



**Pacific Northwest**  
NATIONAL LABORATORY

*Proudly Operated by **Battelle** Since 1965*

PNNL-SA-102551

# Photon and Neutron interrogation techniques for chemical-explosives detection in air cargo: A critical review

TIM WHITE

Pacific Northwest National Lab

ADSA10



# Summary

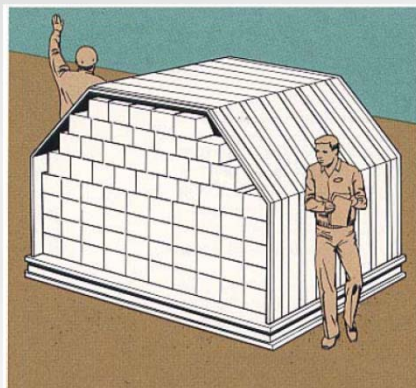
- ▶ Air-cargo screening for explosives with ionizing radiation is hard
  - The object is larger with a wider variety of contents
  - The task is the same
  - Cargo categories may offer tailored solutions
- ▶ Multi-mode interrogation may be needed
  - Photon-neutron radiography
  - Transmission-backscatter radiography
  - Correlated-neutron measurements, NRF
- ▶ Practical limitations
  - Innovative interrogation approaches expensive and complicated
  - Who owns the problem?

# Objects



Pacific Northwest  
NATIONAL LABORATORY

Proudly Operated by **Battelle** Since 1965



Passenger planes carry 7,500 tons of cargo a day in storage areas under passenger cabins that also hold luggage.



## Commodities (partial list)

- Electronics and computer equipment
- Printed material
- Fresh flowers
- Machine parts
- Perishables, grains, animal feed
- Non-metallic mineral products
- Seafood and shellfish
- Chemicals, alcohol, glass
- Wearing apparel
- Paper products (non printed)
- Multiple commodities



# Photon Interactions

“Existing data for explosives detection (FAA-conducted blind tests) indicate that the x-ray systems are not effective in the inspection of full cargo containers to detect explosives and that random selection would be equally useful.”

