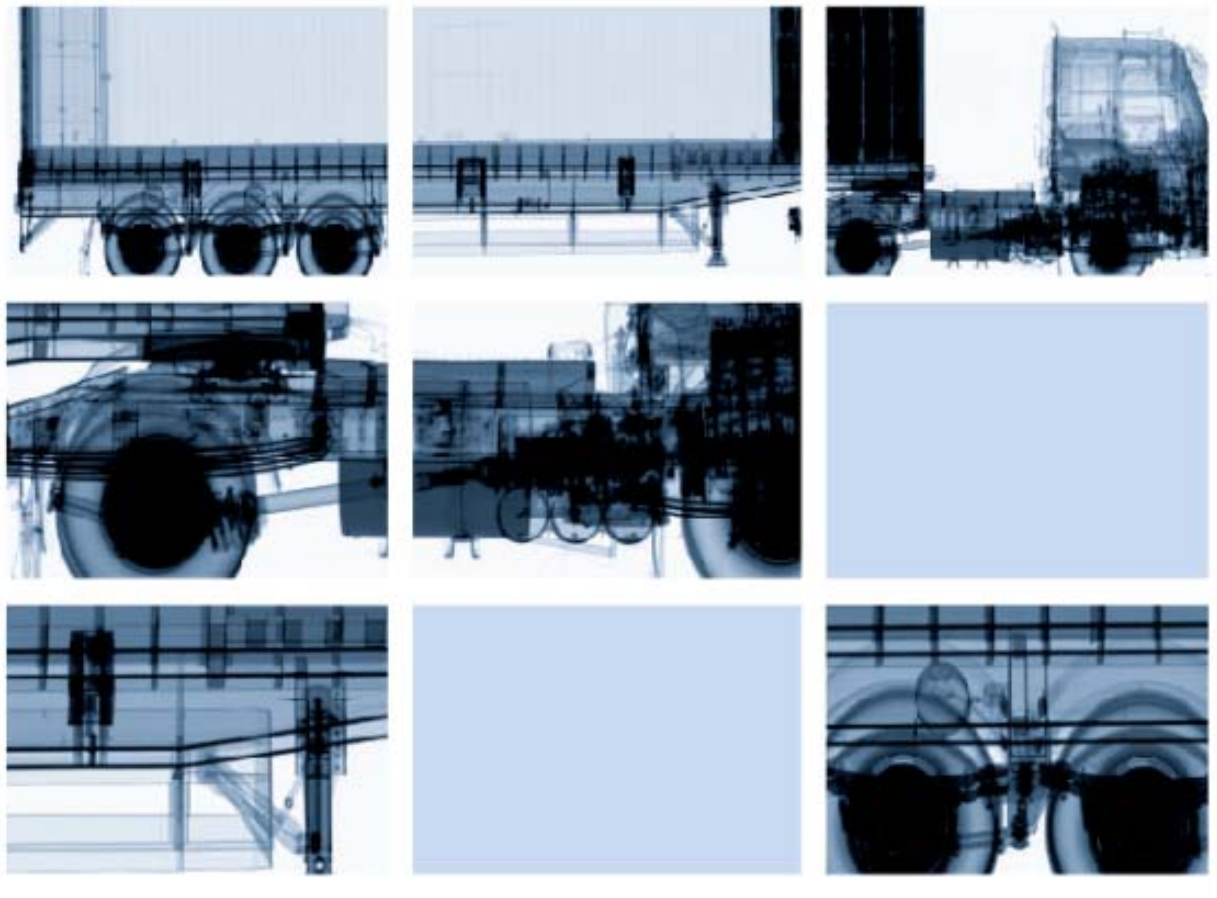
Rapiscan systems
An OSI Systems Company

ONE COMPANY - TOTAL SECURITY

From Steady State to Pulsed: A Review of Neutron Interrogation Techniques for Explosives Detection

Dan Strellis

Rapiscan Laboratories



for

ADSA10

Boston, MA

May 2014

So what? Who cares?

- Screening air cargo is difficult (adequately covered yesterday by Crawford, White, Garms, et al.)
- Neutron-based techniques offer a measurement of material specificity of the cargo that widely-deployed systems today cannot provide (examples also provided by Perticone, Cutmore, Gregor)
- Using neutrons faces many hurdles, even for situations when technology is demonstrated to work (ref. Martz): regulations, end-user acceptance, technology maturation
- Review of neutron techniques Rapiscan (or predecessors) has tried (and deployed in some instances) for air cargo screening

Using Neutrons - Sources

Cf-252 spontaneous fission source

Steady state ← → *Pulsed*

dT 14MeV or 2.5MeV sources

No timing

µs timing

Time-of-Flight (TOF) ns timing

dT – Associate particle imaging source

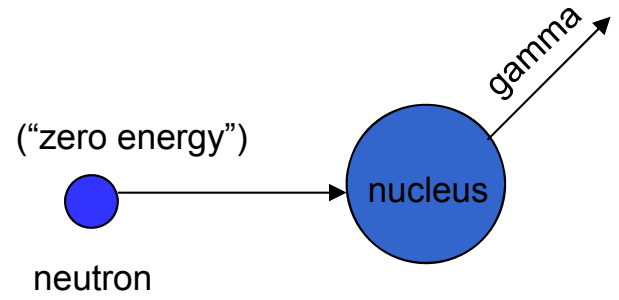
TOF ns timing

Van de Graff accelerators dD ~8MeV source

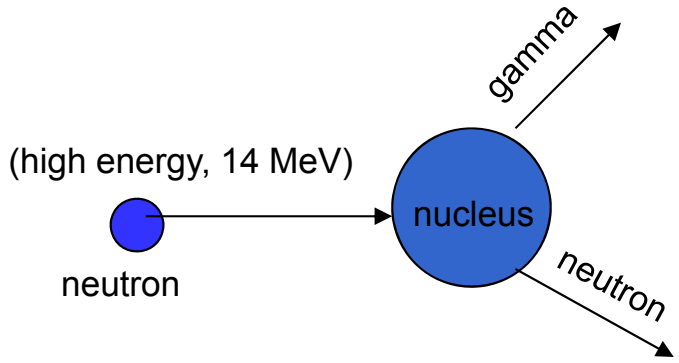
Using Neutrons – Basic Physics Principles

Two Primary Reactions Involved

- **TNA** **Thermal Neutron Analysis**
  - **"Room temperature" neutrons completely absorbed by material**
  - **Characteristic gamma ray identifies element**
- **FNA** **Fast Neutron Analysis**
  - **High energy (e.g. 14 MeV) neutrons "bounce" off material**
  - **Characteristic gamma ray identifies element**



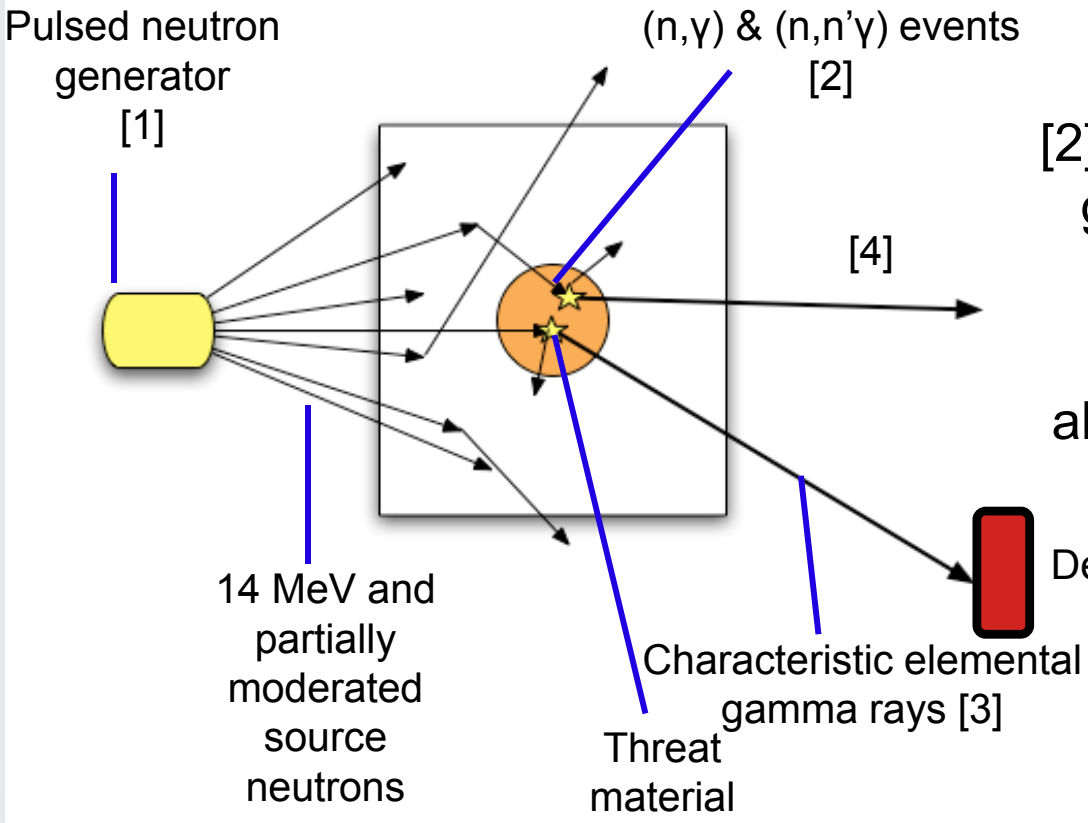
Thermal neutron absorption reaction



Inelastic scattering reaction

Neutron-based Interrogation

[1] Source neutrons generated during the pulse. Some are partially moderated in the source spectrum tailoring system. These and the uncollided source neutrons can either interact in the cargo materials as fast neutrons, or thermalize and be absorbed in the cargo, leak out, or…



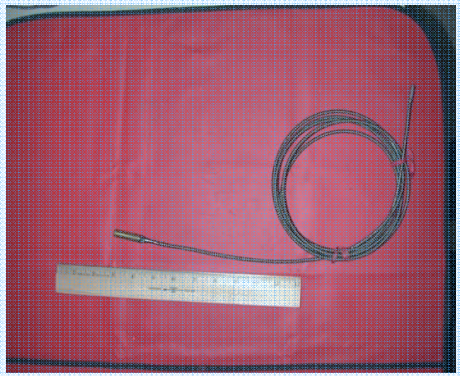
[2] interact with the threat elements and generate characteristic gamma-rays

[3] Some of the gamma-rays escape absorption in the threat or cargo and are detected by system detectors

[4] Other gamma-rays escape detection by the system detectors

Bulk Measurement Techniques – non-TOF

Using Neutrons - Sources



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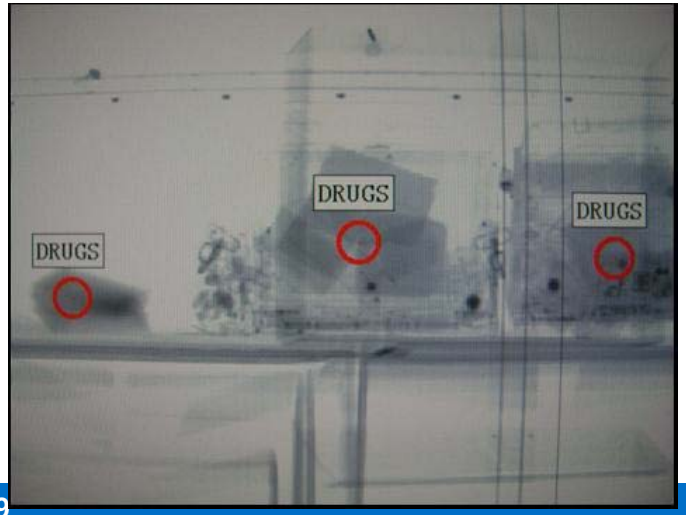
X-ray / Neutron Combined System - Taiwan

