Center for Awareness and Localization of Explosives-Related Threats (ALERT)

A DHS Center of Excellence for Explosive Detection, Mitigation, and Response

Preliminary Year Two Workplan

January 28, 2009

Table of Contents

Center for Awareness and Localization of Explosives-Related Threats (ALERT)
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Research Program Rationale
July 28, 2008

J.C. Oxley (URI) & M. B. Silevitch (NEU)

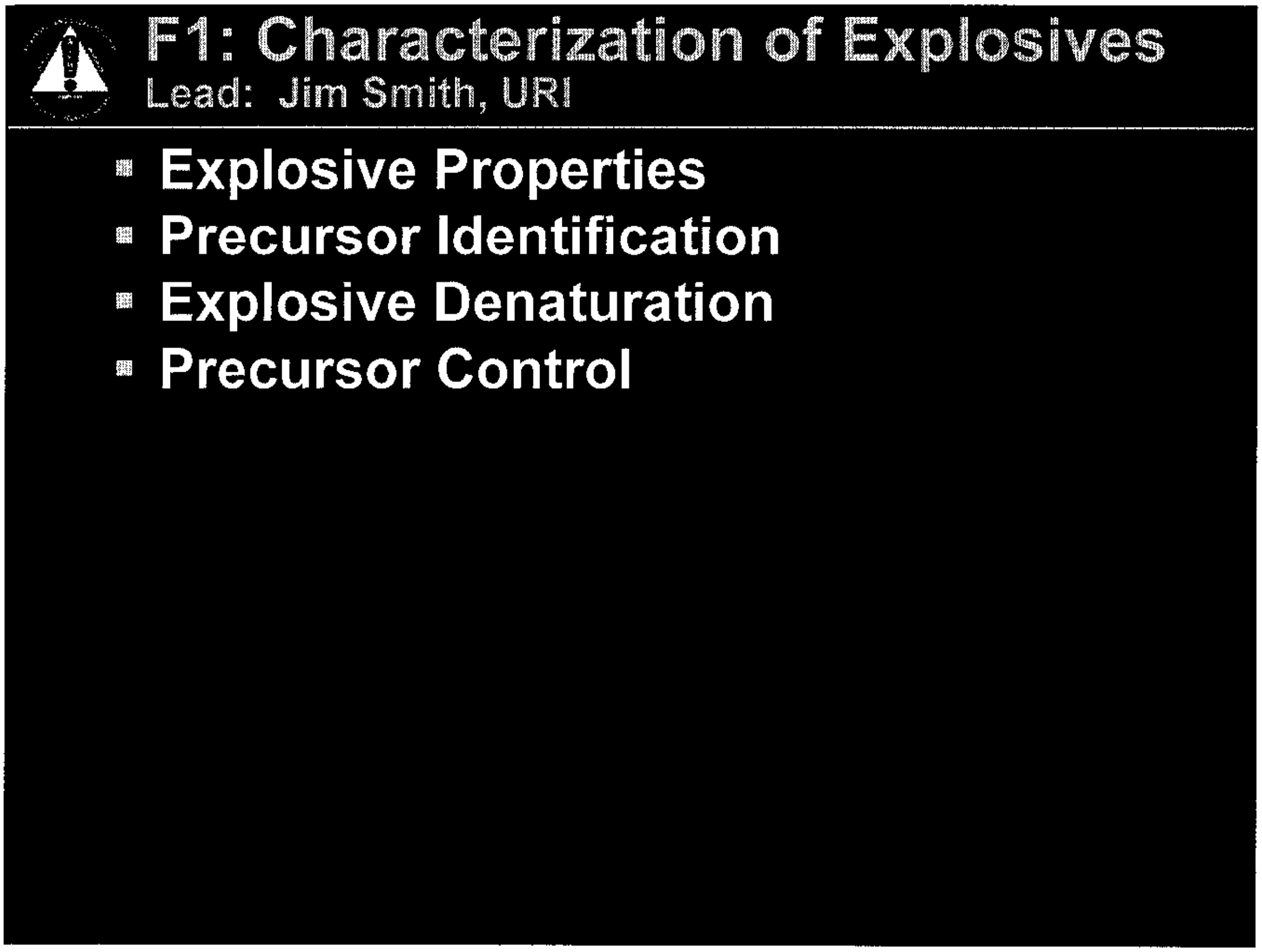
The goal of the ALERT CoE for Explosives Detection, Mitigation, and Response is to prevent the catastrophic damage to U.S. society that can be caused by explosive attacks. One of the most obvious ways to prevent an explosive attack is to foster our ability to detect explosives or improvised explosive devices (IEDs). As a result of our analysis of the various components of the ALERT mission, we distilled the complementary research into four interrelated thrusts. These are: ***Explosives Characterization, Explosives Detection Sensors, Explosive Detection Systems*** and ***Blast Mitigation.*** Moreover, of the myriad approaches to explosives detection, we have chosen some of the most promising of the less mature techniques, where we feel basic research can make the greatest impact. In explosive detection multi-sensor systems, we have focused on sensor fusion, complementarity, effective deployment and management as the areas where new fundamental research is most needed.

To detect explosives and IEDs, a number of basic explosive properties must be known. Military explosives have been subjected to decades of characterization and safety and performance reviews, but homemade explosives only receive such attention after their use by terrorists. Properties that influence the signature of an explosive or IED are an obvious area where much characterization is required. The ***Explosives Characterization*** thrust area will continue to characterize homemade explosives (HME) and provide that data to those involved in counterterrorism efforts. However, even determination of potential threat materials is not straightforward. One of the efforts in Characterization will seek to create a small-scale test to assess the threat potential of a given energetic material. Being "energetic," i.e. releasing heat upon decomposition, is a simple property to measure, but not sufficient to guarantee detonability. It is important to identify potential threat materials, and equally important not to label merely hazardous materials as detonable. Presently, identification of potentially detonable materials cannot be done on anything less than full-scale because most HME are relatively poor-performing explosives, compared to military explosives, and require large volumes of material (large critical diameters) to support detonation. Determining explosivity definitively on the lab- or intermediate-scale will save weeks of formulating and testing and tens of thousands of dollars for each mixture evaluated. The proposed groundbreaking research would permit hundreds of formulations rather than a handful to be characterized as to their potential detonability. In addition, the Characterization thrust area will examine ways to prevent bombings by control of chemical precursors. In some cases, administrative controls may be possible; in others the widespread availability of a chemical makes administrative controls ineffective. A few chemicals stand out as major threats: ammonium nitrate (with any fuel); urea (nitrated to form urea nitrate); nitric acid (to nitrate urea or any number of organics, e.g. trinitrotoluene); chlorates (with any fuel); and hydrogen peroxide (to make TATP or HMTD or in concentrated form with miscible fuels as an explosive). Of these, ammonium nitrate and nitric acid may lend themselves to administrative controls; hydrogen peroxide does not. For that reason the CoE will examine ways to denature it such that its original purpose in commerce is not negated, but its use as an explosive precursor is.

Sometimes despite our best efforts, a bomb will go off. We need to be pro-active in protecting our high-value targets against such events. The ***Blast Mitigation*** thrust area will focus on basic research needed to develop novel materials and structures to mitigate blast effects. The research thrust areas chosen initially do not encompass the entire scope of mitigation but have been selected after conversation with a number of researchers in the field as potentially the most promising and, in some cases, offering short-term improvements to structural integrity. Our approach includes development, characterization, and modeling of novel heterogeneous materials (including particulate, layered and functionally graded materials, and sandwich compositions) and their response when subjected to extremely high strain rate blast loading. An integral part of the thrust is the understanding and modeling of structural response, including nonlinear shock propagation, progressive collapse, and various loading scenarios such as external and internal blast, fragments, and fire. Efforts are also aimed at hardening structures: coatings for structural protection during blast; self-healing materials; and smart protective structures.

In the ***Explosives Detection Sensors*** thrust area, we have looked at a combination of advanced concepts for wave-based and chemical-based sensing for both close-in and standoff applications. In the ***Explosive Detection Systems*** thrust area we are examining the use of novel reconstruction and image processing algorithms and multi-sensor fusion strategies to provide optimal information about complex threat scenarios such as those found in the screening of airport passengers and luggage or in the surveillance of critical areas such as subway platforms, urban traffic, within a sports arena or a shopping mall. In both of these thrust areas (and in general for all the thrusts) we have based our assessment of the gaps in the existing fundamental science via several mechanisms. In addition to reviewing literature on the subject, we have consulted colleagues in academia, the national labs, federally-funded research & development centers, and industry. We have attended focused research meetings on topics of relevance (i.e. the Gordon Research Conferences on Explosive Detection and on Energetic Materials). These assessment activities will be ongoing as we determine fruitful areas of research for counter-IED initiatives.

In summary, in all the thrust areas, the "best of the best" were selected from within the NEU and URI proposal teams. It is intended that in future years we will reach out to others in the academic community who can add their novel ideas to the critical mass of fundamental science being conducted from within the Center. We are mindful that the outcome of some of the research may not bear significant fruit in terms of long range impact on the DHS mission. However, we will be cognizant of both the successes and failures of our research and report on both aspects so that future research will not have to "reinvent the wheel." It is expected that though the Center's research will evolve, it will maintain a basic focus relevant to the overall DHS mission.



NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

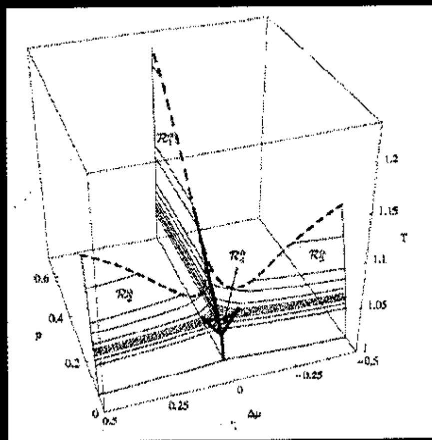
F1-A: Vapor/liquid equilibria & phase behavior of H_2O_2 systems -- BL Weeks, Texas Tech; CS Yoo, Washington State

Purpose/ Relevance: **To determine vapor liquid equilibria (VLE) of $H_2O+H_2O_2$ binary system & $_2O+H_2O_2$+adulterant ternary system.**

Innovation: **Study on 3-phase VLE & phase transitions to determine adulterants to limit hydrogen peroxide distillation.**

Long-range impact: **Discovery of adulterants which make distillation of H_2O_2 difficult. Study will contribute to the understanding of fundamental properties.**

First year accomplishment: **Develop capability for VLE measurements (TTU) & systems for phase identification (WSU). Currently VLE is based on 1952 study with misused thermodynamic model.**



Typical 3D phase diagram for a binary mixture P, pressure, T, temperature, Δμ, % of each component. Each dashed line represents a triple line. The ℜ1-4 are equimolar planes of similar composition.

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F1-B: Intrinsic Detonability Determinations

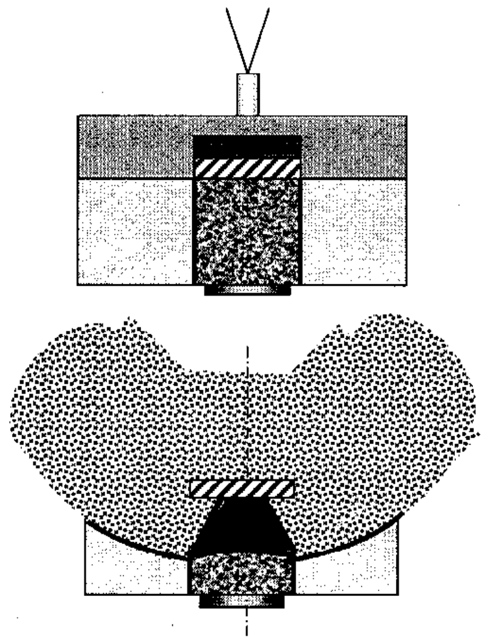
J Oxley, J Smith, J Kennedy, P. Bowden; L. Steinkamp URI; S Stewart UIL

Purpose: **Identify potential explosive chemicals/precursors.**

Innovation: **Presently no test which positively determines detonability. Critical diameter is an issue.**

Long-range impact: **Revolutionary way to evaluate materials for detonability as well as hazards.**

First-year outcome: **1) examination of RDX-spiked chemicals using exising SSED; 2) design & testing of shock-focusing fixture.**



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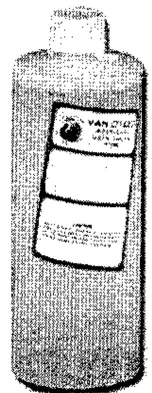
F1-C: Denaturing of Explosive Precursors

J Smith, J Oxley, J. Brady, S. Vadlammanati; URI



<u>Purpose:</u> To identify safe additives which can be added to explosive precursors, e.g. H_2O_2, AN, urea, chlorates, nitrates, and thus prevent their use or make them less effect in illicit bombs.

<u>Innovation:</u> Denaturing, itself, is not innovative, e.g. EtOH, but for some explosive precursor this appears to be the only solution to the threat. (Part of the study will identify cases where administrative controls could be effect, i.e. denaturing not required.)

<u>Long-range impact:</u> To identify potential denaturin ingredients, the fundamental nature of the materials & detonability will be studied.

<u>First-year outcome:</u> H_2O_2 will be focus, identifying its uses in society; literature available; reactivit with a number of ingredients; reaction mechanisms.

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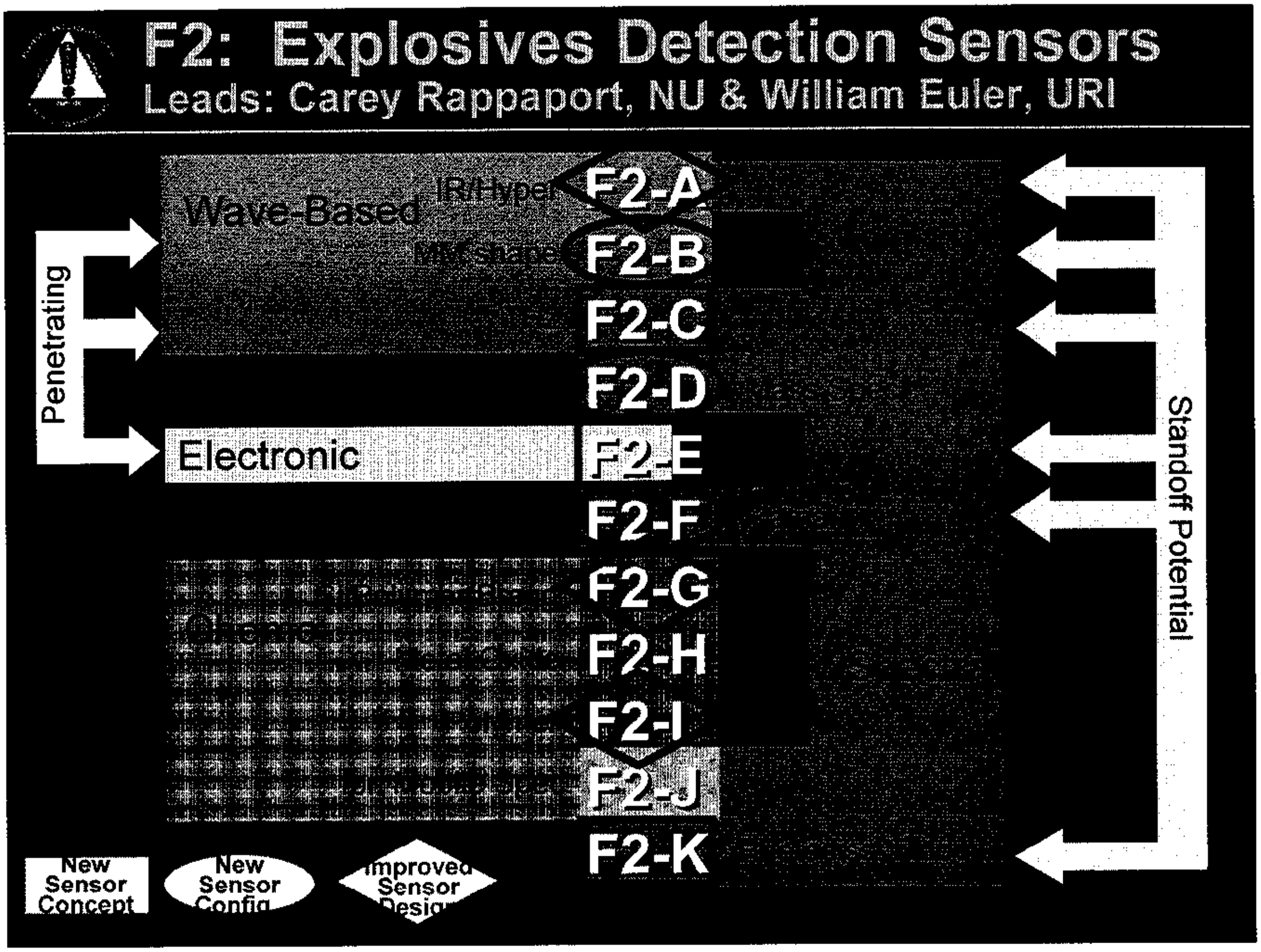

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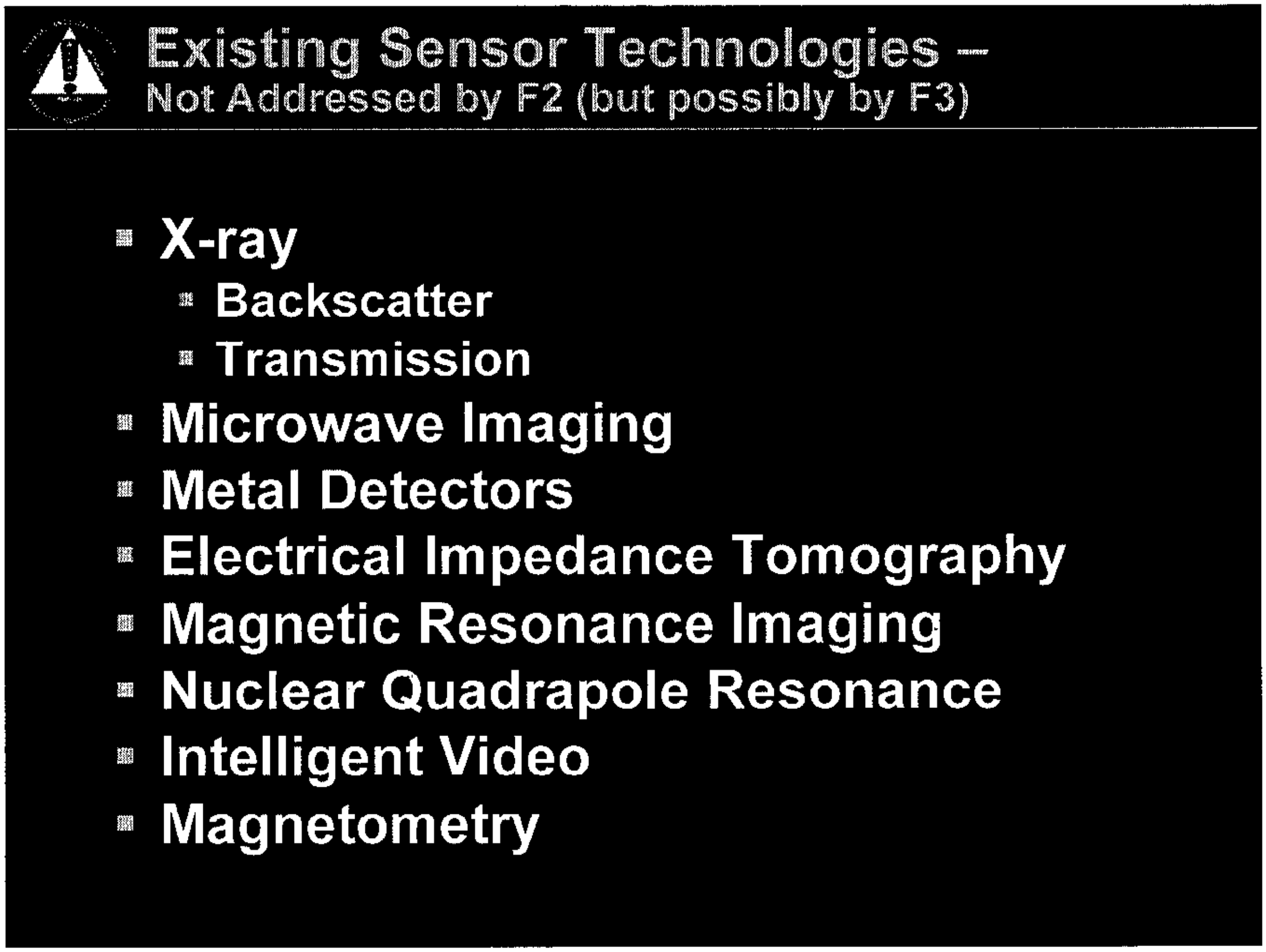

