Detection Technology Overview:
What Else Should Be Discussed?

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Algorithm Development for Security Applications 09
October 22-23, 2013


2013
AMERICAN
LEAGUE
CHAMPIONS

Missed Technologies

- Acoustic
  - Battelle / Sellex – TOF and mm-wave (dielectric properties)
  - {velocity, attenuation, density} form signature
  - Or look for anomalies
- Flavors of IR spectroscopy
  - FTIR, Raman, SORS, CARS, CRDS, … molecular vibrations
- Thermal Imaging
- Metal detectors

- Note on Fusion: likely that no single technology will solve the problem
  - An approach to fusion is to look at available signatures and look for complementary ones (more on that later)

Some Technologies Have Not Made It

- Trace portal (IMS, MS) – maintenance
- Neutrons (PFNA, others) – engineering? (& neutrons are scary)
- X-ray backscatter – ATR?
- Electronic noses – sensitivity and mixtures

- Still in the lab (maybe for a long time)
  - CARS
  - THz

Our Definition of Signature

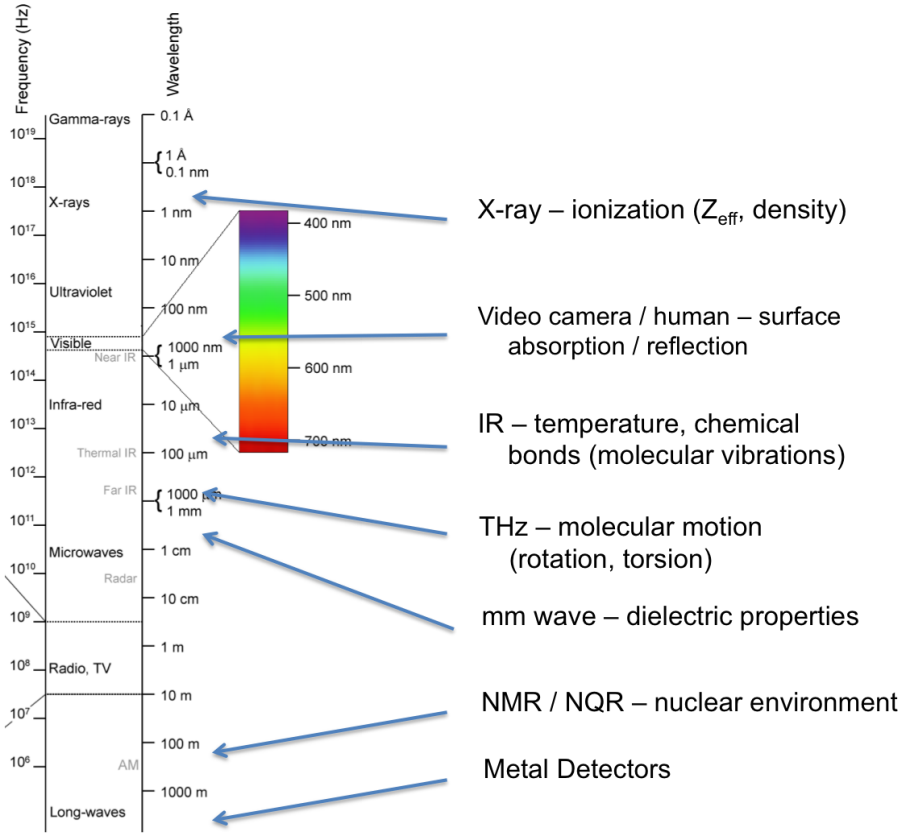
- Signature (strict) – unequivocal evidence identifying a phenomenon