- 4MV x-ray radiography primary
- Cf-252 source (e6 n/s), NaI detectors secondary

Operators Room

Inspection Tunnel

Report on Newspaper (Liberty Times) dated June 30th 2004.
The drugs were hidden inside of laptop computer
The weight for these five pieces is 1028 g only.
(Total weight of drugs found was 4409g)



Taiwan AP Finds
Drug in Cargo Container
using Rapiscan 4MeV x-ray and Cf-252 based neutron combined system

手提電腦藏毒 闖關失敗

走私海洛因 男子褲襠夾藏毒磚被識破

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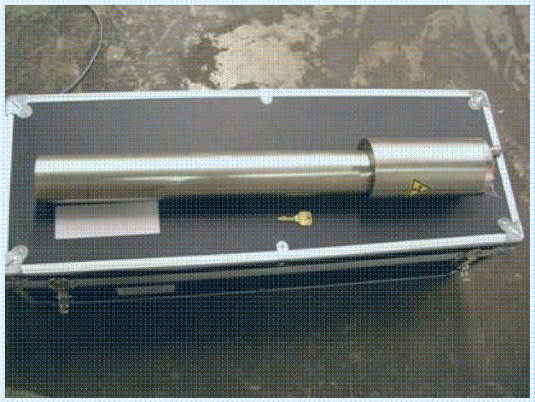

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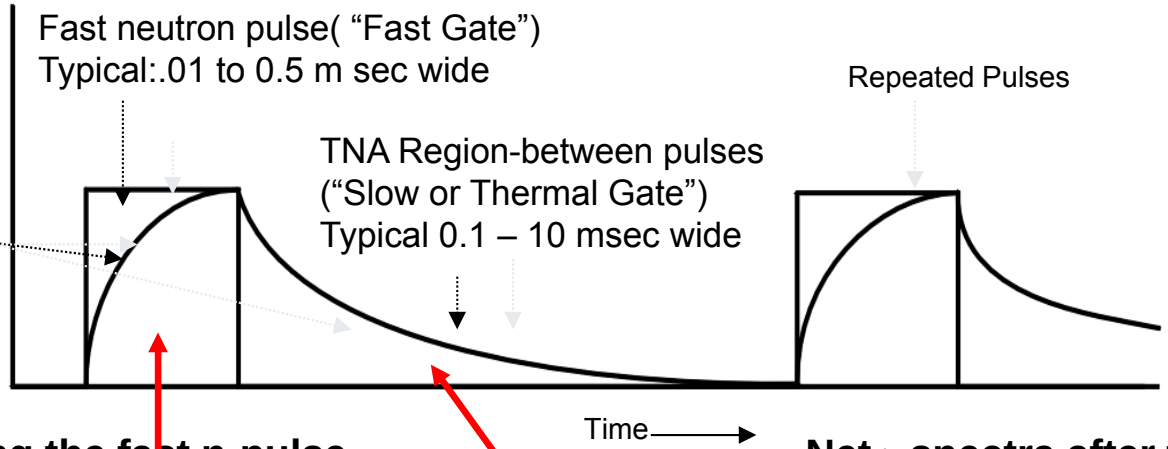
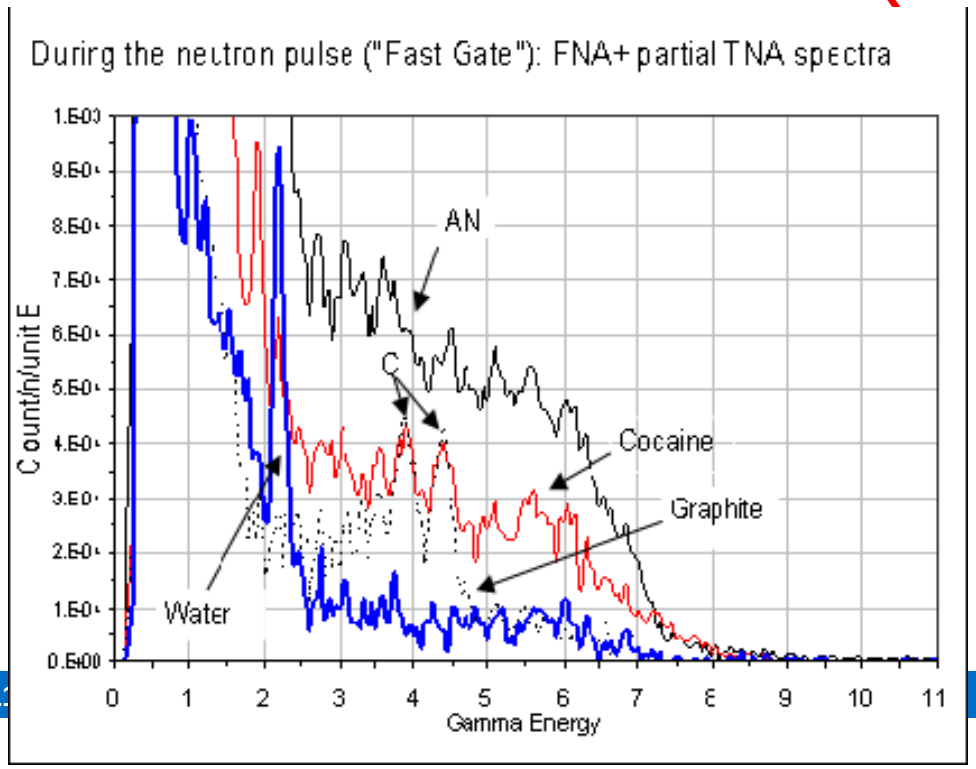
Conventional (microsecond) Pulsed Neutron Inspection

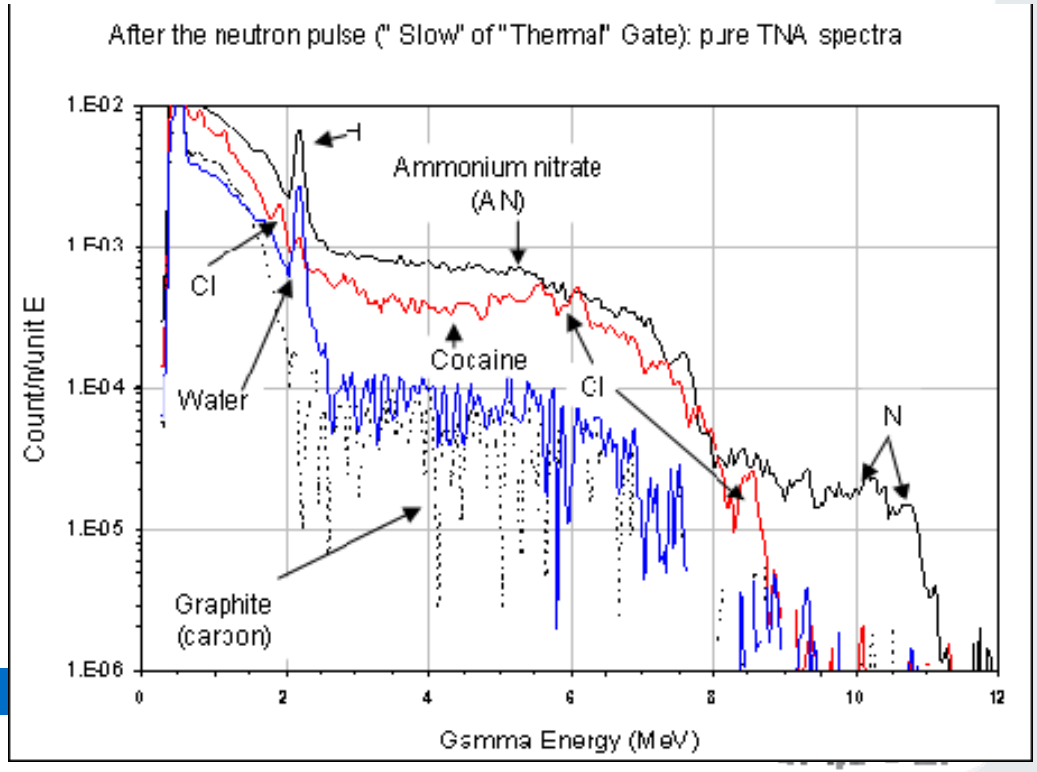
Thermalized neutron time profile



Net γ spectra during the fast n-pulse



Net γ spectra after the fast n-pulse



TOF Techniques

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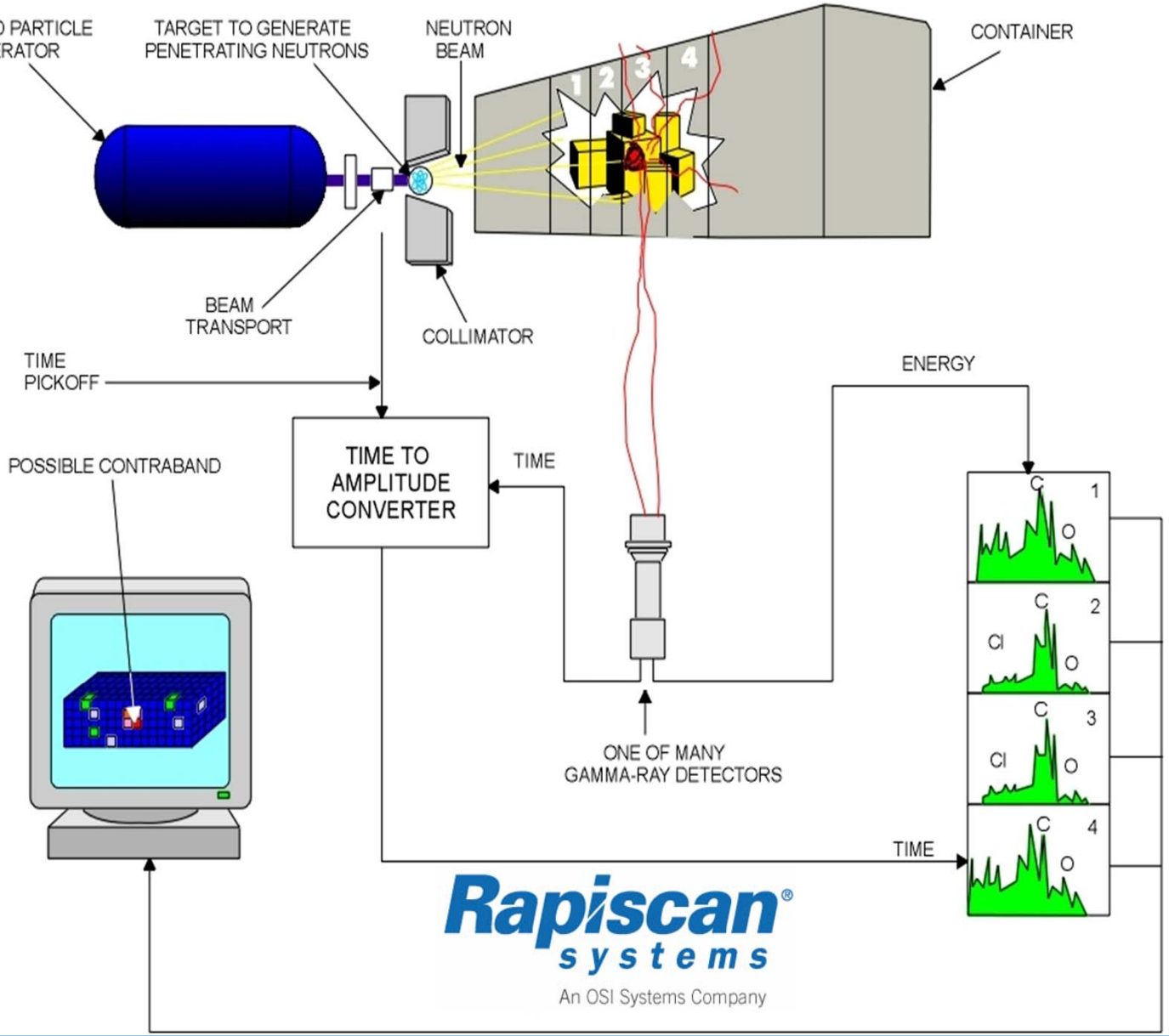
PFNA Overview