National Academy of Sciences, 2002



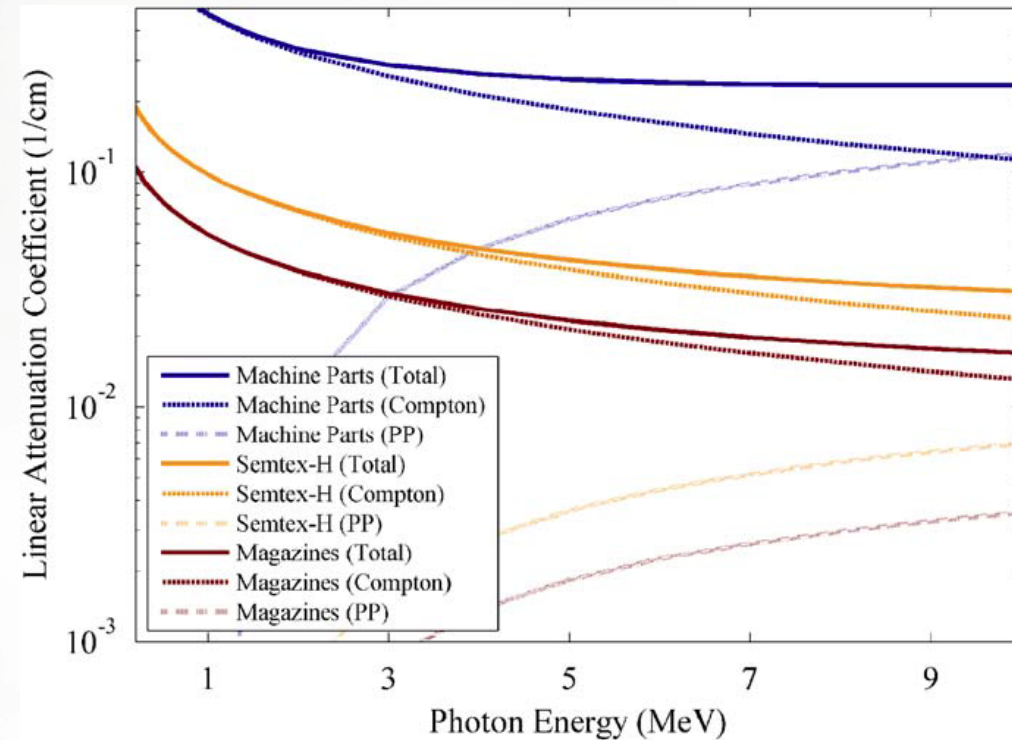
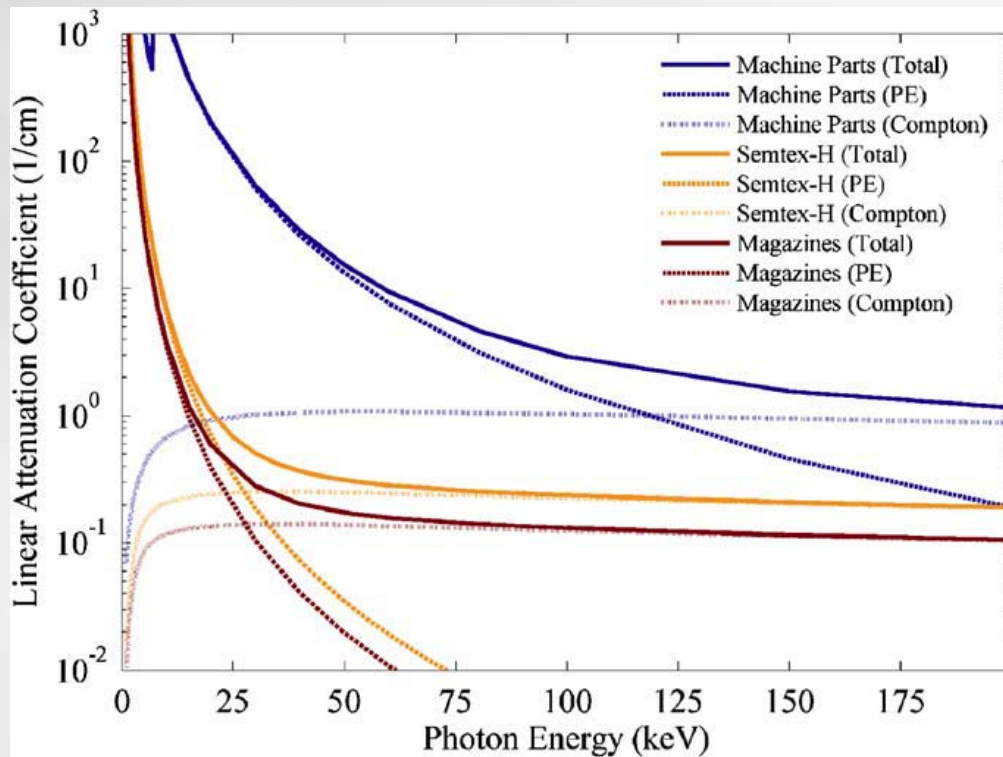
# Photon Interactions