There are precious few strict signatures of an IED available non-intrusively

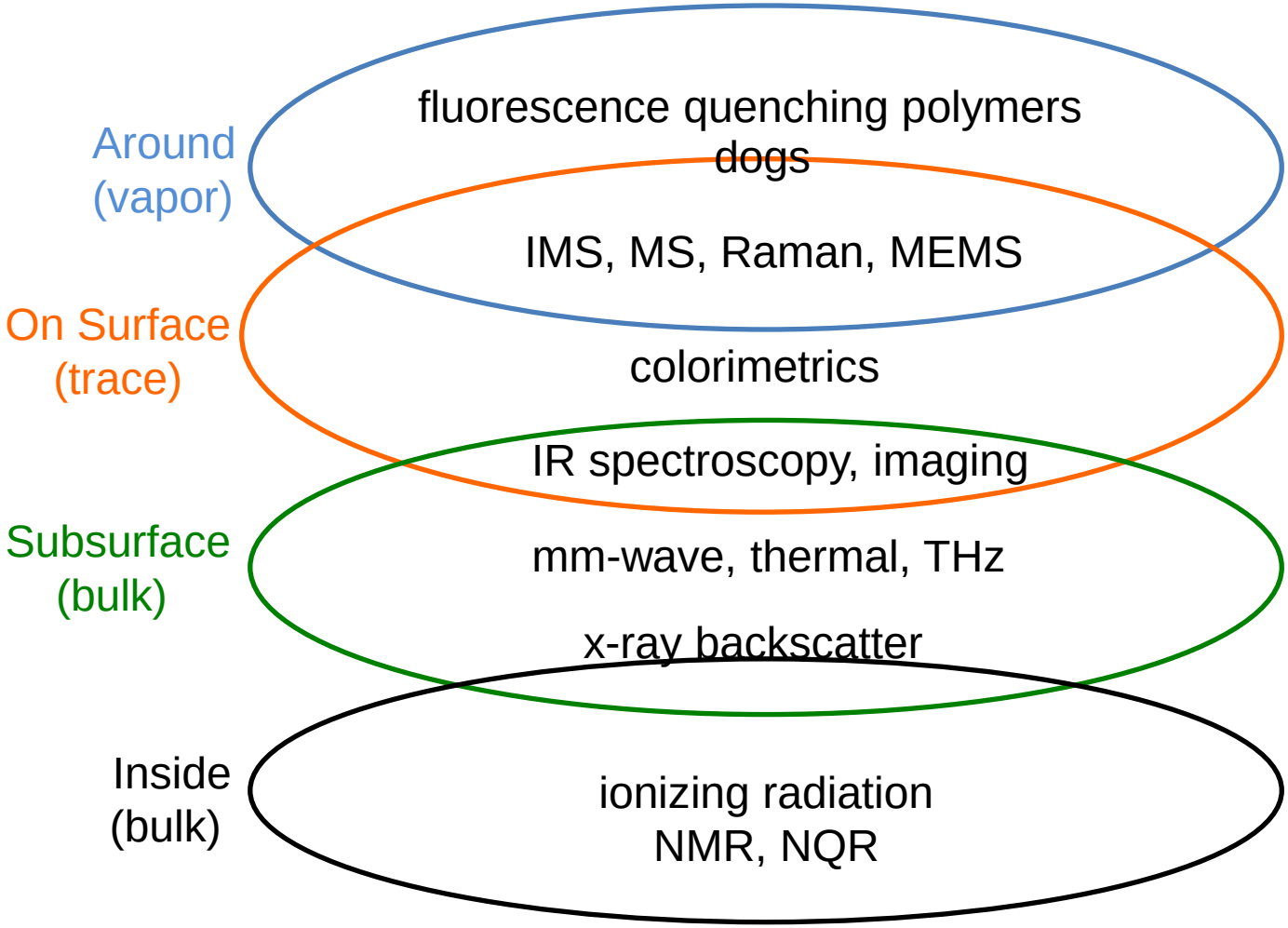
- Signature (less strict) – evidence that implies the presence of a phenomenon
  - Any observable that indicates the presence of an IED or a component of an IED will be considered a signature
  - Signatures can be ranked according to accessibility, availability, and diagnostic utility
- Availability is *how much* of the signature is present
  - Independent of detection modality, Dependent on scenario
- Accessibility is *how easy* it is to get at an signature
  - Dependent upon detection modality, Relatively independent of scenario
- Diagnostic Utility is *how well* the signature points to a chemical explosive, component, or device
  - There is a diagnostic utility of the indicator alone
  - And a diagnostic utility of the detection modality

Signatures and Interrogation Techniques

- Neutrons – elemental ID (& ratios)
- X-rays – Z_{eff}, density, texture, molecular structure (diffraction)
- Imaging – shape, context, contrast (density, reflectance, dielectric constant)
  - Include ionizing radiation and EM
- IR – molecular vibrations (functional- group specific)
  - Raman (more specific. Less sensitive)
- IMS – molecular size and shape
- MS – molecular mass
- Chemical structure – MEMS, colorimetric, AFP
- Acoustic – density, viscosity



Where, What, and How



General Detection Modalities

Signatures for explosives detection grouped depending on point of view

Generic Interrogation Technique	Category of Signature			
Physically Sample and Analyze	Vapor	Trace		
EM Spectroscopy	Vapor	Trace	Bulk	Ancillary
EM Imaging	Vapor	Trace	Bulk	Ancillary
Ionizing Radiation Imaging			Bulk	Ancillary
Magnetics		Trace	Bulk	Ancillary
Acoustics			Bulk	

Physically Sample and Analyze

- Amplifying Fluorescent Polymers
- *Bio-Inspired Detection*
- Canines
- *Cavity Ring-Down Spectroscopy*
- Colorimetric Methods
- Ion Mobility Spectroscopy
- *Mass Spectroscopy*
- Micro-Mechanical Systems (MEMS)
- *Other Species*

EM Spectroscopy

- *Coherent Anti-Stokes Raman Scattering*
- IR Spectroscopy
- *Laser-Induced Breakdown Spectroscopy (LIBS)*
- Nuclear Quadrupole Resonance
- *Photoacoustic Spectroscopy*
- Raman Spectroscopy
- *THz Spectroscopy*