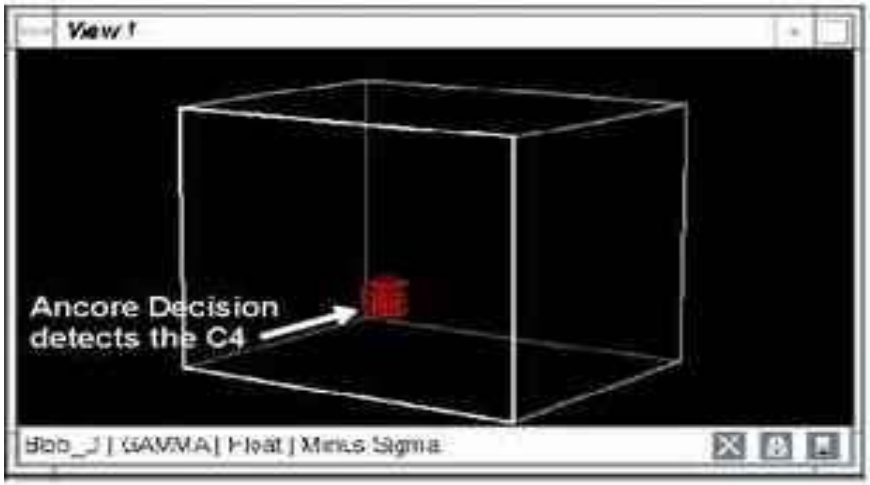


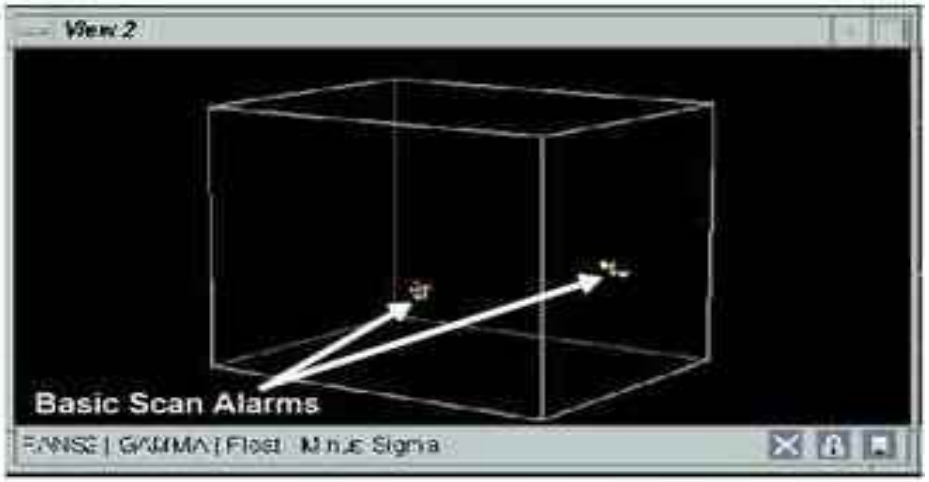
PFNA Air Cargo Inspection Project

Support provided by TSA Contract (HSTS04-07-P-CTO099)

Collaborators at Continental Airlines

Detection of C4 Explosive





Support provided by FAA Grant 99G018

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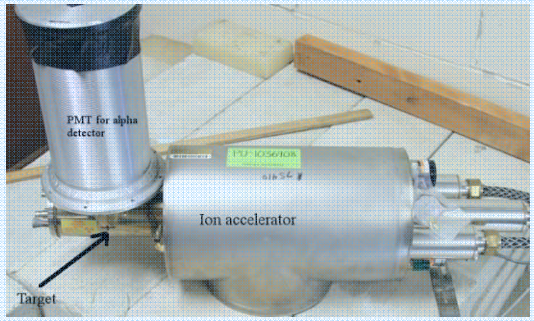

Time-of-Flight (TOF) ns timing

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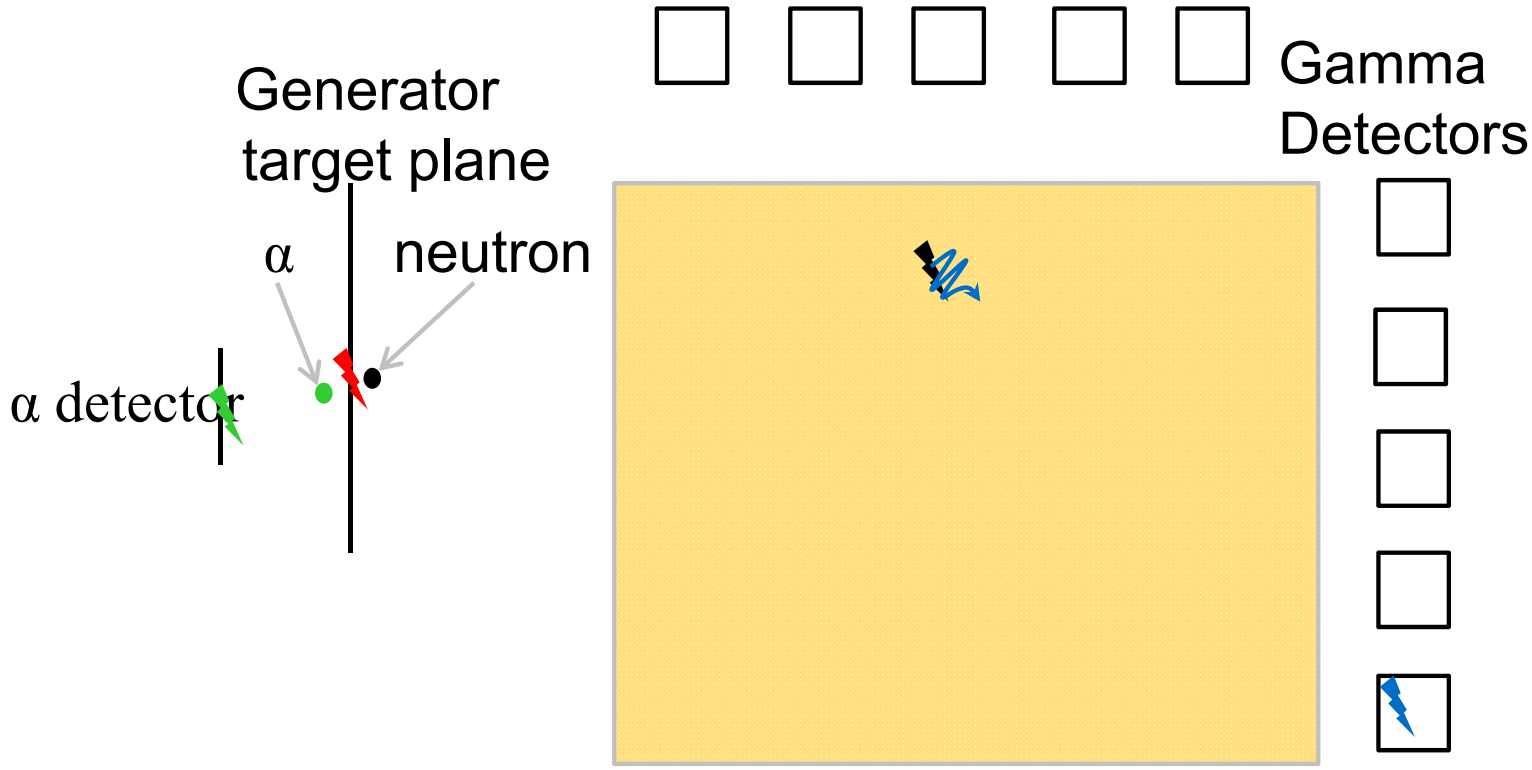
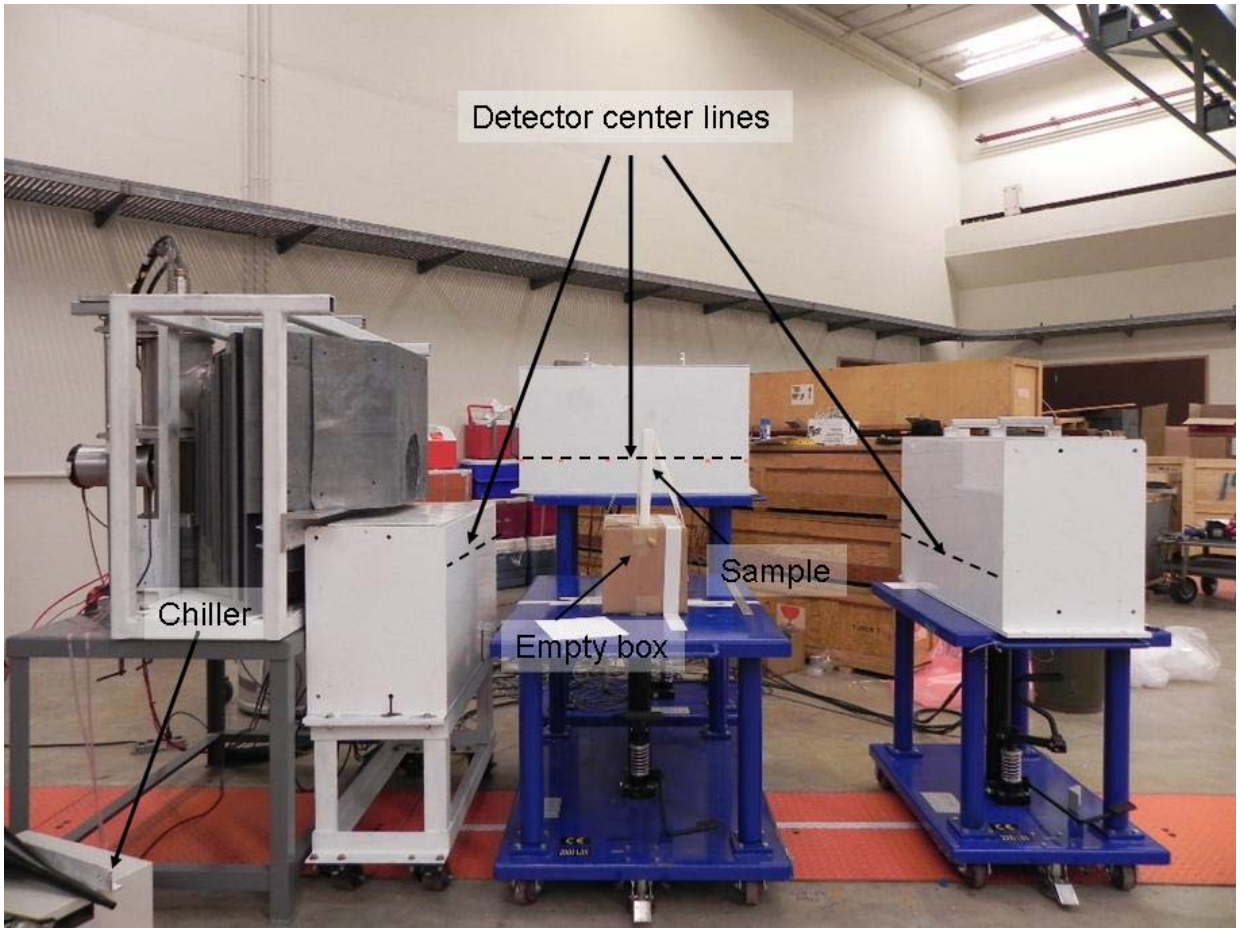
System components