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Industrial and Government Labs Involved in Sensor Development

- CenSSIS / ALERT Partners
  - Analogic
  - GE
  - AS&E
  - Siemens
  - Raytheon
  - Lockheed-Martin
- Ongoing Discussions
  - L3 (US)
  - Reveal Imaging Technologies (US)
  - Smiths (UK)
  - Fraunhofer Institute (Germany)
  - MIT Lincoln Lab (US)
  - Jet Propulsion Lab (US)
  - MITRE (US)

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F2-A Explosive Detection using Hyperspectral Imaging
Vélez-Reyes, Santiago (UPRM), Castañón (BU)

- Motivation and purpose:
  - Increase detection rates while reducing false positive alarms in explosive detection systems with high throughput for standoff and portal-based detection systems using hyperspectral imaging (or imaging spectroscopy)
- Innovative Aspects
  - New theories for detection and classification algorithms that determine when additional information is needed that work in concert with human-in-the-loop.
  - New methods for target/background contrast enhancement based on nonlinear machine learning methods and geometric PDEs
  - New unsupervised methods for hyperspectral image unmixing
  - Use of GPUs for real-time implementation of hyperspectral image processing algorithms
- Year 1 accomplishments
  - Unsupervised unmixing algorithms
  - Study of different geometric PDEs for hyperspectral image enhancement
  - GPU implementation of diffusion geometric PDEs for hyperspectral image enhancement
  - Processing Data from Raman Telescope work of S. Hernandez at UPRM
- Long range impact
  - Novel hyperspectral image processing techniques that can lead to robust and adaptive detection and classification systems for explosive detection

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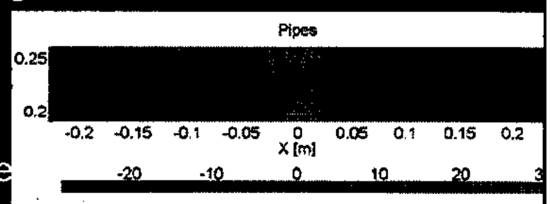
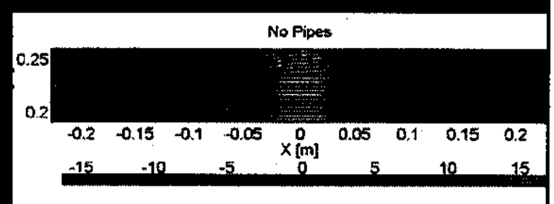
F2-B Millimeter Wave Standoff Detection of Concealed Explosives

Carey Rappaport and Jose Martinez, NEU

- Purpose and Relevance:
  - Detect foreign objects on individuals under clothing at safe distance
  - Use mm-wave radar to safely and unobtrusively screen subjects
- Innovation:
  - Use wide aperture antenna for narrow scanning beam and multiple views
  - Observe large phase variations due to irregularities on skin
- Year 1 accomplishments:
  - Model wave interaction with typical explosive targets to determine feasibility and optimal frequency range / antenna size
  - Experimentally test COTS MMIC radar in array configuration



- Long Range Impact:
  - Fast, automatic, standoff alert of objects hidden under clothes
  - Model-based detection optimization



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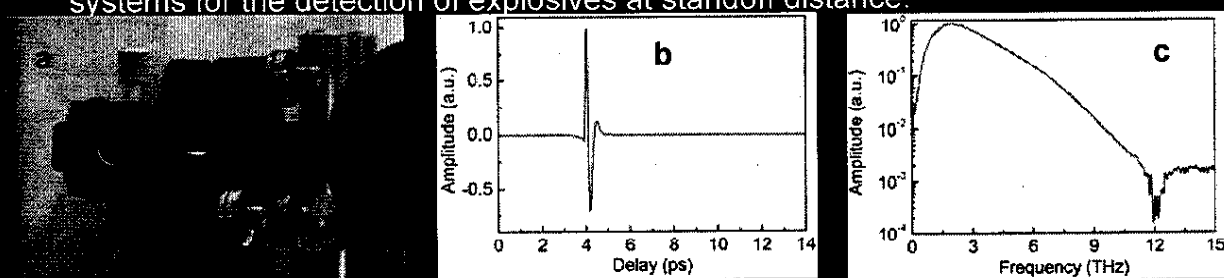
F2-C Science of broadband THz wave photonics: THz generation and detection with gases for standoff detection

X.-C. Zhang, J.M. Dai, E. Gagnon, and M. Yamaguchi, RPI; W. Rockward, Morehouse

- Purpose and Relevance: Understanding the underlying science of THz wave photonics using air and gases as THz wave emitters and sensors might provide a feasible approach for the concealed items' detection at standoff distance.
- Innovative Aspects: We will use a complete quantum mechanical model to fully describe THz wave generation and detection using air (gases) by solving the time-dependent Schrödinger equation; and we will experimentally verify the theory.
- Year 1 accomplishments: Investigation of the physics of intense broadband THz wave photonics in gases; exploration of the fundamental limit of standoff detection.
- Long range Impact: The physical mechanisms behind these effects merit further study and will both illuminate the path to providing useful information about the interaction of intense electromagnetic fields with gases and lead to improved THz systems for the detection of explosives at standoff distance.



a. Laser induced air plasma. b: THz signal emitted and sensed by dry air. c: THz spectrum.

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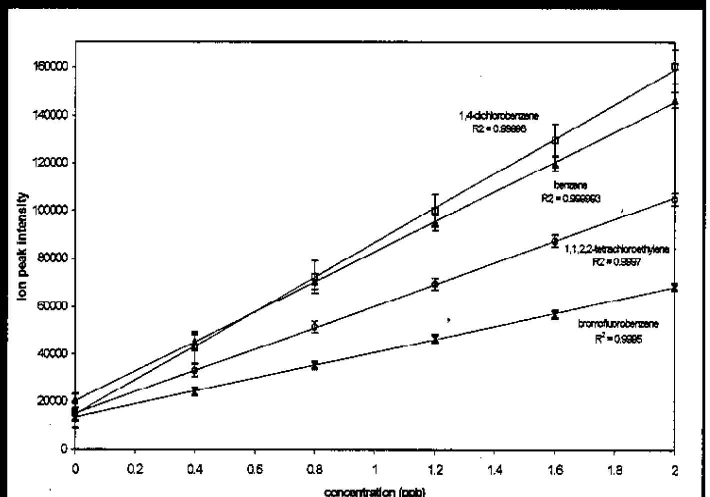
F2-D An Intelligent Mass Spectrometer for Identifying Explosives and Chemical Weapon Threats

Richard Camilli, WHOI

- Purpose and Relevance:
  mobile explosives & chemical weapons detection
- Innovative Aspects:
  in-situ mass spectrometry & autonomous feature classification for determining:
  - threat type
  - location
  - magnitude
  - if multiple threats are present
- Year 1 accomplishments:
  detection capability for explosive agents, precursors, and breakdown products
- Long range Impact:
  rapid, accurate identification and localization of multiple threats across wide classes of explosives



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F2-D continued: Threat identification/localization in complex environments using chemical plume analysis

R. Camilli and M. Jakuba (WHOI)

Objectives: Portable MS as enabler to

Rapidly detect, identify threat plumes (e.g., explosives, chem/bio weapons)

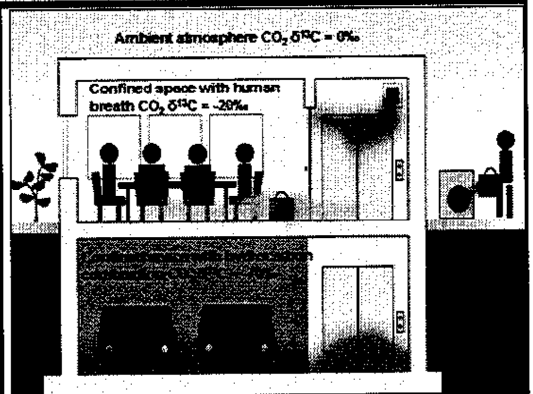
Confirm/rule out source location at large standoff distances without knowledge of flow field

Challenge:

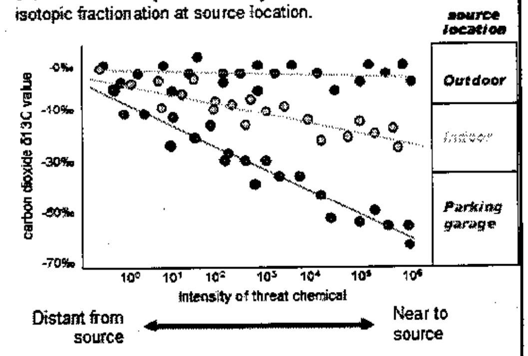
State of the art methods either do not indicate coverage or require extensive a priori modeling of plume mixing and advective flow in complex environments.

