Center of Excellence in Explosives Detection, Mitigation, & Response: Awareness and Localization of Explosives-Related Threats (ALERT)

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To protect the nation from the physical and economic harm caused by the threat of explosive attack, we have pursued research in four interrelated thrusts. These are: ***Explosives Characterization*** to understand the explosive threat and prevent it; ***Explosives Detection Sensors and Explosive Detection Sensor Systems*** to detect the explosive threat; and ***Blast Mitigation*** to minimize the effects of a successful bombing by lessening damage and loss of lives and time. In addition, we strive to educate ourselves, our students, and practicing and future homeland security professionals. This education includes not only the transformational research and advanced technologies but also the principles and culture of safety in working with hazardous materials. Each area overview is followed by a list of individual projects; new initiatives for which white papers have been submitted are in written in blue.

F1. Explosives Characterization

Fundamental questions addressed are: What makes a chemical capable of being an explosive? Can we prevent terrorist acquisition and/or use of precursor chemicals to make explosives? Are there properties of terrorist-used explosives that pertain to safe handling, potential signatures, and creation of simulants? Can we quantify the potential performance of terrorist-used explosives in terms of potential damage that can be caused?

Characterization activities include the following:

- Design of protocols and methods to prevent explosive precursors from being used to make illicit explosives while allowing their intended use (F1-E)
- Examination of commodity chain handling of explosive precursors (inactive)
- Creation of tests and metrics to identify non-ideal explosive and precursors (F1-F)
- Determination of performance and safety margins of explosives on micro-scale
- Determination of physical properties of explosives to design explosive detection instrumentation and explosive simulants. Some properties may be found in the database http://expdb/chm.uri.edu
- Investigation of unique signatures of explosives that can be exploited in stimulant production
- Characterization of the surface-explosive particle interaction in order to best locate and collect explosive residue
- Characterization of hydrogen peroxide (F1-A1) and routes to non-nitrate explosives (F1-A2)
- Formation of thin films of energetic materials (F1-B)
- Design protocols for safe disposal of explosives, e.g. peroxide explosives (F1-D)

F2. Explosives Detection Sensors

Explosives detection concentrates on understanding the fundamental problems of trace detection of explosives, and improvement of explosive sample collection. The goal is to develop sensing systems capable of detecting ultra-low amounts of explosives which are selective (i.e. able to reduce the number of false positives and false negatives), and adaptable (i.e. can accommodate new types of explosives as they become threats). Approaches to these problems include:

- Energetic material detection using hyperspectral imaging and remote IR spectroscopy (F2-A)
- Optimization of millimeter wave standoff sensing of anomalies under clothing to detect body-worn explosives (F2-B)
- Investigation of the potential of generating and detecting broadband THz waves with gases as wave emitters for standoff THz spectroscopic detection (F2-C)
- Development of intelligent in-situ mass spectrometry and autonomous feature classification for determining: explosive type, location , magnitude, and if there are multiple threats (F2-D)
- Development of methods to detect, identify, and interrogate electronics commonly used in explosive devices based on their unintended electromagnetic emissions (F2-E)
- Investigation of remote conventional and Coherent Anti-Stokes Raman Spectroscopy for detection of trace quantities of energetic materials at large standoff distances (F2-F)
- Enhancement of polymer detection techniques (F2-G)
- Development of tiny, inexpensive sensors for persistence surveillance (F2-H)
- Investigation of the fundamental physical processes underlying the traditional trace detection techniques of ion mobility spectrometry and differential mobility spectrometry, including experimental and modeling activities (F2-K)
- Synthesis and evaluation of new trace collection systems which can enhance the explosive signature by improved particle collection, vapor plume stimulation, and analyte specific sorbent substrates (F2-J)
- Shaped Femtosecond Pulses for Remote Chemical Detection
- Creation of sensors for massive distribution and investigation of new sensors fiber optics able to deliver light for stand-off detection and return information to a central site (*i.e.* multi-disciplinary team will approach from orthogonal directions-- electrical, thermal, and optical).
- Fundamental materials research for next generation sensors. For example, development of hybrid quantum dot/polymer array structures. The polymer blend would achieve mechanical stability, increased analyte absorption and signal amplification from quantum confinement effects and coupling between polymer and quantum dots.
- Establishment of an academic-oriented testbed for development and evaluation of multi-modal sensors and algorithms for portal-based whole body Advanced Technology Imaging (AIT) to enable experimentation, model-based reconstruction, and automatic threat detection of body-worn explosives

F3. Explosives Detection Sensor Systems
Explosives detection concentrates on understanding the fundamental problems of trace detection of explosives, and improvement of explosive sample collection. The goal is to develop sensing systems capable of detecting ultra-low amounts of explosives which are selective (i.e. able to reduce the number of false positives and false negatives), and adaptable (i.e. can accommodate new types of explosives as they become threats).