- API Neutron Generator based imaging
- D+T → n (14 MeV) + α



Experimental setup



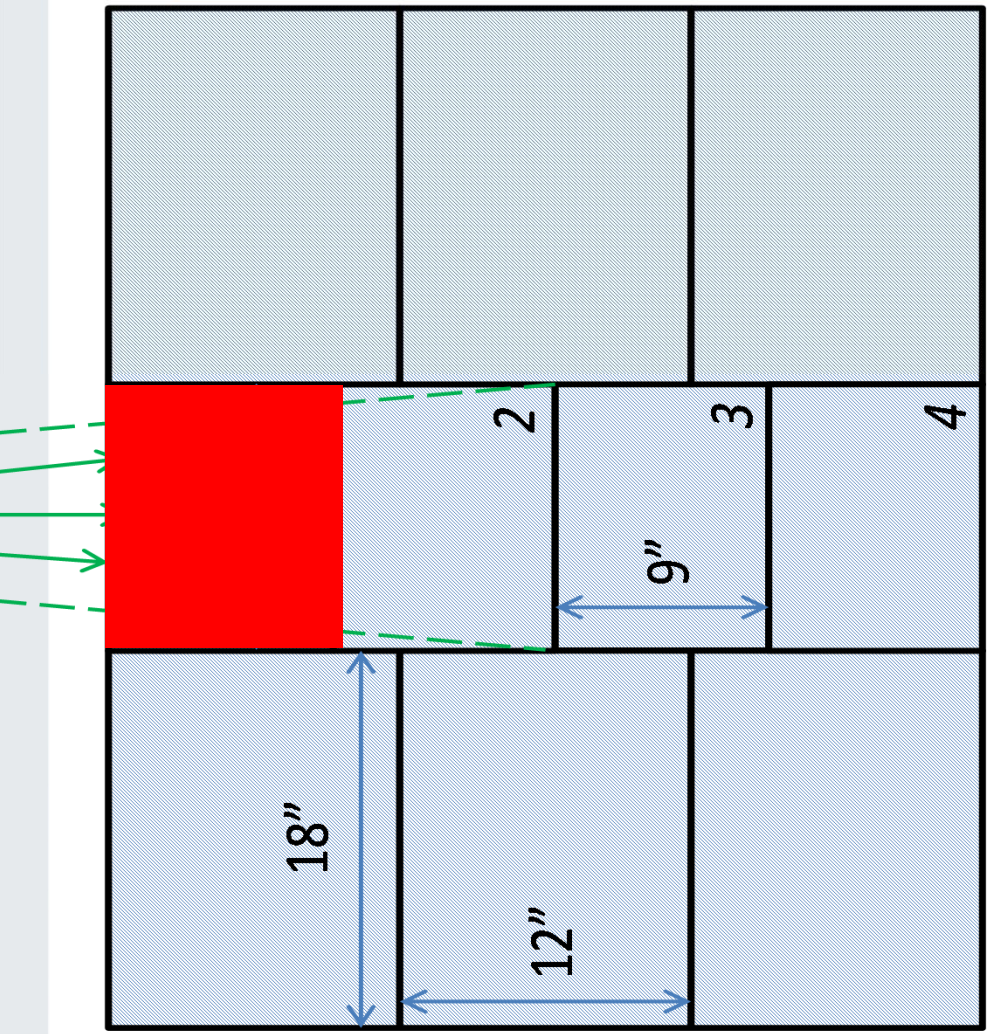
Narcotics detection

Steel and paper cargoes

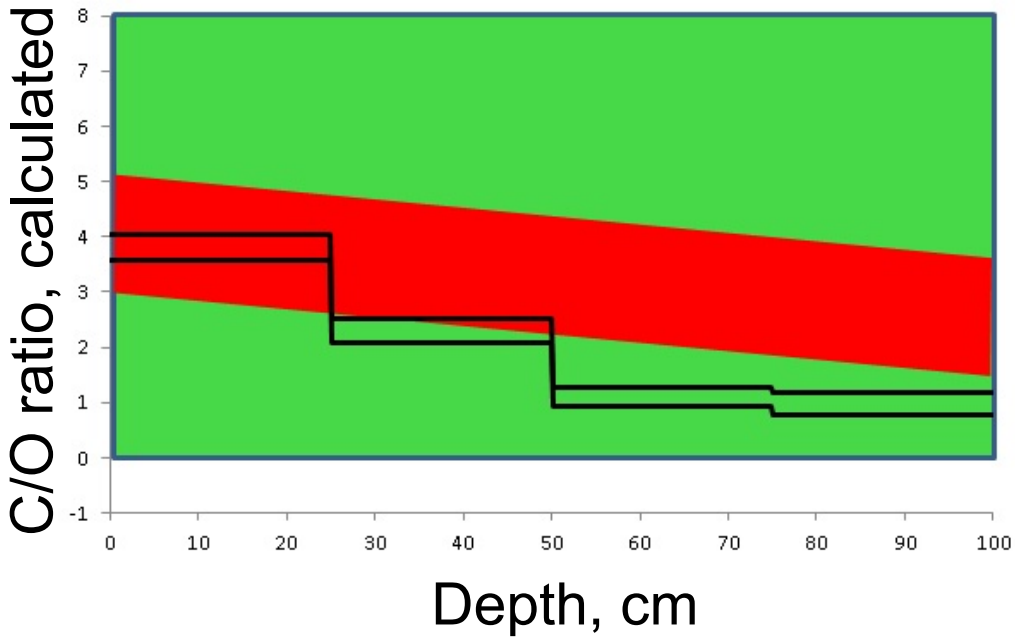
Support provided by DHS S&T Borders and Maritime Directorate CanScan Project

Collaborators at Purdue University – Applied Physics

Results: Samples in cargo



Cocaine simulant in paper cargo
C/O cocaine 4.25
C/O Paper ~1



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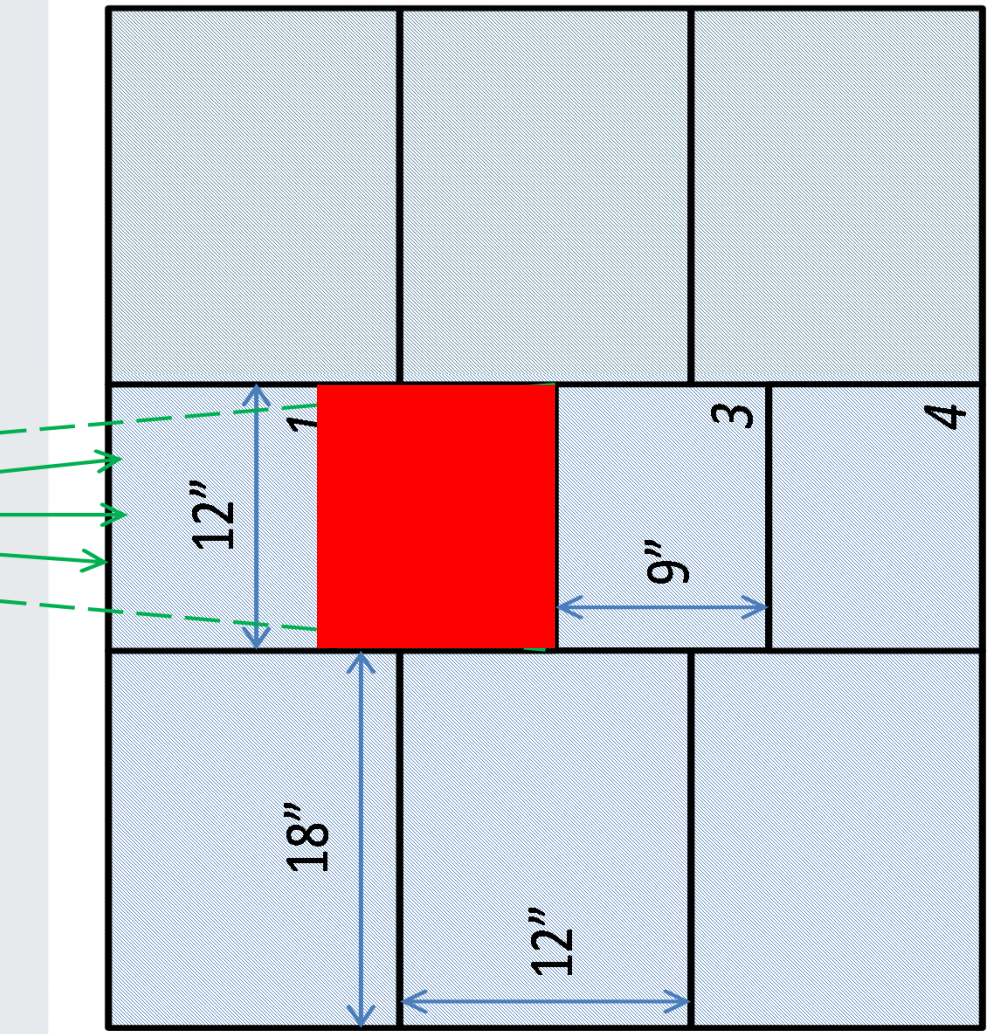