EM Imaging

- *Hyperspectral IR Imaging*
- Infrared/Thermal Imaging
- Mm-wave imaging
- *THz Imaging*
- Visible Imaging
- NMR

Ionizing Radiation Imaging

- Backscatter X-ray Imaging
- *Neutron Inelastic Scattering*
- *Nuclear Resonance Fluorescence*
- *Photonuclear Methods*
- *Thermal-Neutron Activation*
- X-ray Transmission Radiography
- X-ray CT

Detection Technology Categories

- Laser-Based Standoff Spectroscopy – molecular ID
  - IR (Raman (inc. coherent anti-Stokes Raman), LIBS, cavity ring-down spectroscopy, photoacoustic)
  - THz
- Electronic- and Chemical-Based Trace – molecular ID
  - Ion mobility spectrometry, mass spectrometry, MEMS
  - colorimetric, amplifying fluorescent polymers,
  - IR-imaging spectroscopy
- Biosensors – ?
  - Canines, bees, mice, pigs
  - Bio-inspired detection methods
- Electromagnetic – molecular ID, anomaly
  - NQR, mm-wave imaging, THz imaging
- Neutrons – elemental ratios (shape)
  - Thermal neutron activation, neutron inelastic scattering
- High-energy photons – elemental ratios, (shape)
  - Photonuclear, NRF
- X-ray imaging – density, Z_{eff}, shape
  - Radiography, CT, backscatter

Sampling and preconcentration may improve many of these technologies

"Bulk" techniques, often called anomaly detectors

		Wavelength / energy	Signature	Type of detection	Type of data	Status	Threat Recognition
PEOPLE	NQR	0.5-5MHz	RF resonance (molecular environment or N content)	Material ID (N lines)	Spectrum	COTS, lab	Automated
	Active mm-wave	20-40GHz (15-7.5mm)	Anomalous scattering from dielectrics	Anomaly	2D+ images (motion, 3D surface)	COTS	Human / ATR assist
	Passive mm-wave	30-300GHz (10-1mm)	Anomalous attenuation/scattering of natural radiation	Anomaly	2D image sequence	COTS	Human / limited ATR
	THz imaging	0.1-3THz (3-0.01mm)	Anomalous attenuation /scattering from dielectrics	Anomaly	2D image sequence (~4Hz)	COTS, lab	Human
	THz spectroscopy	0.1-3THz (3-0.01mm)	RF absorption bands due to molecular vibrations	Material ID	spectrum	lab	Automated(?)
	Thermography	8-10μm (37.5-30THz)	Differential transmission of thermal emission from body	Anomaly	2D image sequence	COTS	Human
	IR spectroscopy	8-13μm (37.5-23THz)	RF absorption bands due to molecular vibrations	Material ID	Spectrum Spectral image	COTS, lab	automated
	X-ray backscatter	50-125kVp	Differential scattering (Z_{eff}, ρ)	Anomaly	2D image	COTS	Human
	Trace Portals (puffers)		IMS (or MS) spectral match	Material ID	spectrum	COTS	Automated
	Metal Detectors		Eddy current induced in metals	Anomaly (metal)	Alarm (1-2D field pert.)	COTS	Automated
BAGGAGE & CARGO	X-ray transmission imaging	80-160kVp < 450kVp > 1MeV	Differential attenuation (Z_{eff}, ρ)	Anomaly (material discrim. (CT))	2D or 3D image	COTS, lab	Human / Automated
	NMR	kHz	Characteristic decay of RF signal from ^{1}H	Material ID	3D material map	COTS, lab	Automated
	Acoustics	20Hz – 200MHz	Resonant spectra, density, acoustic impedance, velocity	Anomaly (material ID)	2-3D image, spectral data	COTS, lab	Human or automated
	Neutrons Interrogation	eV to 14MeV	Differential attenuation Characteristic gamma emmission	Material ID	Elemental ratios (spectral)	Lab	Automated

Strategies

- Consider approaching explosives detection as a signature "pull" rather than a technology / widget "push"
  - This is tricky 'cause we are widgeteers
- Possible approaches – consider broad categories of…
  - … types of signatures
    - vapor, trace, bulk
  - … technologies and the types of signatures accessible
    - PSA, EMS, EMI, ionizing, metal, acoustic
  - … places to look
    - around object, on surface, subsurface, inside
    - "object" could be person or bag
- Or consider methods to improve existing widgets

ECAC LEDS Testing

European Civil Aviation Conference Liquid-Explosives Detection System

- Testing and performance standards for liquids
- Common Evaluation Process does not constitute certification or approval
- Increasing orders of intrusiveness
- Indication of which technologies fit where

Type	Description	Technologies
A	Open Container	Fluorescence quenching, chemiluminescence, colorimetric, Raman
B	Closed Container	X-ray scatter, {RF, IR, magnetic inductance, gravimetric}, Raman, microwave, {RF & ultrasound}
C	Multiple Containers	Radiography (multiview, multienergy)
D	Containers in baggage	CT
D+	with electronics present	CT