Detection systems are focused on developing the fundamental processing algorithms to extract maximal information from available sensed signals for the purposes of increased probability of correct detection and classification of explosives while reducing the number of false alarms. The objective is to develop the basic science for design and implementation of novel multi-sensor detection systems. The class of systems of interest includes both portal and standoff detection systems. Approaches to these problems include:

- Novel tomographic X-ray image formation and feature extraction algorithms integrating multiple energy excitation and restricted imaging geometries
- Simultaneous segmentation and image formation algorithms for dual-energy X-ray computed tomography
- Multispectral diffraction tomography techniques with spectral signature information for increased sensitivity and specificity motivated by THz tomography
- Sensor management and scheduling algorithms for high throughput screening and active learning using fielded systems
- Compressive sensing techniques for artifact reduction in low-dose tomography to improve throughput in screening
- Information fusion in multimodal sensor networks for standoff classification
- Distributed vision systems for area monitoring, with robust anomaly detection and multi-camera fusion
- Dynamics based anomaly detection and object tracking using video sensing
- Video analytics for anomaly detection, surveillance and activity recognition

F4. Blast Mitigation

The research effort in mitigation will focus on basic science issues that help develop novel materials and structures to mitigate blast effects. Necessary is an underlying understanding of structural response to internal or external blast, fragmentation, or a combination of impacts such as simultaneous blast and fragmentation or blast and fire. Such understanding will be the foundation of modeling and will result in new designs and protocols for infrastructure protection. Furthermore, we are investigating ways to improve resilience of structures. A success to be highlighted this year is our ability to model remaining building-life after an explosive attack. Projects presently supported do not encompass the entire scope of mitigation but have been selected to provide a focus in the initial stages of research.

- Designing, modeling & understanding the response of novel heterogeneous materials, including particulate, sandwich composites, carbon nanotubes & layered, functionally graded materials subjected to extremely high strain rate blast loading (F4-A,I, J, K)
- Understanding damage initiation and crack propagation in various types of glass subjected to high strain rate blast loading conditions (F4-A)
- Studying deformation and progressive failure events of structural steels subjected to coupled high strain rates and high temperatures associated with blast/fire loadings F4-C)
- Studying the response of structures that couple rigid body dynamics, material deformation and load transfer (F4-B)
- Modeling structural response to blast waves from internal explosions, particularly non-ideal explosions (F4-D)
- Investigating ways to ameliorate the blast using water jet (Aug 09 start, F4-E)
- Attempting to create more resilient structures using self-healing materials and integration of a microvascular network (Aug 09 start, F4-F, F4-G)
- Creating coatings for structural protection during blast (F4-H)

- Advanced modeling and numerical simulation of response of full-scale structural systems following member loss due to explosions (F4-I)

Education

The Center reaches out to citizens of all ages to enhance awareness of pertinent science and engineering. We are particularly interesting in preparing the future generation of researchers. To that end we will continue to support the following initiatives.

K-12

Magic Shows "Chemistry is Fun"
Summer Research Experience for High-School Teachers (7 in 2009)

University Students—Grad & Undergrad

New 7 first-time courses
Research experience & employment for undergraduates (9 in 2009)

First-Responders/Law Enforcement

Understanding lab prep of explosives
Courses developed on request
Participated with TSA in VIPR screening

Professional Development

28-32 short courses in last 5-years. This year well over 400 professionals took our classes.
12 new courses this year

Supporting a Culture of Safety

CoE researchers will be asked to review and document, where necessary, the standard operating protocols (SOP) and include safety procedures
Self review and Center-wide review will be conducted
Safety seminars will be created and made available to CoE researchers and others
External final review of safety procedures is intended

Explosive Characterization

James L. Smith (URI) Technical Lead

The immediate focus is on prevention of synthesis of IEDs from homemade explosives (HME).

This year

1. Theoretical calculations for best approach to benign destruction of TATP & for particle surface interactions (F1-C)
2. A method of gentle digestion of TATP is being sought (F!-D).
3. Denaturing explosive precursors is sometimes the best approach to preventing HME synthesis URI is examining additives to denature two precursors-- H_2O_2 and urea.
4. Identifying explosive precursors at lab-scale, to avoid the expense and danger of ton-scale charges, requires the development of a new small-scale test.