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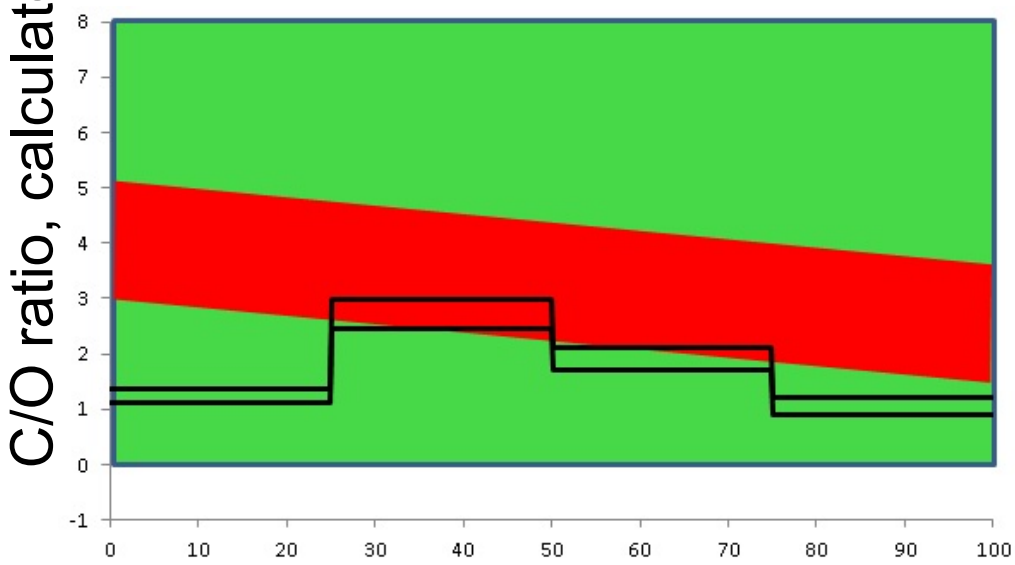
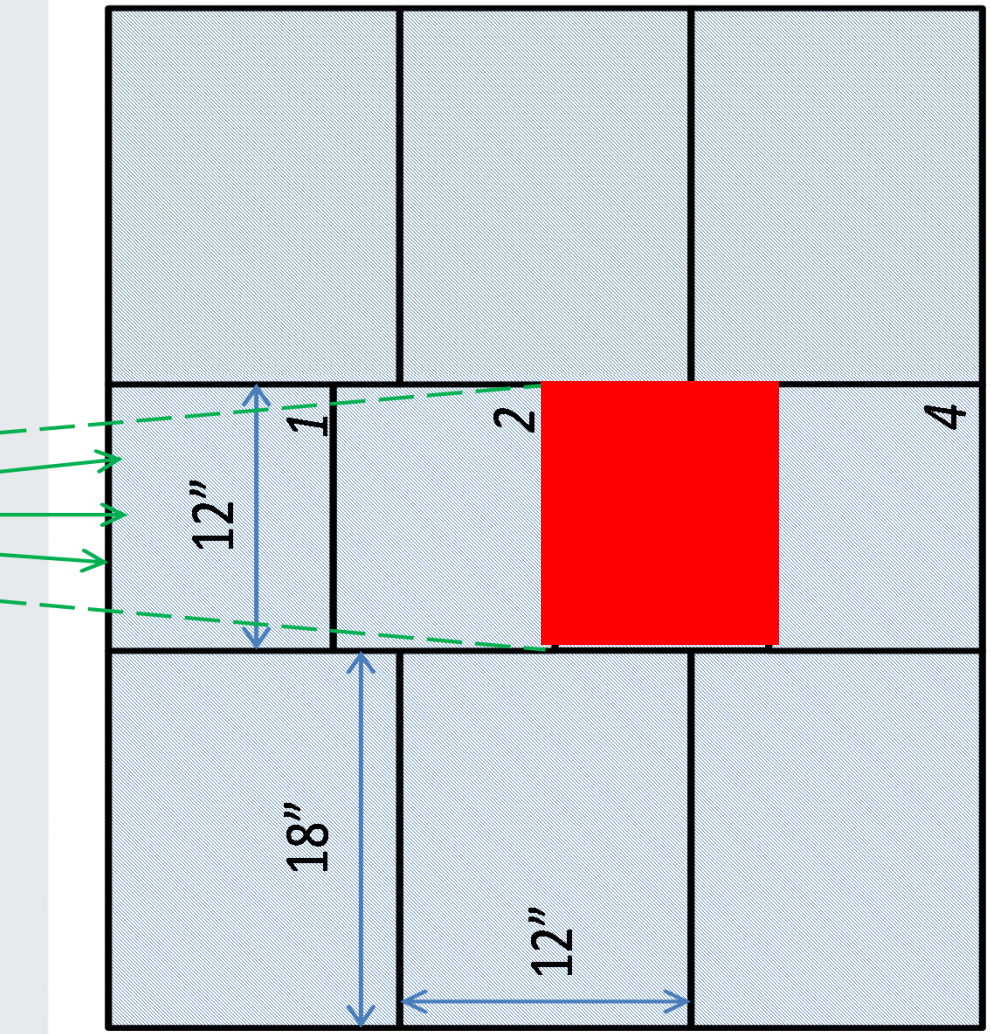


Depth, cm

Results: Samples in cargo



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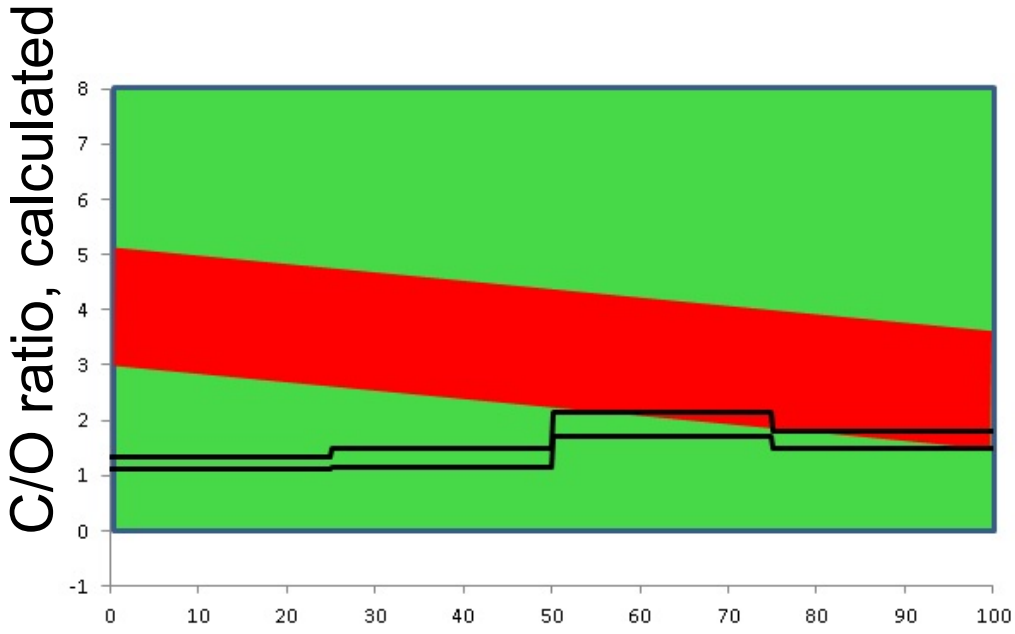

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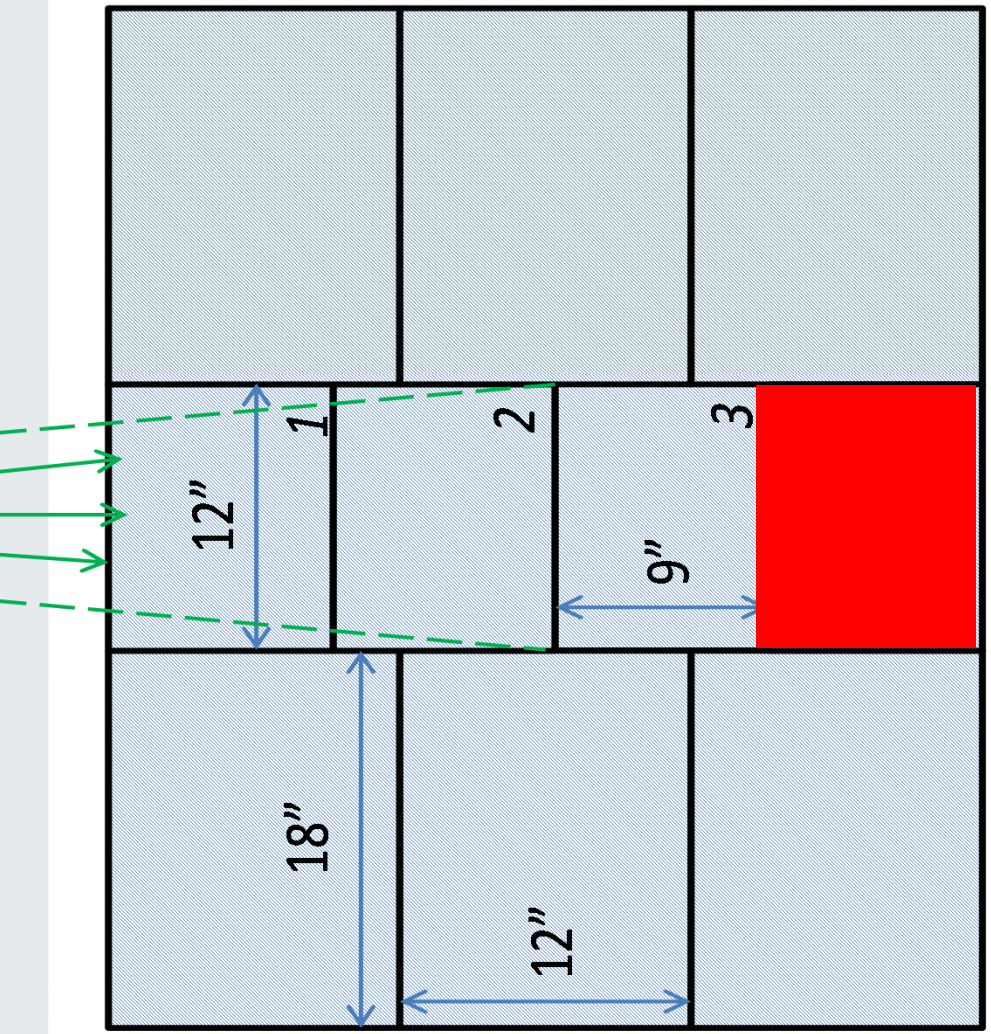

