# Coded Aperture Neutron Imaging

LABORATORY DIRECTED RESEARCH & DEVELOPMENT

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## Problem

**A current critical hole in national security is the difficulty in detecting illicit or smuggled special nuclear material (SNM). SNM emits energetic gamma-rays and "fast" neutrons (~1 MeV) by spontaneous or induced fission. Fast neutrons offer the greatest advantage due to their highly penetrating nature and very low and well understood natural background. Despite this, when small quantities, heavily shielded, and/or distant SNM is of interest, the fast neutron detectors currently in use (e.g., moderated $^{3}$He detectors) fail due to low signal-to-noise.**

**We seek to develop a new detection technology that should offer greatly enhanced signal-to-noise over existing technologies while maintaining high efficiency for improved detection speed, range, and sensitivity.**

## Approach

**We are investigating a new approach to fast-neutron detection—a Coded Aperture Neutron Imaging System (CANIS). Two basic designs have been explored. The first is composed of a mask plane and a position-sensitive detection plane (Fig. 1). A source of fast neutrons within the field of view projects a unique pattern through the mask onto the detection plane, allowing for the calculation of the source position.**
**The second is composed of a single central detector surrounded by a rotating coded mask (Fig. 2). A source of fast neutrons is given a unique time modulation that allows its direction to be determined.**
**In either case, the overall efficiency can be made as high 50 percent, the open fraction of the mask.**

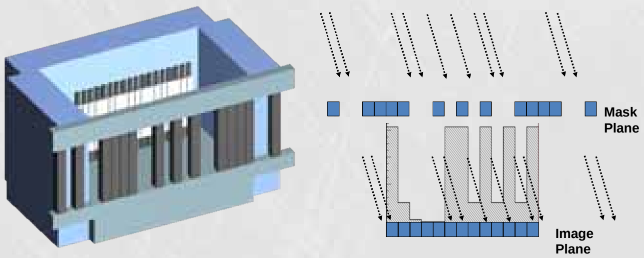


**Fig. 1 – (left)** Illustration of the Coded Aperture Imaging System (CANIS) for a passive aircraft scan demonstration. The mask (front), floor, and lid (removed for illustration) are constructed of high density polyethylene, the surrounding shield walls consist of tanks of water, and the detectors (inside) are 2.5"x2.5"x20" liquid scintillator cells. **(right)** A radiation source casts a shadow of the mask plane onto the image plane. The mask pattern is carefully designed such that the direction of the incident radiation is uniquely encoded in the pattern projected onto the image plane.

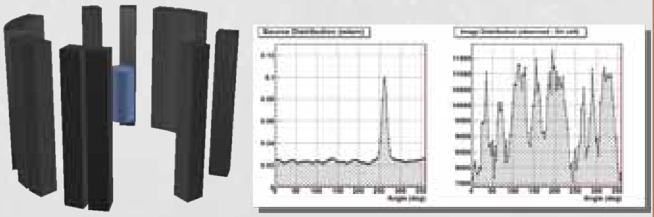

**Fig. 2 – (left)** Illustration of the time encoded detector system (dubbed LIGHTHOUSE). The mask is constructed of high density polyethylene and the central detector is a single 5" diameter liquid scintillator cell. A $^{252}$Cf neutron source (~10 meters distance) produced the modulated signal **(right)** as the mask rotated. The mask pattern is design such that the source direction can be uniquely determined as can be seen in the unfolded neutron rate distribution **(center)**.

## Results

**In the course of this project, we have explored many coding configurations and mask thicknesses using a reconfigurable array of identical 2.5" x 2.5" x 20" liquid scintillator filled detectors coupled to photomultiplier tubes on each end [1]. Using these tools we have successfully demonstrated for the first time coded aperture and double scatter imaging modes of both fast neutrons and high- energy gamma-rays using several different mask configurations [2].**

[1] Brubaker, E., "Calibration and Simulation of a Coded Aperture Neutron Imaging System", IEEE NSS/MIC 2009 conference proceedings.
[2] Marleau, et.al., "Active Coded Aperture Neutron Imaging", IEEE NSS/MIC Conference Proceedings, 2009

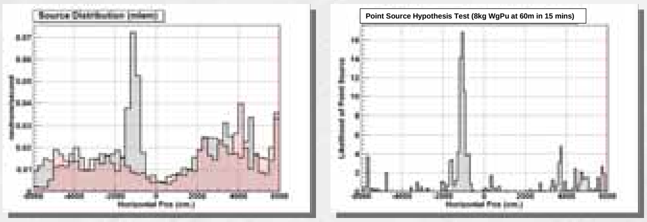


**Fig. 3 – (left)** Reconstructed source distribution for background (red) and a neutron source at 60 meters (black). **(right)** The result of a point source search on only 15 minutes of data. It can be seen that the background is suppressed, increasing the significance of the detection.

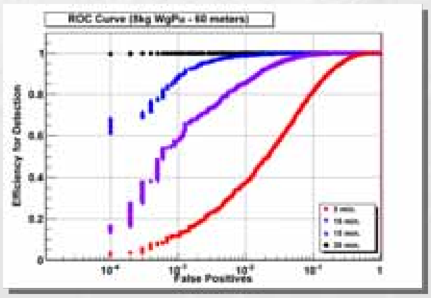


**Fig. 4 – Receiver Operator Characteristic curve for an 8kg WgPu equivalent neutron source at a 60 meter stand off.**

**To illustrate the potential for such a technology to be used for homeland security, we constructed a passive Coded Aperture Neutron Imaging System (CANIS) (Fig. 1) to be used in a large stand-off aircraft screening scenario demonstration. The detector was placed in a 40 ft. sea-land container and a $^{252}$Cf neutron source (IAEA significant quantity of WgPu equivalent) was placed 60 meters away. We achieved a 1 in 1000 false positive rate with 90% efficiency in only 15 minutes of dwell time (Fig. 4). This easily outperforms any technology currently in use.**

## Significance

**National and international security customers in both governmental and private sectors are seeking better tools to search for radioactive threats.**

**This new concept offers a new high-efficiency energetic neutron imaging instrument that is capable of locating SNM at greater distances and shorter dwell times than any existing instrument or technique for this application.**

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