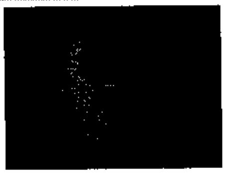
Explosive Characterization

James Smith; Jimmie Oxley (URI); Ronnie Kosloff (HUJI); Yehuda Zeiri (BGU)

Next year: Focus continues to be prevention of synthesis of HME.

1. Theoretical calculations for best approach to benign destruction of TATP & for particle surface interactions (HUJI)
2. We found a method to gently destroy TATP. Next we will determine safety of lab procedure at field-scale (with local bomb squad); mechanism & violence of reaction; general applicability to other peroxide explosives.
3. We have found additives which prevent concentration of hydrogen peroxide (HP). Long term effects of additives on storage must be determined. Encapsulate may be required. Terrorists may move to concentration of HP without heat. We will begin to probe methods to prevent this "work-around."
4. Even low concentrations of HP can form TATP, albeit in lower yield. Our goal is to prevent reaction of acetone with HP from forming TATP. Approaches: add a competing ketone or aldehyde to prevent TATP from precipitating; use radical initiators, scavengers or antioxidants.
5. To prevent terrorists from making UN, nitric acid (NA) was restricted (Iraq). Last year we pioneered prevention of use of alkali nitrates to make NA for making of UN *in situ*. While continuing that effort, we will explore blocking UN syntheses from NA, distilled or commercial.
6. Identifying non-ideal explosives & precursors at small-scale, to avoid the expense & danger of ton-scale charges, requires development of new test.

F1-C Molecular Level First Principle Simulations



Theoretical studies will be strongly linked to the experimental investigations of the Center.

Detonation mode & stability of complexes of TATP & other peroxides: A combination of electronic structure calculations & molecular dynamics simulations will be used to probe stability & detonation mechanisms with the aim of safe disposal.

Spectroscopic features of improvised explosives: Spectroscopy is likely to be the basis of remote explosives detection; thus, the theoretical group will search for spectroscopic features from first principles using quantum chemistry methods and developing novel method using molecular dynamics simulations.

Sensitivity, stability & performance of liquid explosives: The sensitivity & stability of liquid explosives will be examined by electronic structure calculations. Molecular dynamics simulations will be used to study bulk phenomena & shockwave propagation. We want to develop the ability to simulate mixtures and heterogeneous materials.

F1-C Molecular Level First Principle Simulations
Benign disposal of peroxide-based explosives

Search for ion complexes for decomposition of TATP started with metal ions.

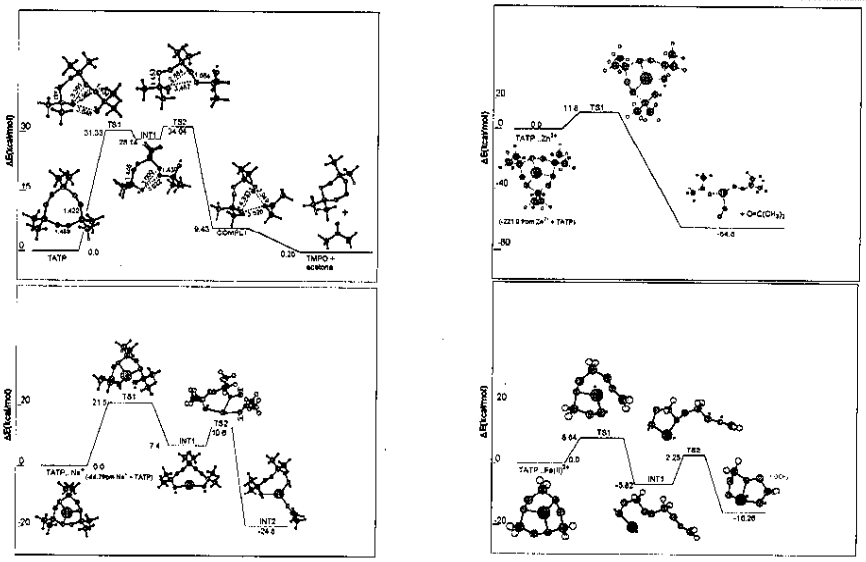
Calculation method and basis set: DFT with B3LYP/cc-pVDZ. Energy value in kcal/mol.