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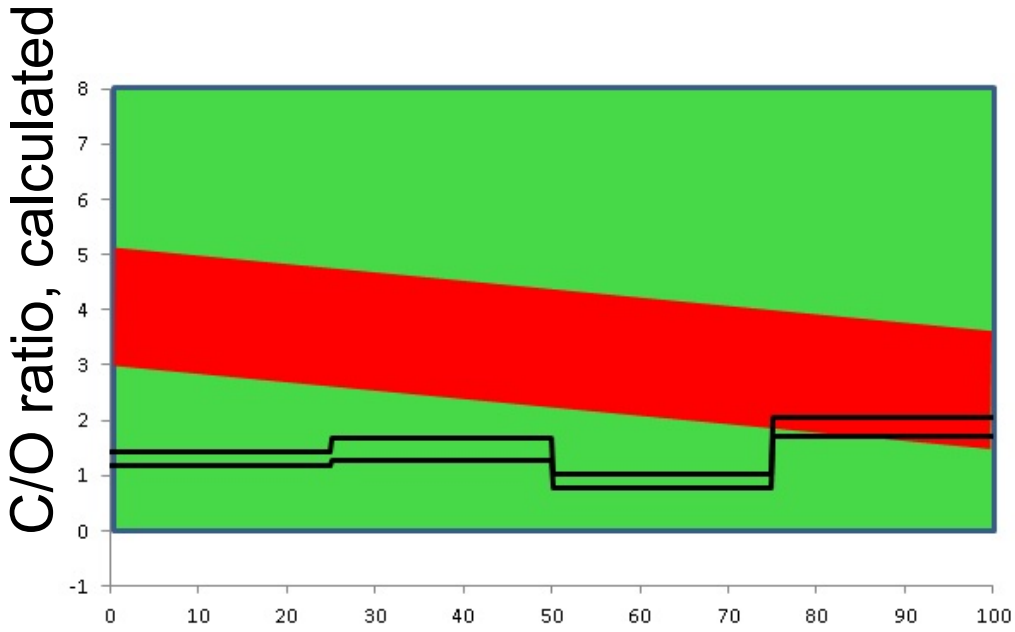
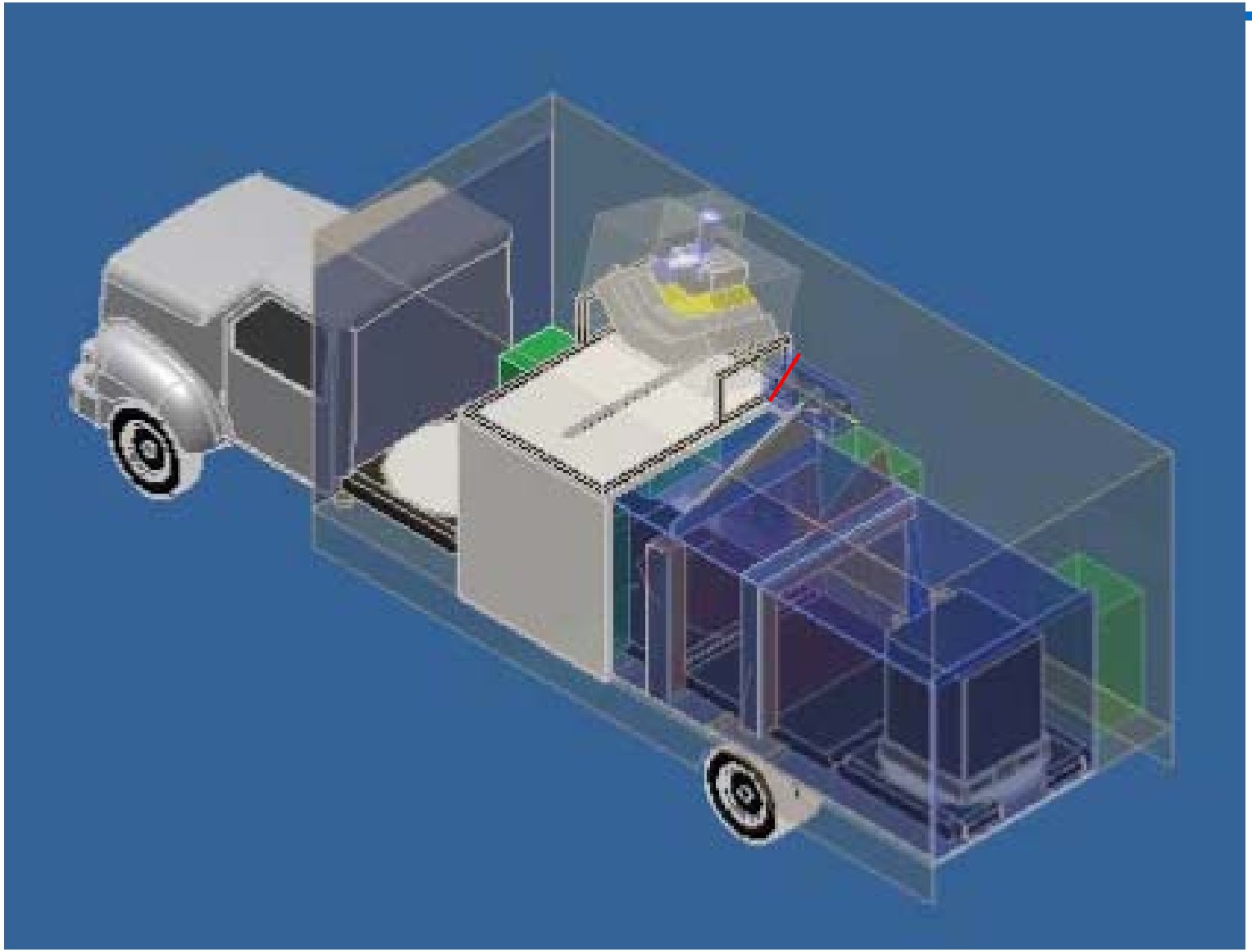


DHS CanScan Prelim Design



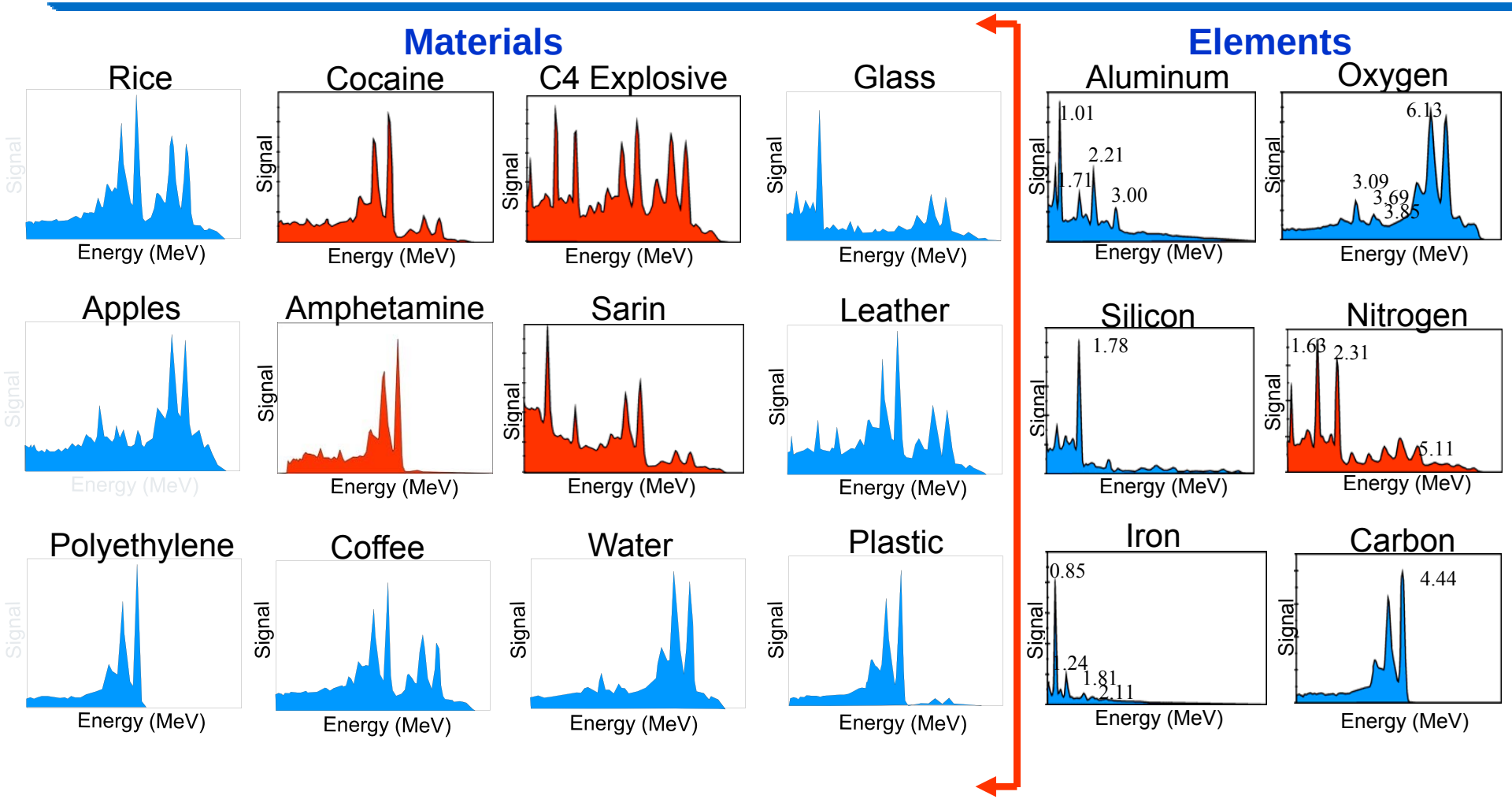
- Multi-view x-ray with n cargo rotations for primary screening
- Pencil beam API for alarm clearing
- Mobile platform under 26k lbs

Summary on Neutron Techniques

- Rapiscan (and predecessors) have been studying neutron-based techniques for security applications for over 3 decades
- Neutron-based technologies are sensitive to elemental composition of the inspected objects, which allow in many cases to identify the materials of interest.
- Time-of-Flight (TOF) technologies allow obtaining elemental information as a function of depth to reduce the elemental superposition, and ultimately improve detection performance
- These techniques have been previously employed with some success.
- Hurdles still exist. Wide spread deployment could only come with:
  1) changes to regulations (like AT for checkpoint),
  2) public acceptance (like AIT), and
  3) possibly technology improvements (smaller and higher output sources)

Backup

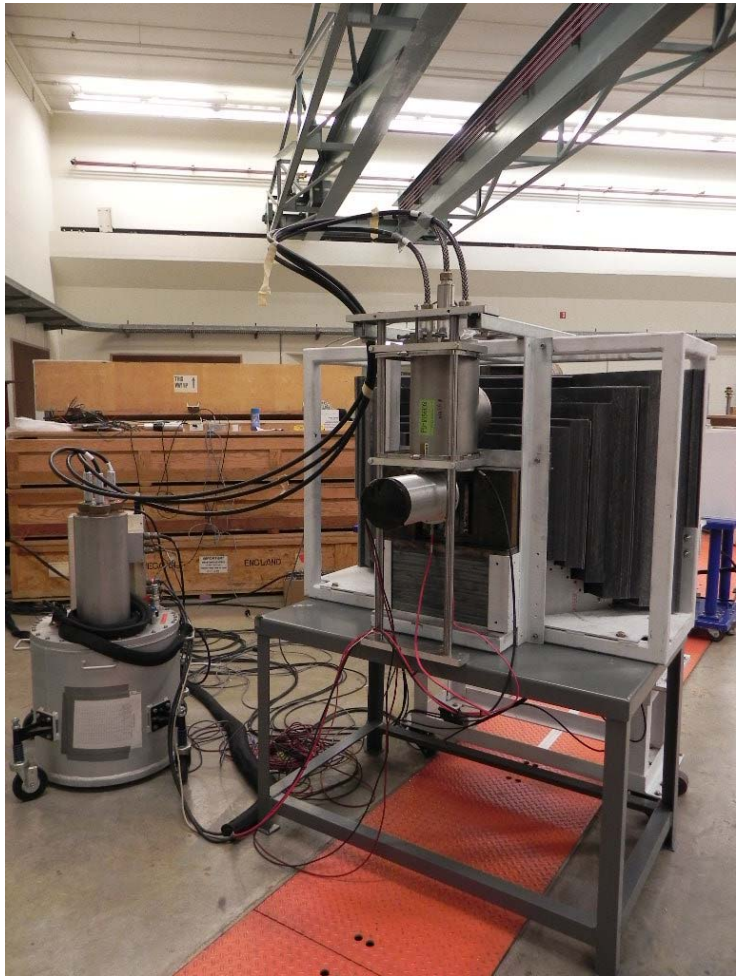
PFNA Material Signatures



The elemental signals combine to give unique material signatures.