Proposed Solution:

Use ambient or synthetic tracers as reference plumes to establish or rule out provenance of plume source. These enable characterization of complex, dynamic environments in real time. Intermingled plumes indicate probable source locations.



Example: determining location of threat based on correlation of threat chemical plume intensity with ambient carbon dioxide isotopic fractionation at source location.



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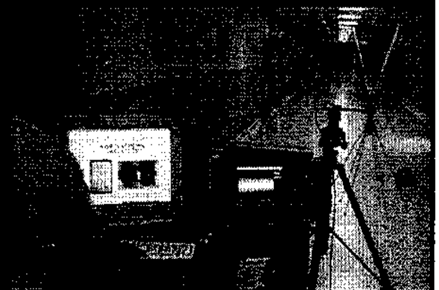
F2-E Detection of Electronically Initiated Explosive Devices

D. Beetner, J. Drewniak, S. Grant, D. Pommerenke, Missouri Univ. S & T.



- Purpose and Relevance
  - Develop methods to detect and identify electronics commonly used in explosive devices based on their unintended electromagnetic emissions
- Innovative Aspects
  - Potentially fast, long-range detection and location
  - Detection basis orthogonal to many other explosives-detection methods, allowing effective sensor fusion.
  - Same physics used to detect devices can potentially be exploited to neutralize device without destroying forensic evidence.
  - More than 15 years of experience performing research for a consortium of 20 companies to help them *reduce* the emissions and susceptibility of their products.

- Year 1 Outcomes
  - Characterize emissions from superheterodyne receivers
  - Design algorithms to detect and locate superheterodyne receivers using *stimulated* emissions. Stimulation method is a patent-pending method that allows rapid detection and location of specific classes o devices from long range
  - Demonstrate performance of detection technique
- Long range Impact
  - Develop firm scientific foundation for methods to detect, identify, and neutralize electronics associated with explosive devices

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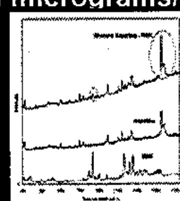
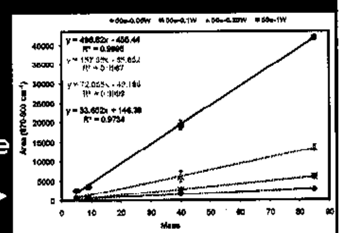
F2-F Remote Raman Spectroscopy Detection of High Explosives

S.P. Hernández-Rivera, Univ. Puerto Rico-Mayagüez; P. Chen, Spelman

- **Purpose and Relevance:**
  - The objective of the proposed work is to extend the existing technology of Remote Raman Spectroscopy (RRS) toward the application of explosives detection in range (greater than 100 m), in detection limits and in terms of detection of Raman signatures of realistic explosives-related materials.
- **Innovative Aspects:**
  - The planned experiments include detection of HEs on test surfaces at collector to target distances of 100 m and larger. Surface loadings will be several milligrams of HEs spread with concentrations of low levels of several micrograms/cm^2.
- **Year 1 Outcomes:**
  - RRS Cross Sections/Excitation Profiles of HEs.
  - Measurement of signatures of HEs on surfaces.
  - Study matrix/interferences effects.
  - Optimization of VIS RRS detection system.
  - Discrimination studies: Mix of RDX and aspirin at 7m target-source
  - Quantification studies: RDX in C4:





- **Long range Impact:**
  - The outcome of these studies will be a better understanding of the chemical signatures from exposed explosives and the ability to predict the performance of spectroscopic measurement techniques for measuring many different types of explosive materials.
  - The results of this work will impact RRS as well as any other technique that is being considered for remote measurements of explosives or chemical threats, in general.

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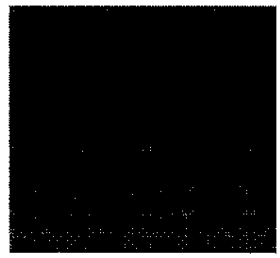
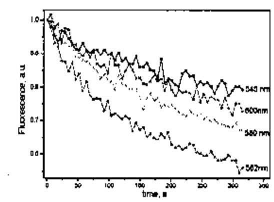
F2-G Explosives Detection via Optical Chemosensors Using Nanocomposites from Porous Silicon Photonic Crystals and Sensory Polymers

William Euler & Igor Levitsky, Jaycoda Major URI

- **Purpose: Improved sensitivity, selectivity, and adaptability for detection of low vapor pressure explosives such as TNT, RDX, PETN, etc.**
- **Innovation: A high surface-area porous Si microcavity (Distributed Bragg Reflector), filled with sensory emissive polymers dyes**
- **Year 1 outcome: optimized pore structure and polymer filling determined**
- **Long Range Impact: Hand held detector for use by soldiers and law enforcement officers**



SEM micrograph of a porous Si Distributed Bragg Reflector showing the layered pores



Fluorescent decay from exposure to TNT at different wavelengths with different time constants

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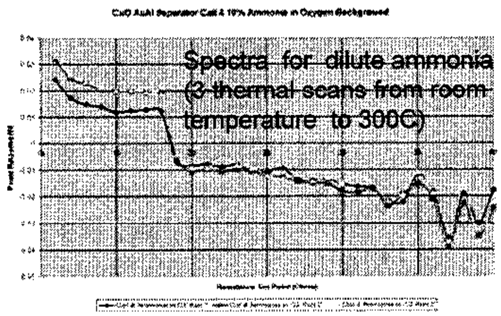
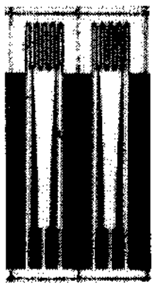
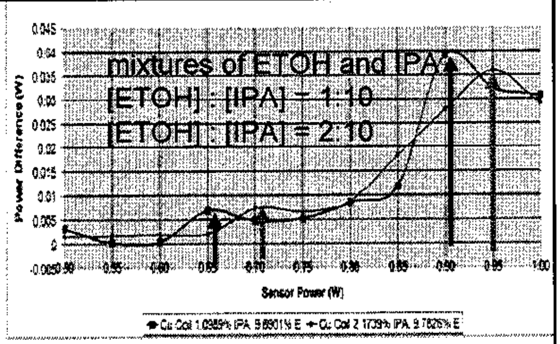
F2-H Gas Sensors for the Detection of Explosive Precursors Using Metal Oxide Catalysts

Otto Gregory - University of Rhode Island

*A simple, inexpensive gas detection system using specific 3D transition metal oxides as catalysts is being developed to unambiguously detect minute concentrations of specific gas molecules..**explosives / explosive precursors***







Purpose and Relevance

- early detection of explosives and explosive precursors in suspected "bomb labs" and other enclosed areas where target gases can accumulate. Nearly immediate detection of specific gas molecules............

  w/o interference effects from background gases
- Small enough to be worn by ground troops yet sensitive enough to be detect minute concentrations in subways, train stations and other confined spaces where the public may be targeted

Innovative Aspects

- apply combinatorial chemistry techniques to create new catalyst libraries for specific target molecules......identify optimal catalyst compounds that can be integrated into different sensor templates
- sensor templates include ceramic microheaters (pictured above) and MEMS based microheaters (produced in conjunction with Georgia Tech) sensors and signal conditioning are sufficiently developed to demonstrate technology in field trials (near term)

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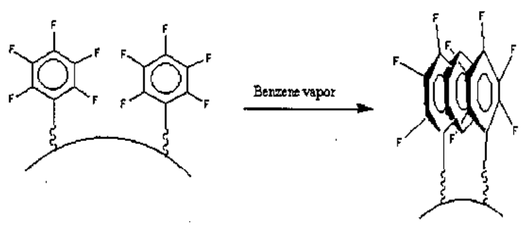
F2-I Polymer-Aided Detection
Nathan S. Lewis, Caltech

- **Purpose:**
  Stand-off Detection Through Hybrid Sensors

- **Innovative Aspects:**
  Target Analyte Tailored Sorption Into Sensor Films

- **Year 1:**
  Synthesize Semi-Specific Nitroaromatic Sensor Films
    Use in both fluorescence and chemiresistors



- **Long range Impact:**
  Develop New Standoff Explosives Detection System

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F2-J Decomposition rate constants, heats of associations, & ion lifetimes of explosives in air at ambient pressure

G.A. Eiceman, NMSU; Y. Zeiri, Z. Karpas, R. Kosloff, HUJI

- Purpose and Relevance:

  Determine kinetic and thermodynamic properties (*in title*) of gas phase ions of explosives at ambient pressure using a broad selection of high explosives and improvised explosives.
- Innovation:

  These will be the first ever such studies using newly developed methods and instrumentation where kinetic values and thermochemical constants can be measured at ambient pressure. No measurements or understandings of these properties are reported for explosives and yet these properties underlie the fundamentals of response in trace detectors of all kinds where atmospheric pressure ionization is employed (API MS, IMS and DMS).
- Year One Outcomes:

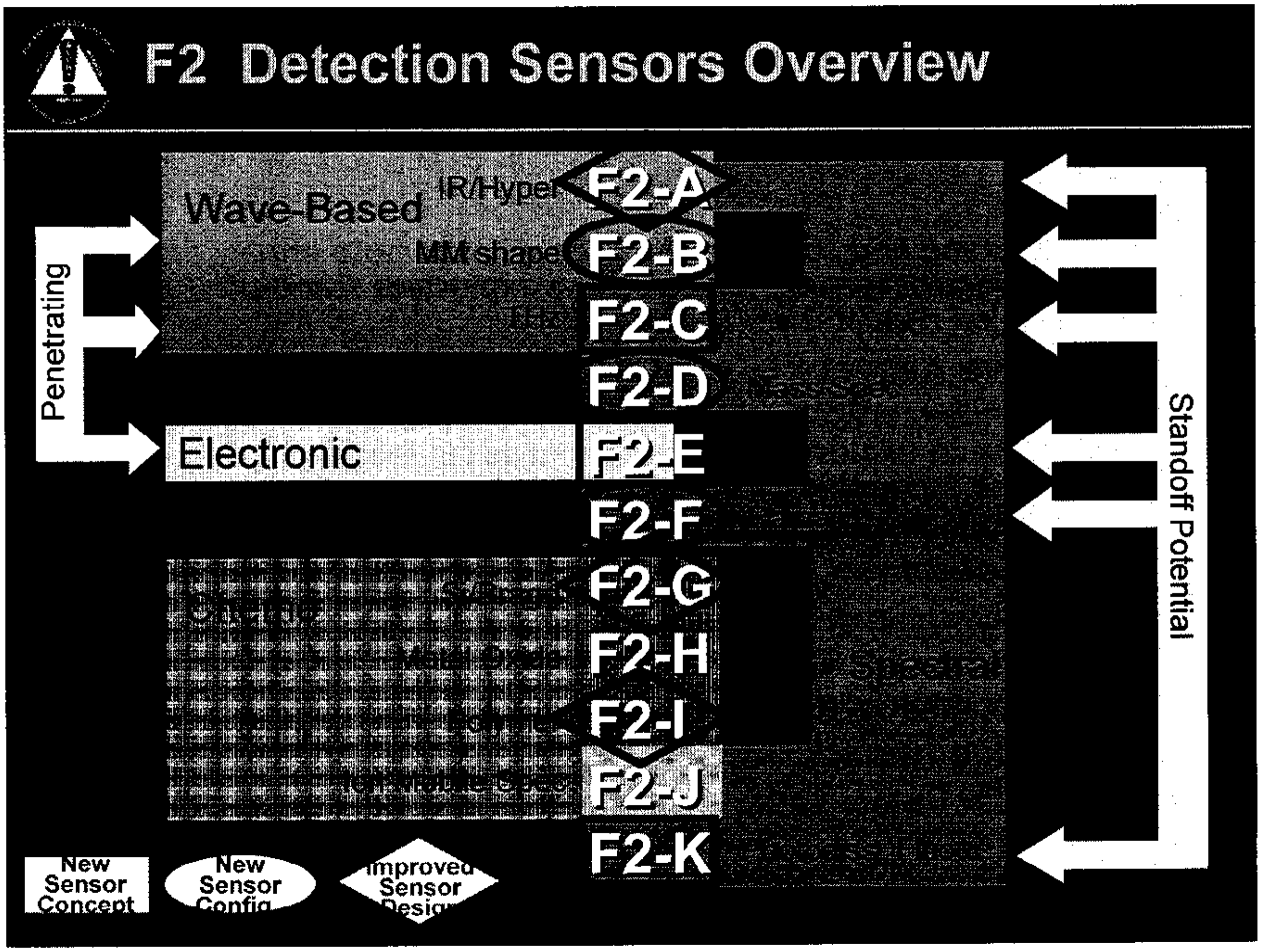
  The construction of a refined instrument on mobility-mass spectrometry for kinetic studies and the determination of properties (*in title*) of peroxide-based substances in positive ion mode.
- Long Range Impact:

  Knowledge of these title properties will inform both the design and use of the next generation of trace detectors and provide background data for innovations on their deployment or philosophy of use.

F2-K Remote vapor enhancement

Talya Arusi-Parpar, NRC Soreq, Yanve 81800 Israel

- **Purpose**
  - Understand and optimize the process of remote enhancement of explosives' vapor for increasing explosives stand-off detection capabilities
- **Innovative Aspects:**
  - Experimental results show for the first time a 100-1000 fold increase in explosive vapor concentration leading to dramatic increase in stand-off detection capabilities by PF (Photodissociation Fluorescence)
- **Year 1 outcome:**
  - Study of enhancement process
  - Setup of dedicated laboratory
  - Development of diagnostic tools
- **Long range Impact:**
  - Basis for further improvement of this method, and its efficient implementation in future stand-off detection systems for explosives or any other illicit material



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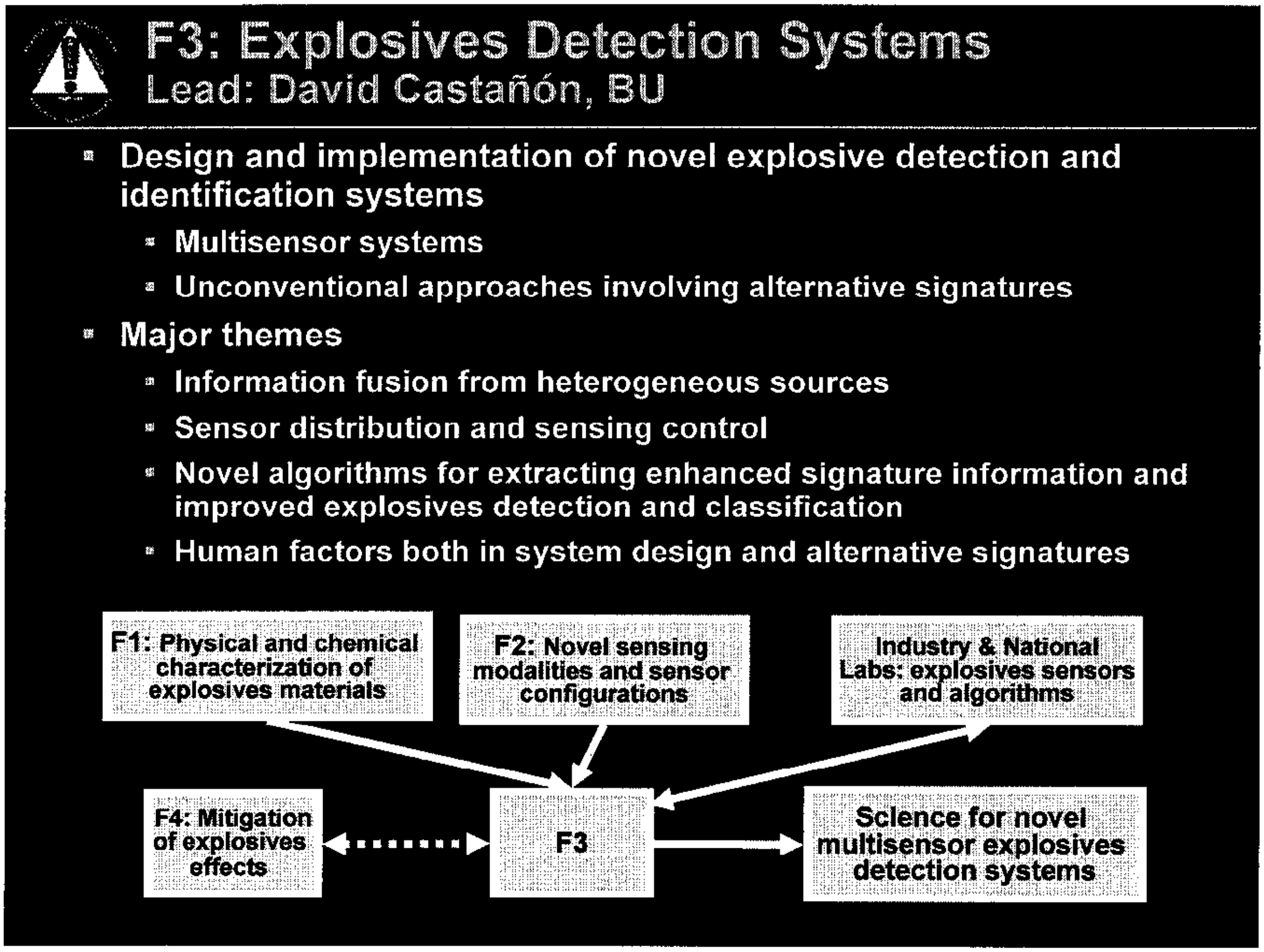

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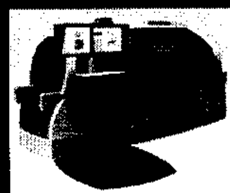
Portal and Standoff Systems

- Portal systems
  - Suite of sensors in controlled environments
  - Key requirements: detection accuracy, throughput, clutter rejection, integration with human operators
- Standoff systems
  - Spatially distributed, heterogeneous networks of sensors, perhaps mobile
  - Moving targets, lots of clutter → lots of data
  - Key requirements: area coverage, early detection, accurate warning





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The Academic Research Team

D. Castañón (BU)	Optimization, information fusion, stochastic control, estimation, sensor networks, machine learning
W. C. Karl (BU)	Statistical signal and image processing, detection, estimation, inverse problems and tomography
V. Saligrama (BU)	Sensor networks, information theory, compressed sensing, information fusion
O. Camps (NU)	Computer vision (tracking, object recognition), machine learning, image processing
M. Sznaier (NU)	Robust identification and model validation, tracking, information-based complexity, optimization
G. Tadmor (NU)	Dynamical systems, large scale systems modeling, model reduction, robust control
R. Radke (RPI)	Distributed computer vision, video networks, modeling 3D environments, machine learning
B. Yazici (RPI)	Statistical signal processing, inverse problems in imaging, biomedical optics, radar, tomography.
E. Miller (Tufts)	inverse problems, tomographic processing, inverse scattering, statistical estimation and detection theory
M. Vélez-Reyes (UPRM)	Remote sensing, hyperspectral imaging, machine learning, component unmixing

NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

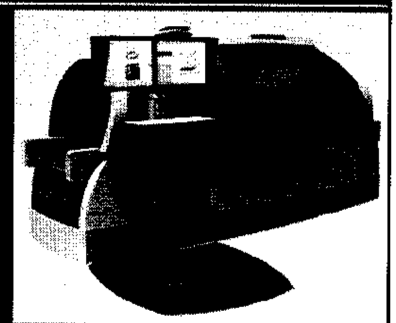
Current Projects

- **Two groups of projects: Portal and Standoff**
- **Projects: Applications-motivated basic research**
  - Connections to existing sensor concepts to provide representative domain components
  - Focus on fundamental basic research questions of design, processing and control to enhance system effectiveness
  - Exploit ties to industry, national labs and other DHS resources for assistance in concept evaluation
- **Key cross-cutting themes**
  - Principled foundations for information fusion in multisensor, multimodal systems
  - Enhanced automation for increased throughput
  - Improved detection/classification performance: reduced false alarms, improved accuracy
  - Active, adaptive management of information acquisition and processing
  - Emerging theories for systems design and architectural tradeoffs

NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F3-A: Next Generation Image Formation for Portal Systems -- Miller (Tufts), Karl, Castañón (BU)

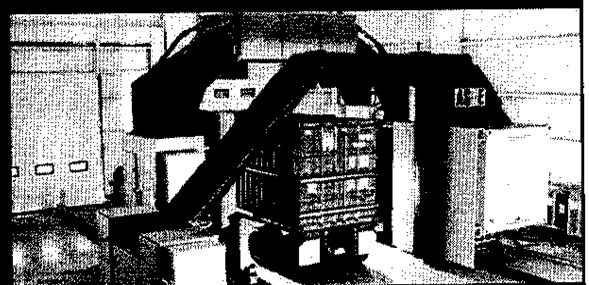
- Motivation and purpose:
  - Reduction of false positive alarms in explosive detection systems
- Focus:
  - Advanced physics-based and geometric image formation and object detection methods
  - Feature-enhancement/artifact suppression
  - Incorporation of prior knowledge on explosive characterization
  - Enhanced quantitation and localization
- Year 1 accomplishments
  - Feature guided image formation from dual energy scanner data
  - Collaboration with Analogic
- Long range impact
  - Robust, enhanced formation methods
  - Large scale portal applications with limited view data sets

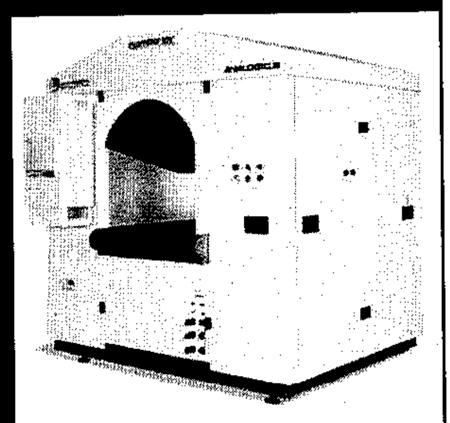


NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F3-B: Multi-modal Imaging for Portal-based Screening
Yazici (RPI), Miller (Tufts), Karl, Castañón (BU)

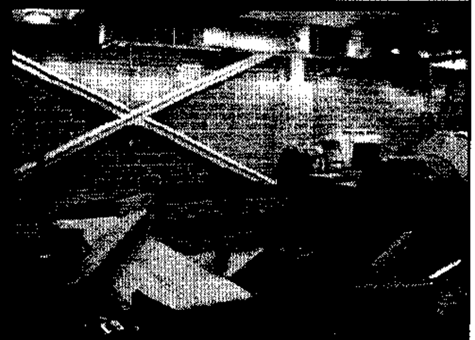
- Motivation and purpose:
  - Increased specificity and sensitivity
  - Reduction of false alarms
  - Increased throughput
- Focus:
  - Fusion of multiple modalities
    - Dual energy X-ray, X-ray Backscatter
    - THz data sources
    - Bulk and trace sensors . . .
  - Exploit shared physical structure, super-resolution imaging
- Year 1 accomplishments
  - Fusion of X-ray and Thz data
  - Collaboration with Analogic, AS&E
- Long range impact
  - Principled methods for multi-modal fusion for explosive detection



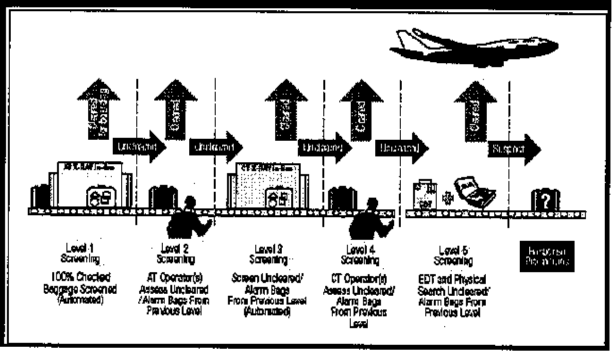


NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F3-C: Sensor Management for High Throughput Screening -- Castañón, Karl (BU), Miller (Tufts), Yazici (RPI)



- Motivation and purpose:
  - Increase throughput while maintaining high probability of detection
- Focus:
  - Optimal sensor and algorithm management
  - Sequential design of experiments integrated into detection/classification
  - Increased throughput to remove airport/port bottlenecks
  - System-level stochastic optimization
- Year 1 accomplishments
  - Theory and algorithms for sequential multistage classifiers
- Long range impact
  - High throughput screening management algorithms with good sensitivity/specificity



NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F3-D: Compressive sensing for portal screening

Yazici (RPI), Miller (Tufts), Karl, Castañón (BU)

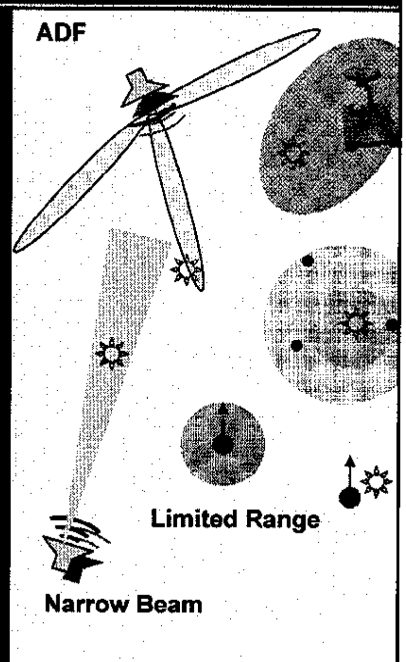
- Motivation and purpose:
  - Increased throughput while maintaining specificity and sensitivity
- Focus:
  - Application of compressive sensing to determine needed set of optimal projections for spiral CT
  - Goal is faster inspection with reduced measurements
  - Classification from compressed sensing measurements
- Innovative Aspects -
  - Extension of on the emerging technology of compressive sensing to classification from tomographic data
  - Integration of sensing/feature extraction/classification
- Year 1 accomplishments - A method of recognition directly from "compressed" measurements as opposed to reconstructed image
- Long range Impact - New, more efficient and less expensive portal-based screening systems

NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F3-E: Multi-modal Sensor-Networks

Saligrama, Castañón, Karl (BU)

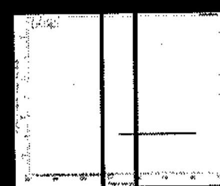
- Motivation and Purpose
  - Pervasive wide-area explosive threat detection
- Innovative Aspects
  - Foundations for optimal sensor network design
    - Understanding of “sensing capacity” of a system
  - Theoretical structure for performance limits
  - Development of framework for multi-modal fusion of distributed/mobile sensors
  - Development of a theory for active, adaptive employment of sensors
- Year 1 accomplishments
  - Sparsity constrained distributed fusion for threat detection
- Long range Impact
  - Tools for robust, reliable, real-time threat detection, localization & classification
  - Development of novel sensing sensing systems



NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F3-F: Dynamics-Based Detection and Tracking of Explosive Threats -- Camps, Sznaier,Tadmor (NU)

- **Purpose and Relevance:**
  - Robust detection of potential threats using multimodal (e.g. video, micro-pulse radar, IR), physically distributed sensors.
- **Innovative Aspects:**
  - Dynamic models as the key to handle a "data deluge":



Detecting events via jumps in Hankel rank

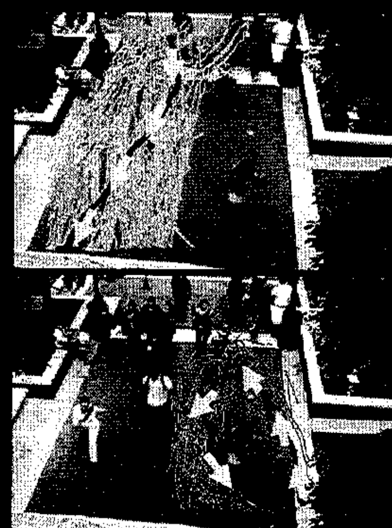
- **Year 1 accomplishments:**
  - Robust tracking , contextually anomalous event detection.
- **Long range Impact:**
  - Real time threat detection/assessment via integration and analysis of very large amounts of surveillance data.
  - Sensor coordinated threat response and impact mitigation.