	E_{bind}(Ion-TATP)	TS1	INT1	TS2	INT2
TATP TATP* TATP*		31.33	28.14	34.04	9.34
Na^+...TATP Na^+...TATP* Na^+...TATP*	-44.7	21.50 19.90 20.01	7.35 -7.30	10.64 11.95	-24.80
Cu^+...TATP	-65.8	16.76			
Ag^+...TATP	-54.1	20.94			
Li^+...TATP	-67.3	19.67			
Zn^{2+}...TATP Zn^{2+}...TATP*	-215.2	11.77 9.81	 -40.6		
Fe^{2+}...TATP*	-252.3	8.84	-5.82	2.25	-15.26

*TATP with all methyl groups exchanged by hydrogen atoms
TS1=first transition state barrier height, INT1=energy associated with first intermediate species.

Note that binding of Cu+ to the TATP is about 3 times smaller than that of Zn2+ with a barrier to TS1 larger by about 35%. This may suggest that energy release will be smaller and rate of decomposition will be slower. This suggests that Cu+ might be a better candidate for destruction of TATP than Zn2+.

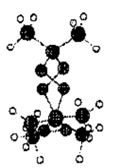
TATP(top left), Zn^{2+}-TATP(top right), Na+-TATP (bottom left); Fe2+-TATP (bottom right) initial stages in the decomposition process. The decomposition path corresponds to complexes in the gas phase.



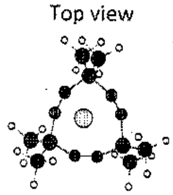
F1-C Molecular Level First Principle Simulations

For anion-TATP interactions, DFT was used with B3LYP & PBE functionals (to compare the two) Cl^- and TATP

Side view



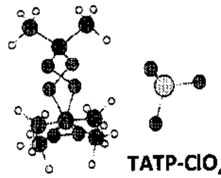
Top view



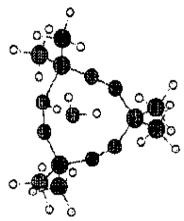
Calculations performed for gas phase complex as well as for the complex in water and the complex between TATP and the acid molecule, HCl. The binding energies obtained are (energies in kcal/mol):

Complex	B3LYP	PBE	Solvent
TATP-Cl-	10.7	13.7	none
TATP-Cl-		0.3 (no bond)	water
TATP-HCl		6.3	water

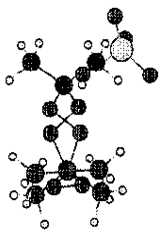
F1-C Molecular Level First Principle Simulations



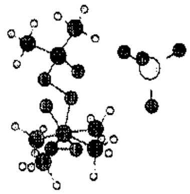
TATP-ClO_4^-
Using DFT with PBE functional get binding of 12.4 kcal/mol in water



TATP-H_3O^+
Binding by DFT using B3LYP functional is 50.5 kcal/mol; using PBE functional 65.90. The C-O distances in complex are stretched. Complex in water.



TATP-$HClO_4$
Using DFT with the PBE functional get binding of 13 kcal/mol in water



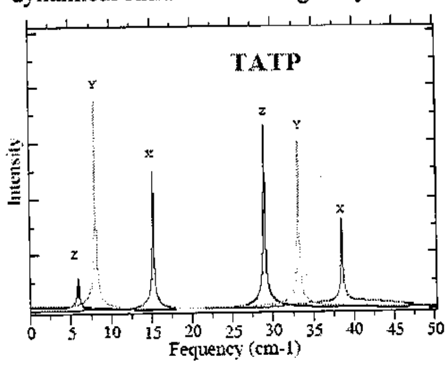
TATP-SO_4^{2-}
Binding by DFT using PBE functional is 54.6 kcal/mol; using the B3LYP functional 41.3. The C-O distances in complex are stretched. Complex in water.

F1-C Molecular Level First Principle Simulations

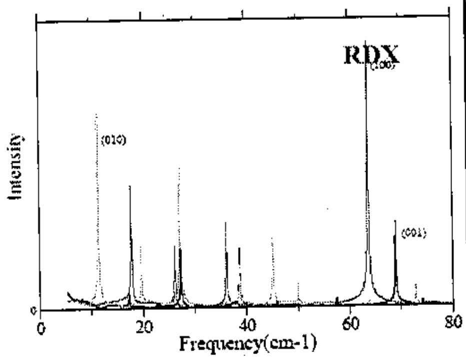
Developing novel method to simulate THz spectra

Simulations of THz spectra of single TATP or RDX crystal

Spectra is calculated from dipole correlation function (DCF) obtained by a molecular dynamical simulation of single crystal.



Spectra polarized in the Z direction as a result of compression in the three other axeses. This spectra correlates high frequency phonos with sensativity to compression.