The target data base can be continually updated.

API components: shielding



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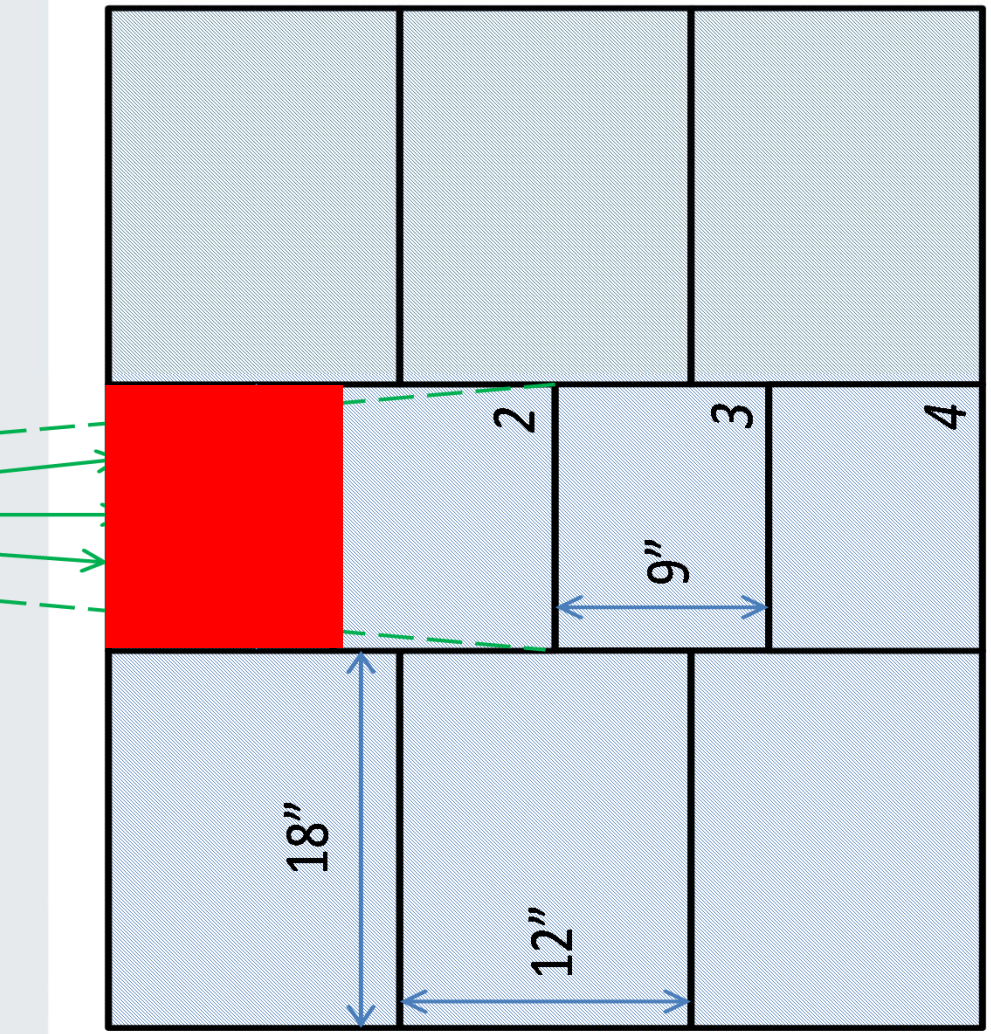
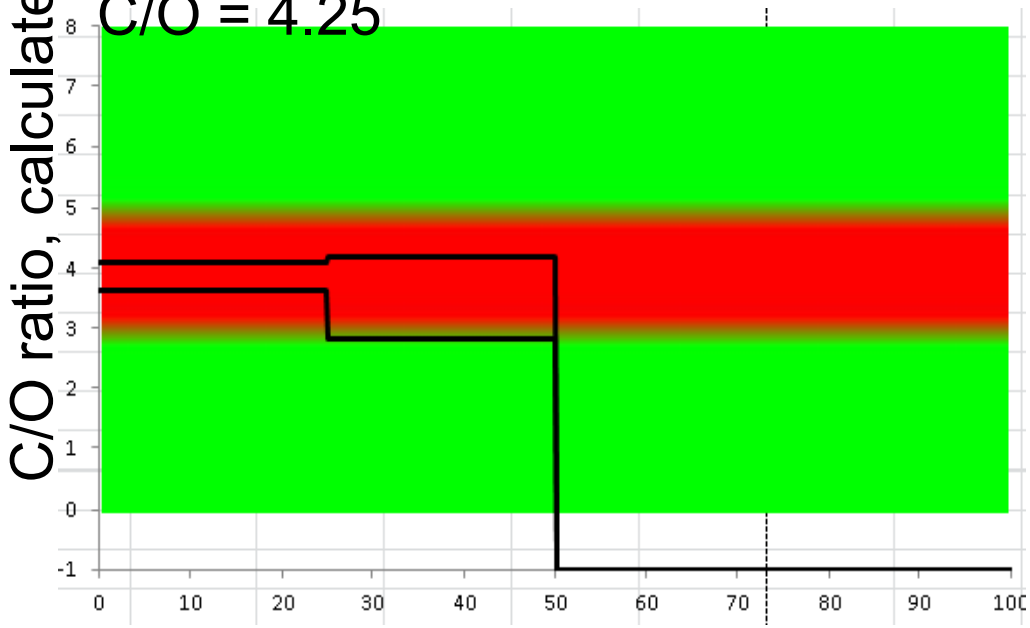


Cocaine simulant in iron cargo
C/O = 4.25



Depth, cm

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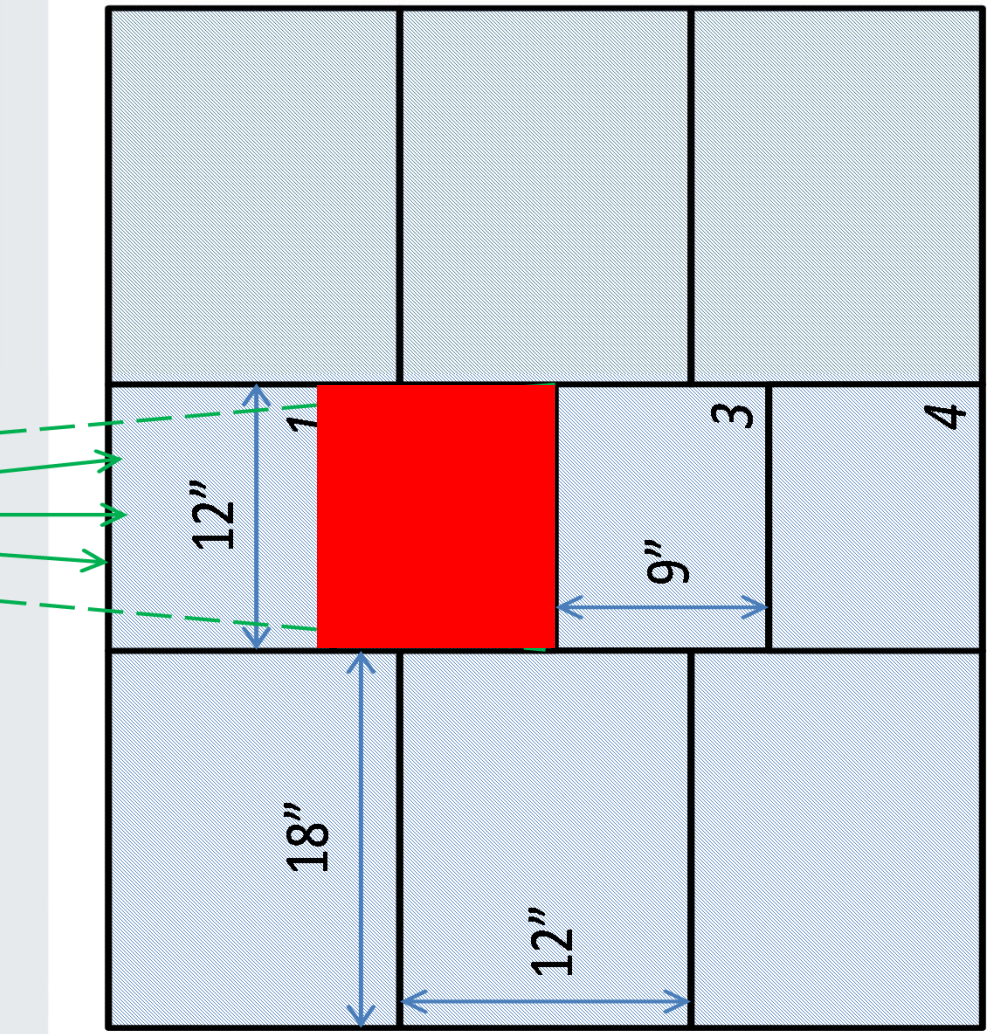

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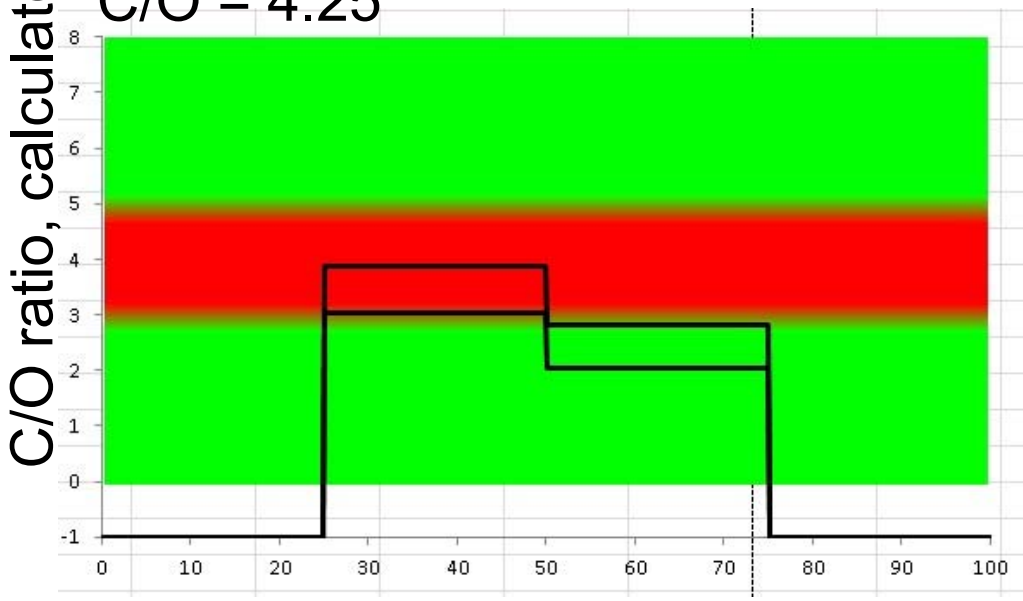