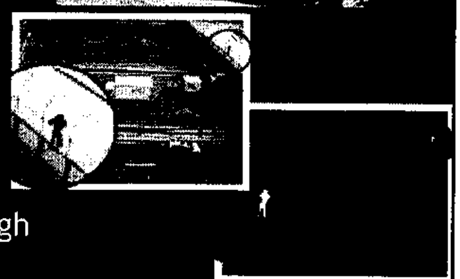
NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F3-G: Distributed Anomaly Detection

Saligrama, Castañón, Karl (BU), Radke (RPI)

- **Motivation and Purpose**
  - Detection of suspicious, anomalous, irregular behavior in highly cluttered urban scenarios
- **Innovative Aspects**
  - Learning of normal patterns of behavior
  - Detection and annotation of anomalies
  - Automated methods for pattern discovery in high-dimensional data
- **Year 1 accomplishments**
  - Activity characterization in urban cluttered scenes from distributed video
  - Detection of anomalous motion in crowds
- **Long range Impact**
  - Robust surveillance system for pervasive and persistent detection of anomalies.
  - Creation of framework for optimal analysis of high dimensional data





NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F3-H: Multi-platform passive and active synthetic aperture radar for IED detection -- Yazici (RPI), Castañón, Karl (BU)

- Purpose -
  - Develop waveform, polarization, frequency, space and time adaptive receive and transmit algorithms for IED control wire detection using multistatic airborne RF antennas
  - Scan large area (20 m/sec) with high resolution in all weather
- Innovative Aspects -
  - RF based IED detection algorithms that take advantage of multistatic geometries and waveform diversity to maximize detection probability and to minimize false alarm rate
  - New adaptive synthetic aperture image formation algorithms based on vector wave equation that provide material characterization
- Year 1 accomplishments - Optimize trajectories of the airborne antennas to maximize the detectability of IED control wires
- Long range Impact - New algorithms will lead to small UAV based IED defeat systems

NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F4: Blast Mitigation
Lead: Arun Shukla, URI

This research effort will focus on basic science issues that help develop novel materials and structures to mitigate blast effects

Research Thrust Areas:

Designing and understanding the response of novel heterogeneous materials, including particulate, layered and functionally graded materials subjected to extremely high strain rate blast loading conditions.

Designing and understanding the response of sandwich composite structures subjected to extremely high strain rate blast loading conditions at room and at high temperatures.

Studying deformation and progressive failure events of structural steels subjected to coupled high strain rates and high temperatures associated with blast/fire loadings.

Studying the response of structures that couple rigid body dynamics, material deformation and load transfer.

NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F4: Blast Mitigation (*Cont'd*)
Lead: Arun Shukla, URI

ynamic
hoto echanics
aboratory

- Understanding structural response to separate and simultaneous blast and fragment impact.
- Understanding structural response to blast waves from internal explosions, particularly non-ideal explosions.
- Coatings for structural protection during blast.
- Self healing materials and smart protective structures.

The above mentioned research thrust areas, while they do not encompass the entire scope of mitigation, have been selected to provide a focus in the initial stages of research.

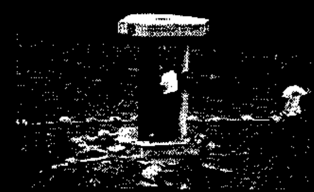
F4-A: Optimal Design and Use of Advanced Structural Materials to Mitigate Explosive and Impact Threats

J. Baird and J. Myers, Missouri S&T

Purpose: Advanced material design & development to mitigate explosive & high-velocity impacts.

Innovation: Integration of materials modeling & in-situ measurements at high stresses (1-30 Gpa) & short time (ns-us) scales relevant to explosive detonations & fragment impact.

Year 1 accomplishments: Determine the suitability of hybrid materials in barrier/wall systems to provide enhanced blast and fragment resistance



Charge setting

Test of column fixture - wrapped reinforced concrete

Long range Impact: The design and development of materials that perform well under severe dynamic events, and the understanding of material dynamic response to explosive detonations and fragment impacts is critical to the next generation of blast-resistant structures

Shot; 30 lb TNT-equivalent

NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F4-B: Structural Response to Non-ideal Explosions

JE Shepherd, California Institute of Technology

- Purpose/Relevance: Investigate fuel vapor cloud explosions inside yielding structures.
- Innovative Approach: Develop methods that are useful for analyzing potential explosive hazards or investigating accidental or deliberate non-ideal explosions inside a structure.
- Unique focus on non-ideal gas explosions (deflagration) inside weak structures.
- Year 1 Outcomes: Simple models and small-scale experiments.
- Long range Impact: Develop mitigation measures and improved structural design guidelines.

NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F4-C: Deformation and Progressive Failure of Structural Steel Subjected to Coupled Blast/Fire Loadings – Experiments & Modeling -- Hamouda Ghonem & Otto Gregory, URI

Purpose and Relevance: An integrated multidisciplinary program to develop a fundamental understanding of the mechanics and mechanisms of deformation of structural steel subjected to blast/fire loadings. This approach will result in the development of a real-time numerical simulation platform to serve as a tool to predict progressive collapse of steel members in blast loaded structures.

Innovative Aspects: A collaborative effort that includes a novel and highly accurate Internal State Variable model, dynamic experimentation and large-scale simulation that aim at producing a computationally efficient predictive model suitable for large-scale structures and accurate enough to capture detailed behavior of steel members' inelasticity and instability associated with effects of explosion and fire.

Year 1 Outcomes: Large scale experimental program which will provide the kinematic, isotropic and relaxation response of structural steel as a function of blast deformation and thermal exposure parameters.

Long range Impact: Develop efficient real-time simulation platforms as a prediction tool to establish design requirements and survivability criteria for steel members in a structure subjected to blast & fire loadings.

NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F4-C Cont'd: Deformation and Progressive Failure of Structural Steel Subjected to Coupled Blast/Fire Loadings
Hamouda Ghonem & Otto Gregory, URI

Develop economically viable techniques for of a new generation of structural steel with high deformation and creep resistance.

- **Metrics:The viscous flow equations of structural steel will be generated using materials subjected to a set of measured shock waves energies coupled with & without thermal exposure. These equations, which currently do not exist, will be tested by comparing their outputs with the response of steels subjected to blast conditions. The reliability of a large scale progressive failure model, based on the developed viscous flow equations, will be examined using optimization techniques & comparisons with scaled steel structures subjected to blast.**
- **Importance in "filling gaps:" For many years, steel members will remain the key components in large structures designs. The first goal of the project is the generation of a model to predict failure events associated with blast shock waves. This failure mapping will be translated into a survivability (after events) criteria for future steel structure designs. The long term objective of this work is the development of a steel microstructure with high resistance to blast loadings. This type of steel has not been developed to date.**

F4-D: Novel Composite Materials & Structures for Blast Mitigation

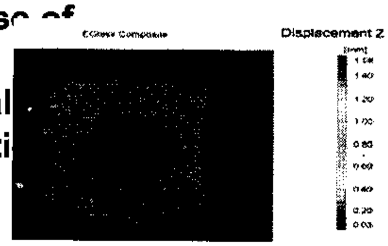
Arun Shukla, URI

Dynamic PhotoMechanics Laboratory

- Purpose/ Relevance: **Conduct fundamental experiments to elucidate physical mechanisms responsible for damage in novel composite materials & structures subjected to extreme environments associated with blast & fragment loading, thus leading to new more efficient materials & structures.**
- Innovation: **Highly controlled experiments with real time measurements at extremely h loading rates to give full field load-deformat & damage information at material & structur**

Shock Tube

- 1st year outcome: **Constitutive behavior of selected materials at very high strain rates and also at high temperatures. Incorporating the new DIC technique in initial experiments to investigate blast respons some selected materials and architectures.**
- Long-range impact: **Design of new multi-functional materials with excellent blast mitigation capabiliti with ability to heal and overcome other hazards.**

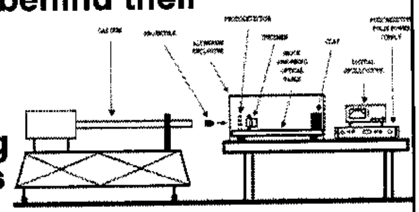


Digital Image Correlation

NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

F4-E: Shock Mitigation through Particulates - Carl-Ernst Rousseau, URI

- Purpose and Relevance: Focus on understanding Stress Wave Scattering, and using it as a means of mitigating suddenly imposed stress conditions due to explosions or impact. Efficient diffusion of those waves can help with the development of advanced materials that have the merit of withstanding high loading rates.
- Innovative Aspects: Stress weakening through the use of particulates is generally acknowledged, though the phenomenon is seldom studied and understanding of the physical phenomenon is in its infancy. Tracking of stresses as they travel through particulate materials will help identify reasons behind their behavior.
- Year 1 Outcomes: Establish geometries that reduce severity of traveling wave & identify those that sustain stresses near their incoming levels. Intensive use of Lagrange stress gages will constitute a primary tracking mechanism.



- Long range Impact: Development of materials based on particulates will find direct applications to infrastructure, transportation, and blast shielding, including sheltering of sensors.

NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

Center for Awareness and Localization of Explosives-Related Threats (ALERT)
A DHS Center of Excellence for Explosive Detection, Mitigation, and Response
Education Program Rationale
July 28, 2008
J.C. Oxley (URI) & M. B. Silevitch (NEU)

There is a need to educate the next generation of professionals to work in the fields of science and engineering, in general, and specifically in counterterrorism and homeland security. It is widely recognized that the U.S. needs to put more emphasis on fielding new workers in the STEM (science, technology, engineering and mathematics) disciplines. The development of the ALERT education program was guided by the need to provide a meaningful impact on the pipeline of university students, K-14 students and their teachers, first responders, and career professionals who will be important contributors to DHS and to the success of its critical mission. The major elements of our program are grouped into the following areas: ***K-12 and Community Colleges***, ***University Undergraduate and Graduate Programs***, ***First Responder and Law Enforcement Programs*** and ***Professional Development and Short Courses for DHS Career Professionals.***

To channel people into the STEM disciplines, they must be reached at an early age, typically in middle school; at that time their attitude toward math and science is critical to their future path. Therefore, K-14 outreach will be emphasized. It is important that the elements of the education program strive to have a sustained effect on the students, teachers and the educational institutions, rather than just providing one-time "feel-good" experiences. We feel strongly that to reach the most students we must reach their teachers. In structuring the ALERT educational program we took into account the importance of placing young people and teachers into research laboratories that are immersed in cutting edge activities related to the DHS mission. K-14 teachers need to feel much more comfortable with the science and mathematics content that is the background to the materials that comprise the STEM disciplines. Outreach to existing teachers will include research experiences for teachers (RET) and training workshops. We will promote distribution and training in available materials that can be used to excite interest in STEM. High-quality materials have been prepared by previous education initiatives, e.g. those of NSF, but those materials are ignored because they are not widely known to be available and because teachers are not trained in how to use them. In addition, we plan to work with future teachers, supporting training in STEM disciplines in our respective Universities' education departments. While the emphasis will be on teacher training, we plan to participate in select programs where outreach to students is particularly effective. We intend to leverage existing networks and efforts that could contribute to the ALERT program. One example is the RE-SEED program that has created a nationwide network of ~500 retired scientists and engineers who are trained to become resource agents to middle school teachers and children. Another is the RI School of the Future robotics efforts.

The primary mission of Universities is undergraduate and graduate education. As DHS funding fuels research at the various partner Universities, we will leverage that funding into an educational opportunity--both the education that comes along with doing research, i.e. research experiences for undergraduates; and the education that comes with the development with new and exciting teaching modules. In addition, we have a strong commitment to education in support of first responders and DHS/counterterrorism career professionals. Both NEU and URI have been actively reaching out to the detection industry and law enforcement for over a decade. That outreach will continue as we provide on-demand courses and workshops for law enforcement, first responders and detection professionals.

Education Programs/Initiatives at NEU

K-12 and Community Colleges

Research Experiences for Teachers- NEU STEM Center
Young Scholars Program (High School)- NEU STEM Center
RE-SEED Retirees Working with Middle Schools- NEU STEM Center
Professional Development for K-12 Teachers –NEU STEM Center

Undergraduate and Graduate

High Tech Tools and Toys "Hands On" modules (examples)

- IR Spectroscopy
- THz Imaging
- Electronic Signatures of "Triggering" Devices

Toolboxes for Use in Courses (examples)

- Hyperspectral and Tomographic Analysis
- Nonlinear Shock propagation in Complex mitigative materials

Research Experiences for Undergraduates
ALERT Pipeline: Co-op and Capstone Experiences
HBCU Collaboration - Morehouse, Spelman
Community College Outreach
Develop Distance Learning and Short Courses for the ALERT Partnership
Gordon Engineering Leadership Program (Grad. Level DHS Candidates)
Progressive Collapse Competition (Undergraduate)

NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

Educational Programs/Initiatives at URI

K-12
Research Experience for Teachers
Research/Education for Teacher Education
Teachers reviewing existing NSF materials
Robot clubs

University Students—Grad & Undergrad
- New modules/courses
- Research experience & employment
- Graduate student exchange programs
- Summer programs for faculty at HBCU, MSI, & 2-yr colleges

First-Responders/Law Enforcement
- Review professional materials
- Video preparation
- Understanding lab prep of explosives
- Courses developed on request

Professional Development
- 28-32 short courses in last 5-years....

NOTE: Dark background: Northeastern-supported projects updated for Year 2 workplan; light background: URI-supported projects with Year 1 workplan information

ALERT Contact List

ALERT Contact list by Project						
	Area		Contact	E-Mail	Office Phone	Cell
F1:	**Explosives Characterization**	**URI**	**James (Jim) Smith**	(b) (6) [redacted]		
F1-A:	Determining Vapor Liquid Equilibria & Phase Diagrams of Wate/H2O2 Binary & Ternary Sys.	TTU	Brandon Weeks			
	Texas Tech University (TTU)		Louisa Hope-Weeks			
	Washington State University (WSU)		Choong Shik Yoo			
F1-B:	Testing for Precursors Identification	URI	Jimmie Oxley			
		URI	James Smith			
		URI	James Kennedy			
		UIL	D Scott Stewart			
F1-C	Precursor Denaturing	URI	Jimmie Oxley			
		URI	James Smith			
F1-D:	Modeling of surface-particle interaction	HUJI	Yehuda Zeiri			
	Hebrew University Jerusalem	HUJI	Zeev Karpas			
		HUJI	Ronnie Kosloff			
F2:	**Explosives Detection Sensors**	**NEU**	**Carey Rappaport**			
		URI	**William (Bill) Euler**			
F2-A:	Explosive Detection using Hyperspectral Imaging	NEU	Charles (Chuck) DiMarzio			
	Northeastern University (NEU)		Max Diem			
		NEU	Stephen (Steve) McKnight			
	University of Puerto Rico-Mayaguez (UPRM)		Miguel Velez-Reyes			
		UPRM	Nayda Santiago			
F2-B:	Millimeter-Wave Standoff Detection of Concealed Explosives	NEU	Carey Rappaport			
		NEU	Jose Martinez			
F2-C:	THz generation & detection with gases for standoff detection	RPI	X.-C. Zhang			
		RPI	Masashi Yamaguchi			
		RPI	Jiaming Dai			
		RPI	Etienne Gagnon			
		Morehouse	Willie Rockward			
F2-D:	Intelligent Mass Spectrometer for Identifying Explosives & Chemical Weapons; (Woods Hole)	WHOI	Rich Camilli			
F2-E:	Detection of Electronically Initiated Explosive Devices	MST	Daryl Beetner			
	Missouri U of Science & Technology	MST	James Drewniak			
		MST	Steven Grant			
		MST	David Pommerenke			
F2-F:	Remote Raman Spectroscopy Detection of High Explosives	UPRM	Samuel Hernandez			
		Spelman	Peter Chen			
F2-G:	Detection via Optical Chemosensors Using Nanocomposites from Porous Silicon Photonic	URI	William (Bill) Euler			
		URI	Igor Levitsky			
		URI	Jaycoda Major			
F2-H:	Gas Sensors for the Detection of Explosive Precursors Using Metal Oxide Catalysts	URI	Otto Gregory			
F2-I:	Polymer-aided Detection	CalTech	Nate Lewis			
F2-J:	Decomposition rate constants, heats of associations, & ion lifetimes of explosives in air at	NMSU	Gary Eiceman			
	Modeling of surface-particle interaction	HUJI	Yehuda Zeiri			
		HUJI	Zeev Karpas			
		HUJI	Ronnie Kosloff			
F2-K:	Remote vapor enhancement	Soreq	Talya Parpar			
F2-L:	ED via THz; Technische U Braunschweig	TU	Martin Koch			

F3: Explosives Detection (ED)		**BU**	**David Castanon**	(b) (6) [redacted]
F3-A:	Next Generation Image Formation for Portal Systems	BU	David Castanon	
		BU	William C. (Clem) Karl	
		Tufts	Eric Miller	
F3-B:	Multi-modal Imaging for Portal-based Screening	BU	David Castanon	
		BU	William C. (Clem) Karl	
		Tufts	Eric Miller	
		RPI	Birsen Yazici	
F3-C	Sensor Management for High Throughput Screening	BU	David Castanon	
		BU	William C. (Clem) Karl	
		Tufts	Eric Miller	
		RPI	Birsen Yazici	
F3-D:	Compressive sensing for portal screening	BU	David Castanon	
		BU	William C. (Clem) Karl	
		Tufts	Eric Miller	
		RPI	Birsen Yazici	
F3-E:	Multimodal sensor networks	BU	David Castanon	
		BU	William C. (Clem) Karl	
		BU	Venkatesh Saligrama	
F3-F:	Dynamics-Based Detection and Tracking of Explosive Threats	NEU	Mario Sznaier	
		NEU	Octavia Camps	
		NEU	Gilead Tadmor	
F3-G:	Distributed Anomaly Detection	BU	David Castanon	
		BU	William C. (Clem) Karl	
		BU	Venkatesh Saligrama	
		RPI	Richard (Rich) Radke	
F3-H:	Multi-platform passive and active synthetic aperture radar for IED detection	BU	David Castanon	
		BU	William C. (Clem) Karl	
		RPI	Birsen Yazici	
F4: Blast Mitigation		**URI**	**Arun Shukla**	
F4-A:	Optimal design and use of advanced structural materials to mitigate explosive & impact threats	WSU	Yogendra (Yogi) Gupta	
	Washington State University	WSU	Choong Shik Yoo	
		MST	Jason Baird	
		MST	John Myers	
F4-B:	Structural Response to Non- Ideal Internal Explosions	CalTech	Joseph (Joe) Shepherd	
F4-C:	Deformation & Progressive Failure of Structures with Blast & Fire Loadings	URI	Otto Gregory	
		URI	Hamouda Ghonem	
F4-D:	Novel Composite Materials & Structures for Blast Mitigation	URI	Arun Shukla	
F4-E:	Attenuation & Mitigation of Stress Waves Propagating in Blast Shielding Materials	URI	Carl-Ernst Rousseau	

ALERT Contact List

Targeted Education Projects	URI	Jimmie Oxley
	NEU	Kristin Hicks
	NEU	Claire Duggan
	NEU	Stephen (Steve) McKnight
Administration/Contacts	URI	Jimmie Oxley
	NEU	Michael Silevitch
	NEU	John Beaty
	NEU	Phil Cheney
	NEU	Horst Wittmann
	NEU	Anne Magrath
	NEU	Deanna Beirne
	NEU	Mariah Nobrega
	MST	Samuel Frimpong
	MST	Steve Tupper
	MST	K.Krishnamurthy
	WSU	Sheila Heyns
	WSU	Kristine Ashby

(b) (6) [redacted]