Spectra of RDX for three polarization directions as a result of compression in the 010 direction.

1 terhertz ~ 30 cm(−1)

TATP 20 mg + additive + 50 uL 5 M sulfuric acid (40%). Solvent was added (50uL EtOH, diesel or water). TATP was destroyed in EtOH more often than in other solvents.

F1-D

BF_3 - etherate	complete destruction
$CaCl_2$	"
$Co(NO_3)_3$	"
$CrCl_3 \cdot 6H_2O$	"
$CuCl_2 \cdot 2H_2O$	"
$CuCl_2 \cdot 2H_2O$ / Cu	"
CuI	"
Fe_2O_3	"
Methanesulfonic acid	"
$ZnCl_2$	"
$ZnCl_2$ / Zn	"
Charcoal	almost complete
Fe_2O_3 / Cu	
Fe_2O_3 / Fe	"
Ferric-Ferrous Oxide	"
$KMnO_4$ / Cu	"
$KMnO_4$ / Fe	"
LiCl	"
$MnSO_4 \cdot H_2O$	"
$ZnSO_4$	"

alcohol solvent

TATP 20 mg + additive 20 mg + 100 uL solvent + 100 uL acid, 11hr

Percent remaining (area TATP + additive/area TATP)

Additive	HCl	no acid	H2SO4	NH4OH
NH4 Sulfamate	1%	88%	30%	
NH_4I	0%	81%	11%	
NH_4 BF4	0%	91%	12%	
AlCl3-6H2O	0%	84%	7%	
FeCl3-6H20	0%	95%	1%	
Ca3(PO4)2	0%	102%	48%	
Sn (0)	21%	94%	25%	
Sn (0) (100 mg)	0%			
none	1%	101%	26%	98%
none	0%	99%	33%	90%

Percent remaining (area TATP & additive/area TATP)

Additive	HCl	no acid	H2SO4
none	0%	100%	16%
AIBN	0%	98%	10%
Ascorbic acid	0%	108%	6%
Titanium (0)	0%	103%	10%
Amm Persulfate	0%	86%	13%
Silico-Tungstinic Acid	0%	89%	5%
Chromium (ACAC)2	0%	103%	0%
Cu(II)S	0%	98%	0%

TATP 50 mg + moist with 50 uL EtOH +1-2 drops HCl, 12 hr

50 uL EtOH	100%
50 uL EtOH / 1 drop	79%
50 uL EtOH / 1 drop	71%
50 uL EtOH / 2 drops	23%
50 uL EtOH / 2 drops	9%