$$\mu_{pe} \propto \rho \frac{Z^4}{A} \frac{1}{E^3}$$

$$\mu_C \propto \rho \frac{Z}{A} f_{KN}(E)$$

$$\mu_C \propto \rho \frac{Z}{A} f_{KN}(E)$$

$$\mu_{pp} \propto \rho \frac{Z^2}{A} f_{pp}(E)$$



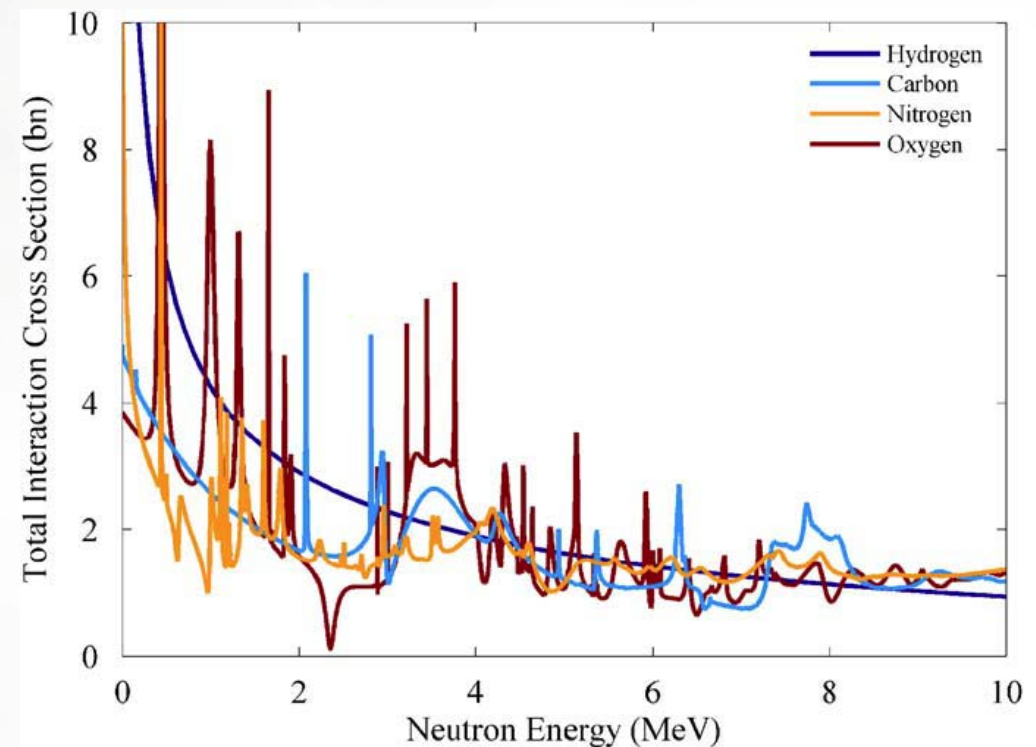
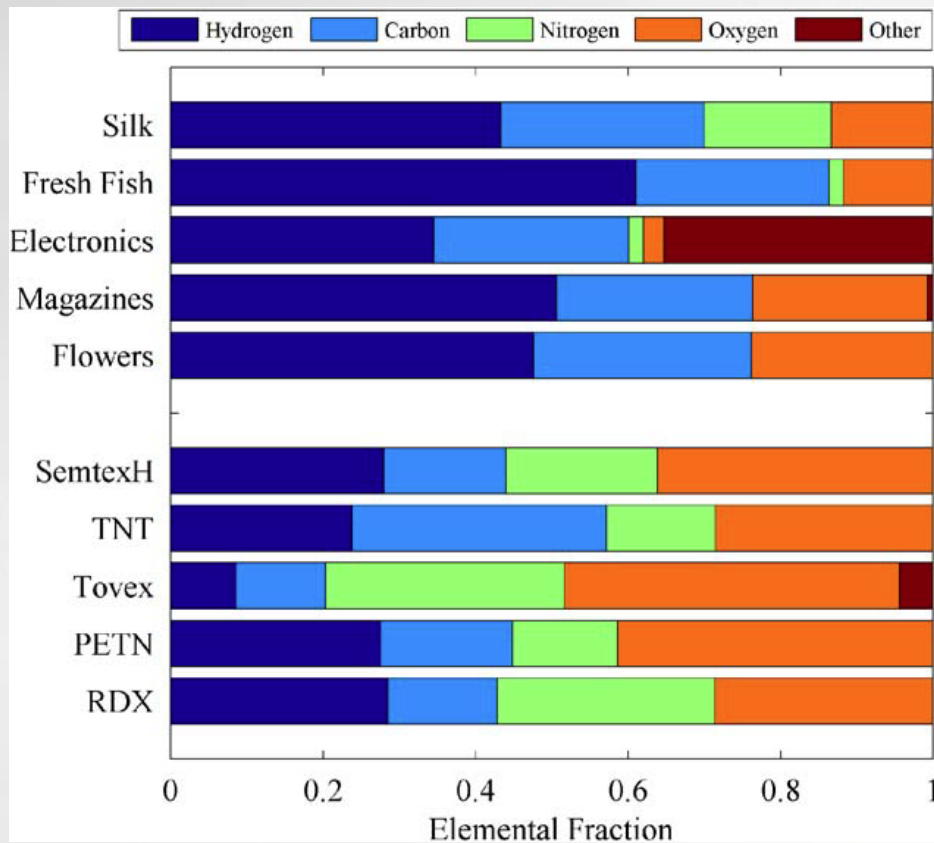