Depth, cm

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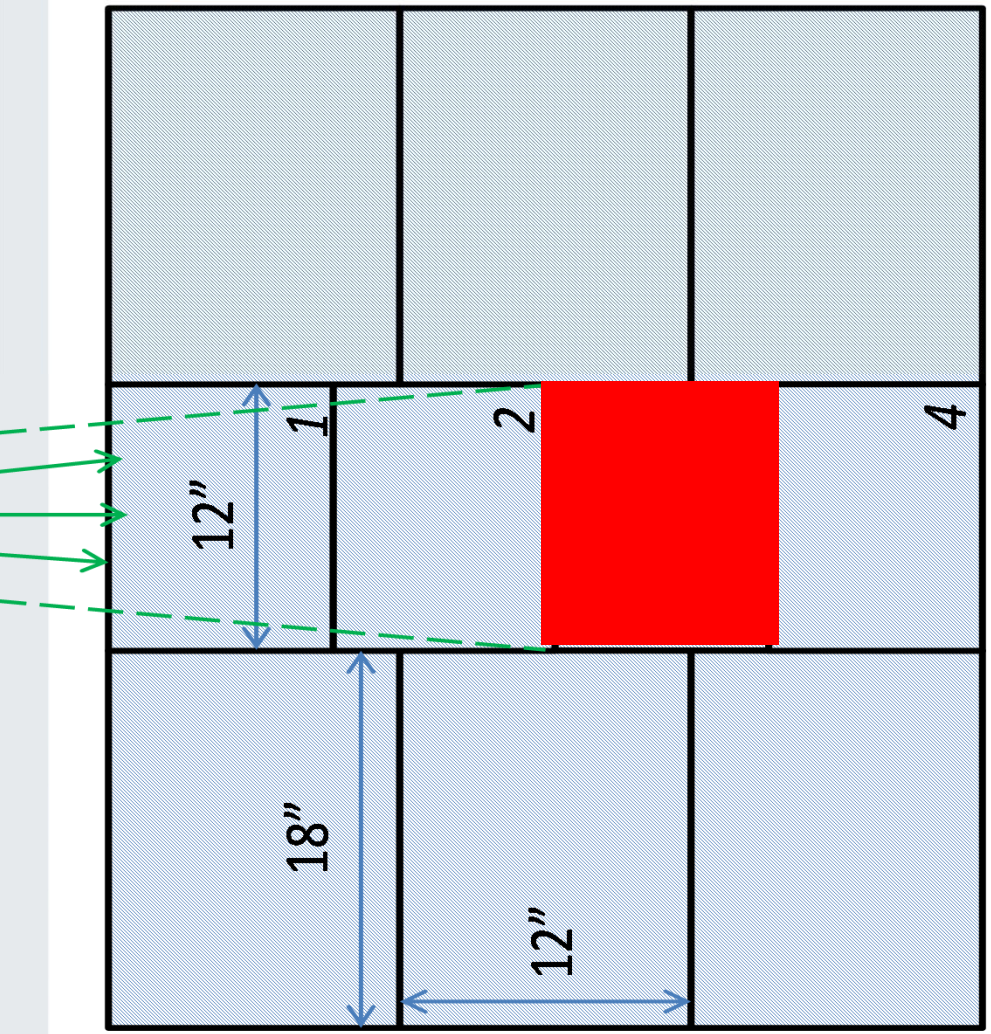

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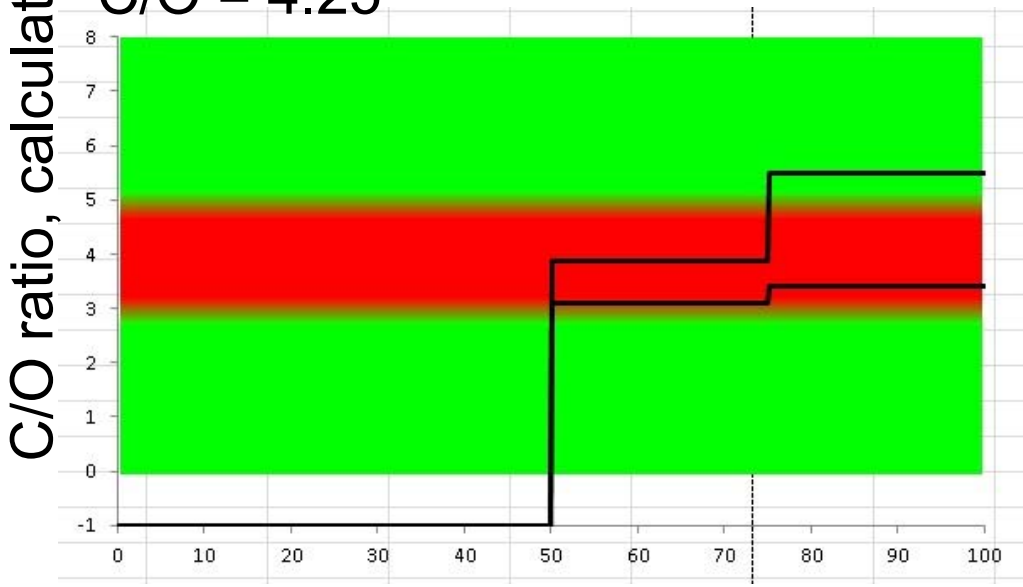

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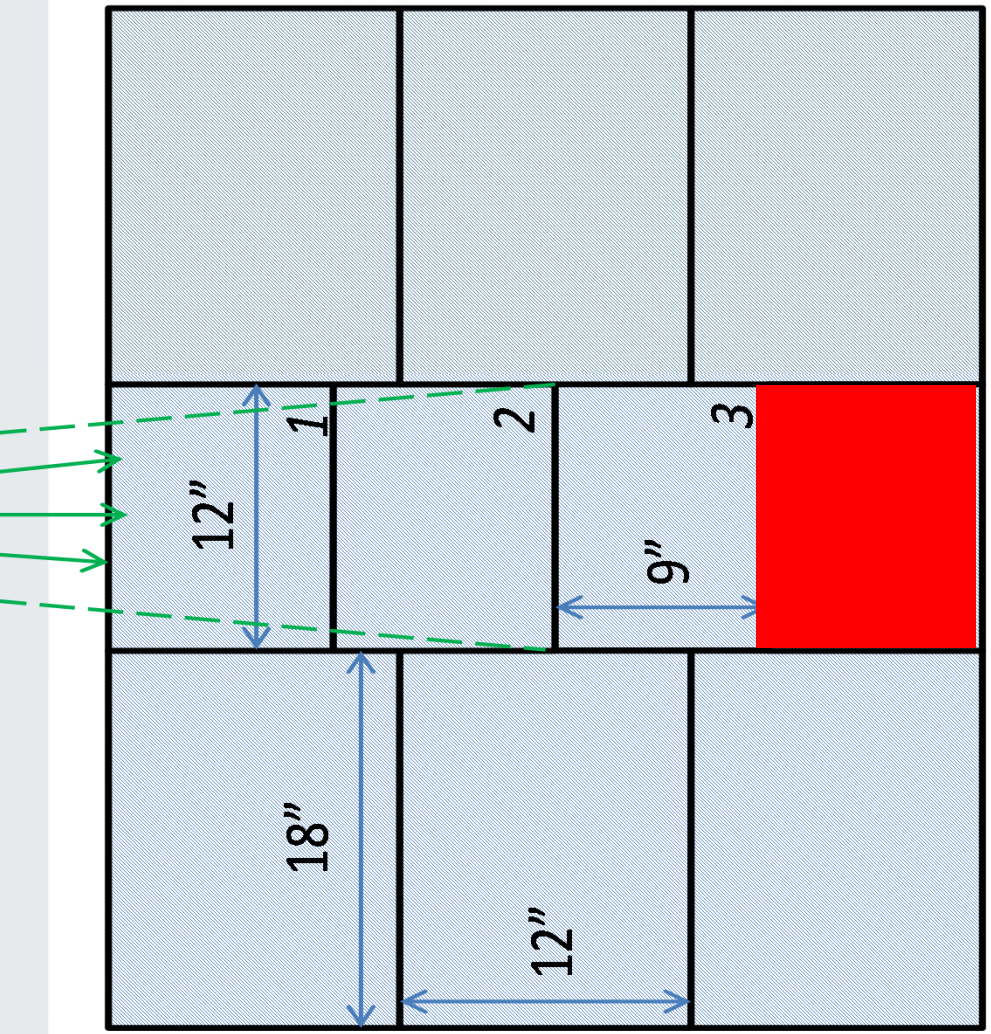

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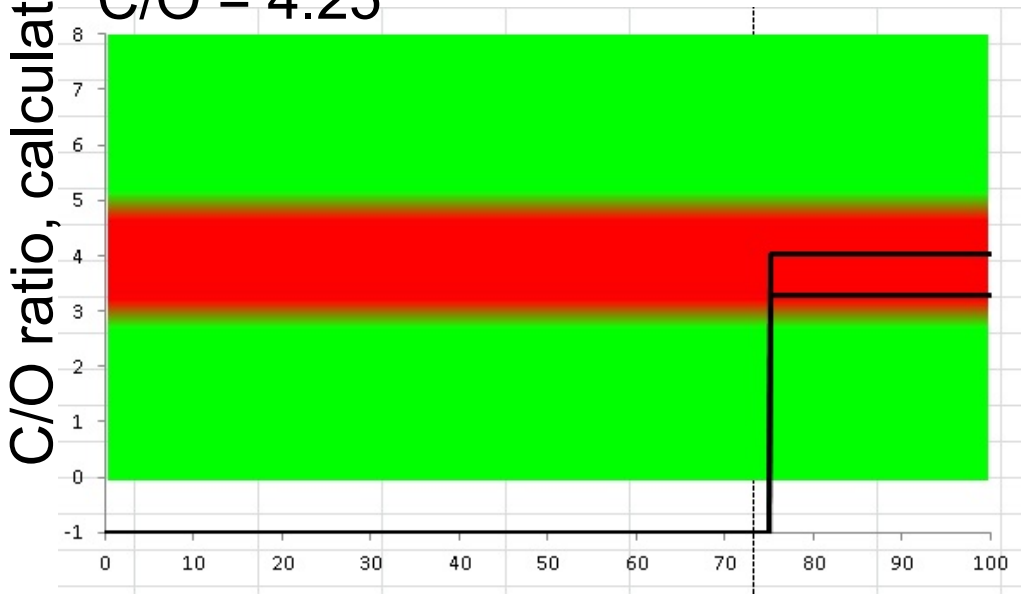

Depth, cm

Lessons learned with API

Significant system performance improvement is expected with:

- Neutron generator with high precision anchor points for easy alignment. Better alignment will reduce background by ~25%
- Better (and heavier) generator and gamma detectors shielding. With better shielding we can increase neutron output by a factor of ~ 2 – 5.
- Optimizing geometry of gamma detector placement. 16 detector configuration will increase signal by a factor of ~2.
- Better spatial resolution can be obtained with faster detector PMTs.

Summary Conclusions

- With mentioned improvement system performance will improve compared to the system used at Purdue.
- Spatial resolution of ~10 cm is achievable.
- Detected cocaine in paper and steel cargo. System did not alarm on sugar.
- Similar performance demonstrated in other cargos.
- API-based neutron interrogation technique with a compact DT generator is a viable drug detection method in small to medium aircraft-size cargo containers. It provides excellent depth imaging information on the elemental composition of the cargo content.
- Further details on results: CARRI 2014, San Antonio, TX May 26-29, 2014