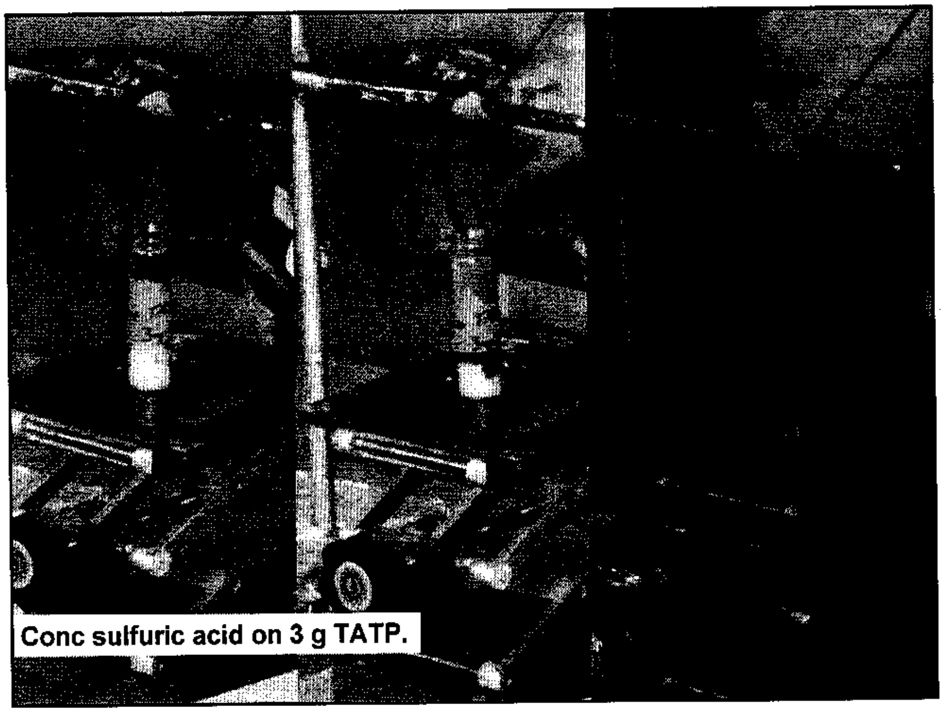
F1-D TATP Destruction: Lab Tests

MeSO$_3$H — H_2SO_4 — HNO$_3$ — HClO$_4$ — HCl

acid/water min	conc CH3SO3H (99%)	1:1 19mgKI + 4drops CH3SO3H	1:1 4drops CH3SO3H (59%)	conc H2SO4 (96%)	1:1 3drops H2SO4 (63%)	battery 4drops H2SO4 (33.5%)	1:1 6.5mg NaCl + 3 drops H2SO4 (63%)	1:1 17mg Cr2O3 + 3 drops H2SO4	conc HNO3 (70%)	1:1 4 drops HNO3 (41%)	1:1 4 drops HNO3 (41%)	1:1 4 drops HClO4 (44%)	1:1 4 drops HClO4 (44%)	conc HCl (36%)	1:1 4 drops HCl (19.5%)	1:1 20 drop HCl (19.5%)	1:1 20 drop HNO3 (41%)	1:1 20 drop HClO4 (44%)
Solid	TATP 5 mg													TATP 25 mg				
0	100%	100%	100%	100%	100%	100%	93%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
15	0%			0%					0%									
30														53%				
60		48%	60%		74%	109%	79%	100%		65%	7%	45%	19%	13%	99%	103%	67%	64%
120		43%			68%		49%			15%				3%				
180			16%			102%	66%	98%			0%	0%	0%		63%	78%	15%	25%
300		0%	4%		45%	88%	31%	78%		0%	0%	0%	0%		49%	64%	12%	5%
480		0%	0%		17%	81%	18%	70%		0%	0%	0%	0%		16%	41%	0%	0%
600					7%		7%	57%										
720					0%		0%	48%								30%		
1440																0%		
Solid	HMTD 5 mg																HMTD 25 mg	
0	100%		100%	100%					100%		100%	100%					100%	100%
15	0%			0%					0%									
60			48%								0%	0%					0%	0%
180			43%								0%	0%					0%	0%
300			0%															
480			0%															
Solid	DADP 5 mg																DADP 25 mg	
0	100%			100%					100%								100%	100%
15	0%			0%					0%									
60																	119%	86%
180																	128%	78%
300																	57%	80%
480																	59%	76%

A liquid reagent was sought that digested peroxides in less than 1 hr, but adding conc H2SO4 to 1 g TATP caused detonation.

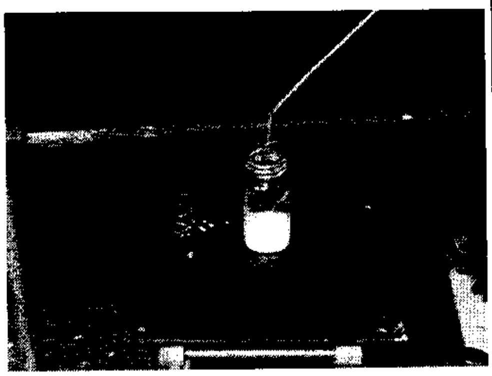
Publication: Oxley, J.C., Smith, J.L.; Huang, J.; Luo, W. "Destruction of Peroxide Explosives," ***J. Forensic Sci.*, 2009** 54(5), 1029-33.



Conc sulfuric acid on 3 g TATP.

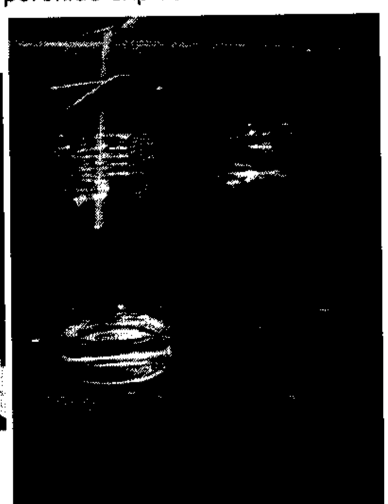
F1-D Proposed New Work:

- Test destruction of TATP in field.
- Identify destruction mechanism.
- Probe applicability to other peroxide explosives.



