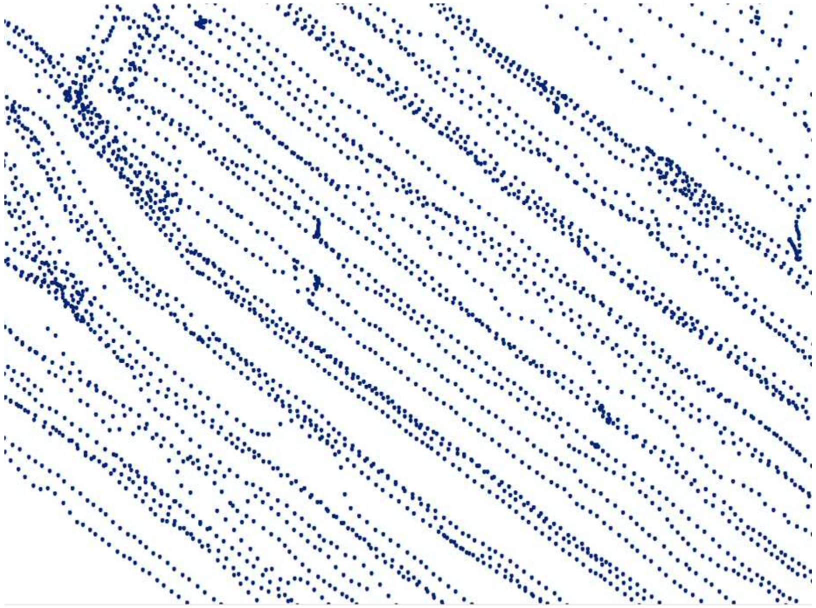
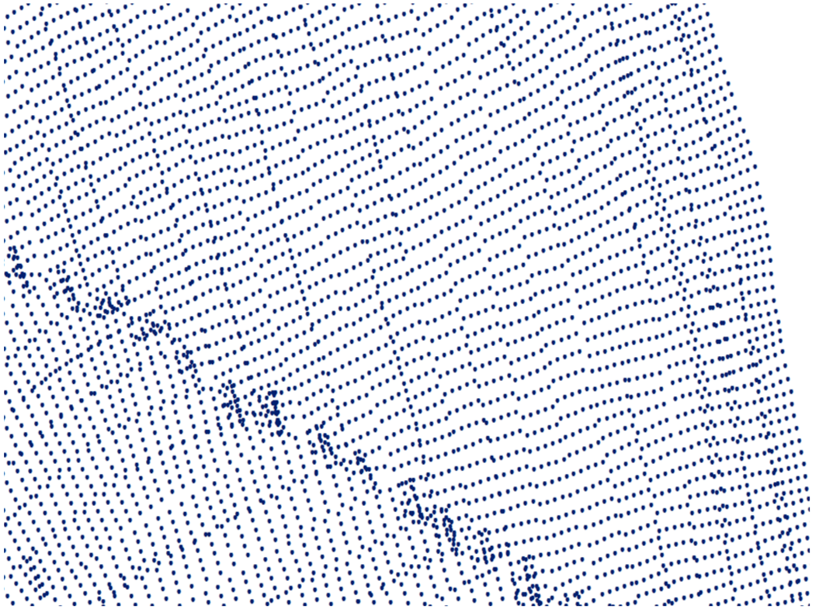
Gamma Surveys A New Approach

Inertial Measurement Unit (IMU) combined with filtering techniques results in **superior accuracy (< 10 cm) without post-processing**, and resolves the common problems with using a single GPS unit with multiple detectors (moving in reverse, quick turns).