# Neutron Interrogation

Allows access to elemental ratios

Cross section is richer

Absorption, elastic-, and inelastic-scatter measurements possible





# Potential Approaches

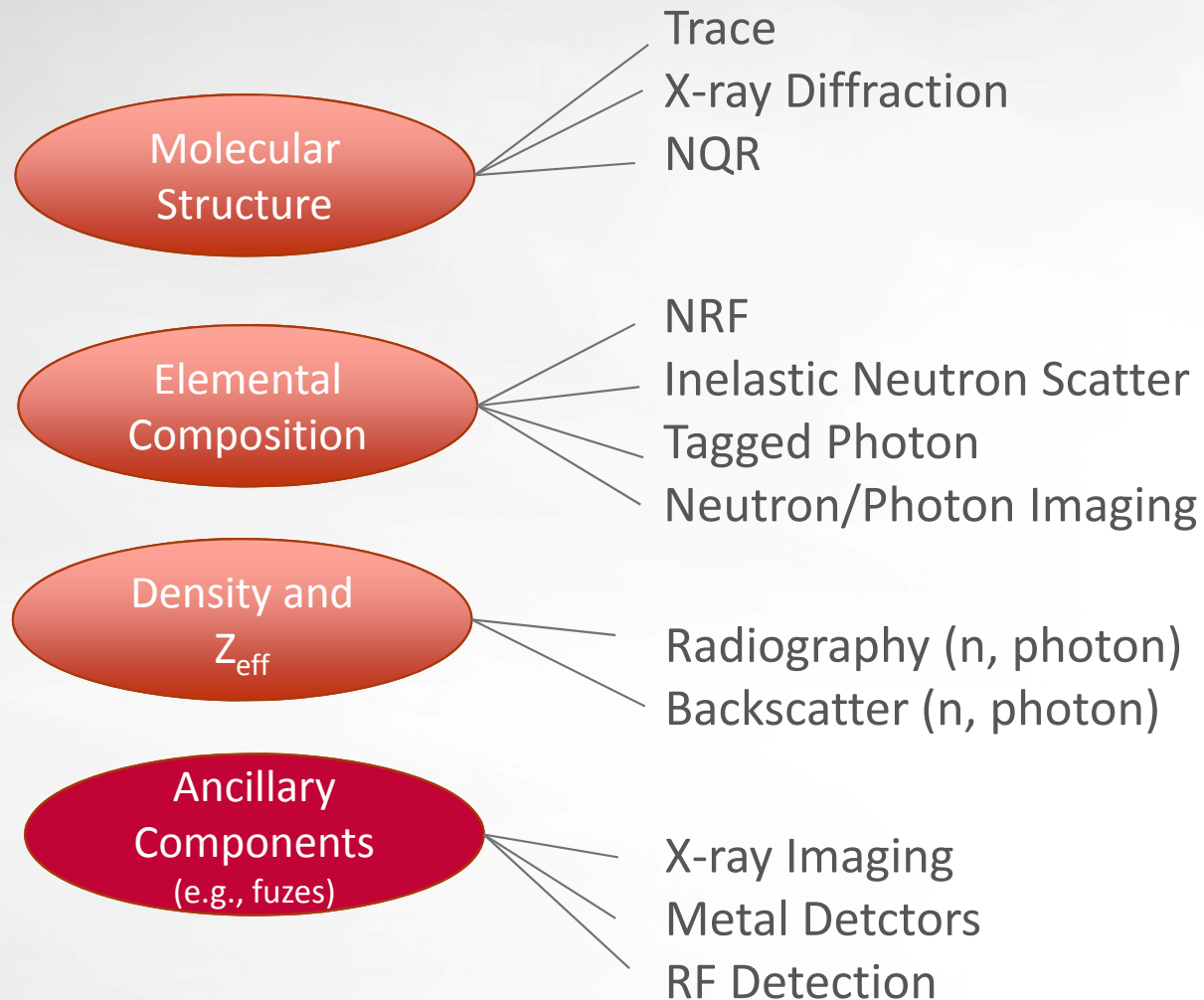
- ▶ Transmission imaging
  - Photons
  - Thermal neutrons
  - Fast-neutron & photon radiography
- ▶ Near subsurface
  - X-ray backscatter
  - Thermal-neutron capture
- ▶ Bulk characterization (photons)
  - PET via  $^{13}\text{N}$
  - Nuclear resonance absorption in  $^{14}\text{N}$
  - Photonuclear reactions with O and N
  - NRF
- ▶ Bulk characterization (neutrons)
  - **Nuclear resonance absorption with fast neutrons**
  - Fast neutron scattering analysis
  - Gamma-ray emissions via fast-neutron scattering (PFNA, API)



# Signatures and Technologies

## Signatures

## Candidate Technologies







# Summary

- ▶ Air-cargo screening for explosives with ionizing radiation is hard
  - The object is larger, the task is the same
  - Cargo categories may offer tailored solutions
- ▶ Multi-mode interrogation may be needed
  - Photon-neutron radiography
  - Transmission-backscatter radiography
  - Correlated-neutron measurements
- ▶ Practical limitations
  - Innovative interrogation approaches expensive and complicated
  - Who owns the problem?