Material before addition of acid.
Barely moistened, not dissolved

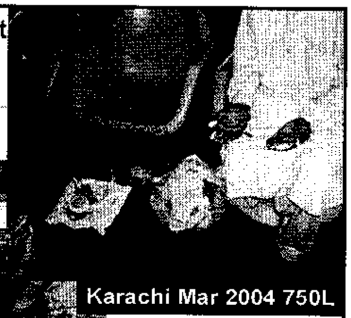
3 g TATP, 3 g EtOH (l) or BuOH (r) 3mL acid

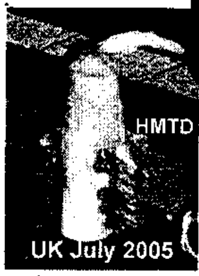


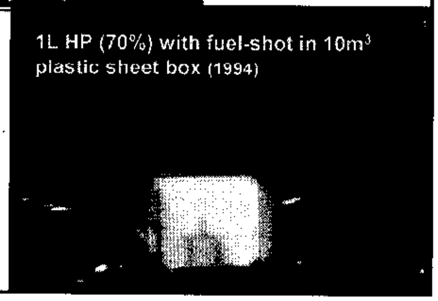
Left: after addition of HCl
Right: after addition of 90% H_2SO_4

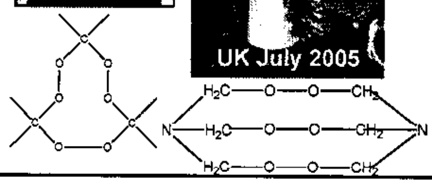
F1-E1 Denaturing H_2O_2 and its Duel Threat
Preventing concentraton by water boil off

Although any concentration H_2O_2 can be used to make TATP or HMTD, for better yield & for liquid HP, solutions must be concentrated. Goal: Prevent concentration by simply boiling off water.







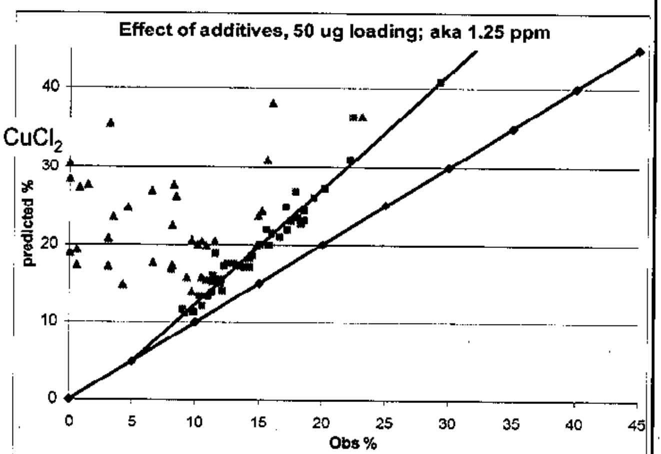


F1-E1 Potential Denaturing Agents for Hydrogen Peroxide

Joe Brady, James Smith, Jimmie Oxley URI

Past Year: Denaturing agents identified to prevent H_2O_2 concentration.

Next Year: Determine long-term storage stability & acceptability in commercial products. Can an additive on the *gras* list be used? *"generally regarded as safe"*



Potential Denaturing Agents: ascorbic acid, citric acid, $FeCl_3$, ethylene glycol (EG), di-EG, glycerin, $CuCl_2$,$Co(NO_3)_2$, $CoCl_2$, $K_2(CO_3)$ $NaHCO_3$ $Na_2(CO_3)$ $NaSO_3$, $Fe(NO_3)_3$, phosphoric acid, biuret, Na benzoate, urea, KIO_3, CuI, $NaNO_2$, $(NH_4)_2SO_4$

F1-E2 Denaturing of Explosive Precursors

James L. Smith; Jimmie Oxley; Joseph Brady, Pat Bowden URI

Urea Nitrate (UN) has been a popular explosive with terrorists for decades.

NH_2CONH_2 (urea) + HNO_3 (nitric acid) → $(NH_2)_2COH^+NO_3^-$ (urea nitrate (UN))

Historically, nitric acid was made from alkali nitrate salts. Industrially, nitric acid is separated from impurities by distillation. The removal of the impurity is dependent on the nitrate salt used.

KNO_3 (s) (alkali nitrate) + H_2SO_4 (aq) (sulfuric acid) → $KHSO_4$ (aq) + HNO_3 (aq)

F1-E2 Denaturing Precursors to Urea Nitrate

There have been reports that improvised labs, lacking nitric acid, make urea nitrate (UN) using nitric acid (NA) generated *in situ*.