Survey using traditional cart setup with 3 detectors



Survey using new approach with 5 detector array

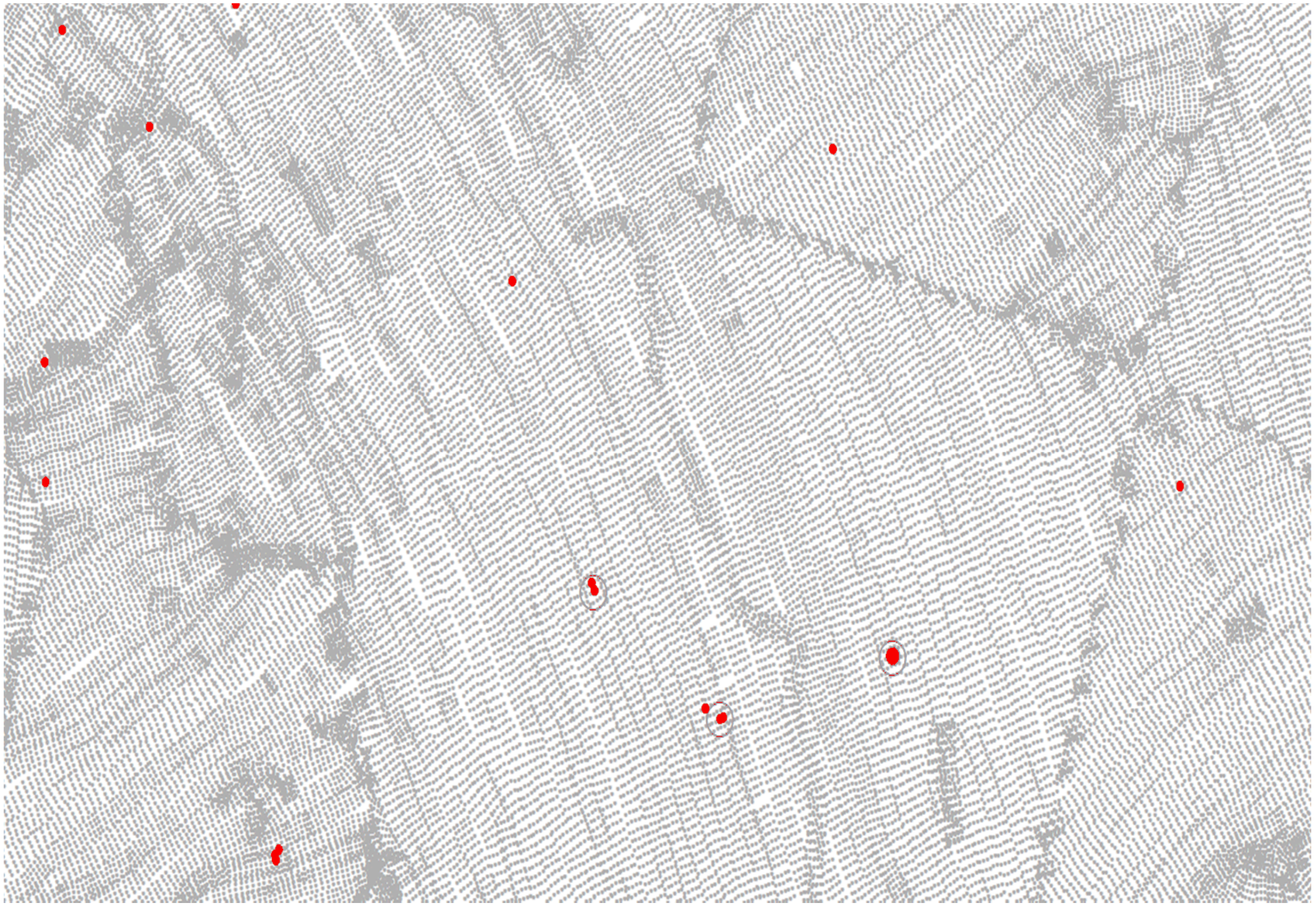
Gamma Surveys   A New Approach

The one-second **scalar** count has proven to be highly beneficial for the detection of small discrete sources.

k chosen such that false positive rate < 0.0001 in dataset of 134,485 points.

m + k*std displayed for both ratemeter data (black) and scalar data (red).

Investigations are performed on highest of the flagged locations (circled) and resulted in positive identification of contamination.



Scanning with Scalers Gives Superior Results

- The use of scalers brings us into the 21st century in scanning, where data are collected that can be:
  - described statistically,
  - the location of the data is without question, and
  - the quality of the data is no longer dependent on performance of a technician.
- Why would anyone prefer scanning using rate meters to the use of scalers?

WIFM?

Nearest Neighbor Averaging (NNA) improves the sensitivity of the instrument and reduces the variance of the data. It can be used to improve the cost efficiency and confidence with which Multi-Agency Radiation Survey Investigation and Release (MARSSIM)-type release surveys are conducted.

Conclusions

Test results show that the method of NNA decreases the L_C and MDC by a factor proportional to the number of neighbors.