Urea + KNO_3 + H_2SO_4 → $UreaNO_3$ + $KHSO_4$

# samples averaged	Preparation with additve 10wt% of urea	Crude Yield (%):	Crude mp (deg C):	Rec. Yield (%)	Rec mp (deg C):
2	HNO3	86%	153 - 155	60%	143 - 147
2	KN/HCl	98%	129 - 132	23%	131 - 136
5	KN/H_2SO_4	89%	133 - 137	21%	142 - 145
4	KN/H_2SO_4/TKPP	62%	134 - 140	9%	133-140
3	KN/H_2SO_4/DAP	85%	131-137	6%	139-150
2	KN/H_2SO_4/MKP	77%	132-138	9%	144-154

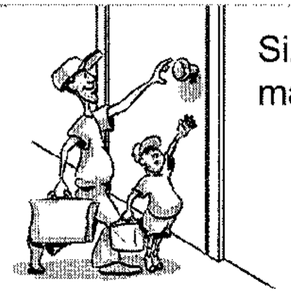
XY + Urea + ENO_3 + HCl → $UreaNO_3$ + ECl + XNO_3 + EY +HY - recryst → UreaNO₃
Mixture A

Goal: Block route to NA via alkali nitrates by leaving byproduct in UN, e.g. $(NH_4)_2SO_4$ diverts acid & promotes contamination of UN. D_{cr} detonable

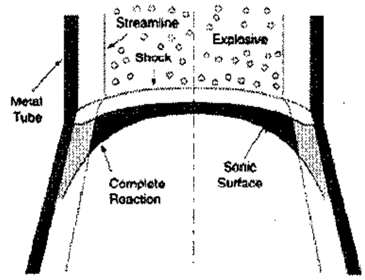
Next Year: Block NA formation so distillation does not fix the contamination problem, approach - complex or trap acid. Pub: Oxley, J.C., Smith, J.L., Naik, S., Moran, J.S. "Decompositions of Urea and Guanidine Nitrates," *J Energetic Materials*, **2009** 27(1), 17-39. Oxley, J.C., Smith, J.L., Naik, S. "Determination of Urea Nitrate & Guanidine Nitrate Vapor Pressures by Isothermal Thermogravimetry," *PEP*, in press

F1-F Identifying Explosive Precursors on Lab Scale

Jimmie Oxley, James Smith, Patrick Bowden, Ryan Rettinger



Size matters



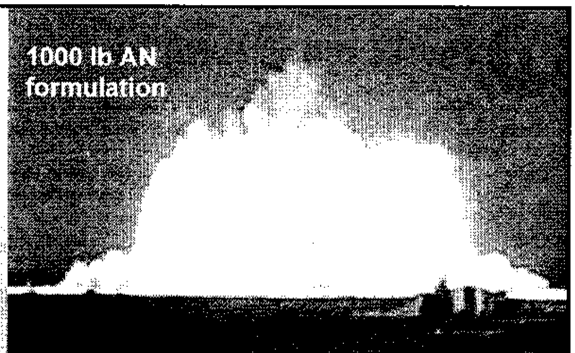
Goal: Identify explosive precursors at lab-scale, to avoid the expense and danger of ton-scale charges. Develop a new small-scale test

This year: preliminary design, made, tested & successfully modeled. Design was such that non-detonable materials became powerful jets which left the largest hole in witness plate.

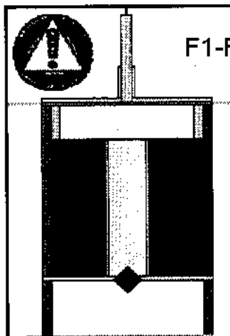
Next year: Employ combination of modeling & testing to "focus implode" rather than "squirt" test material. Determine extent that det velocity must be achieved.

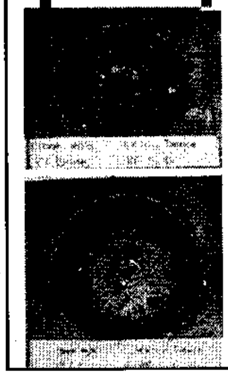
Collaboration with LANL.

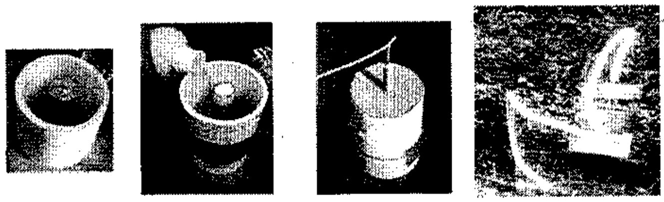
Poor explosives or "non-explosives" require large charges (for self-confinement) or heavy-wall confinement. Another possibility is "explosive" confinement



F1-F Characterizing Potentially Non-ideal Explosives

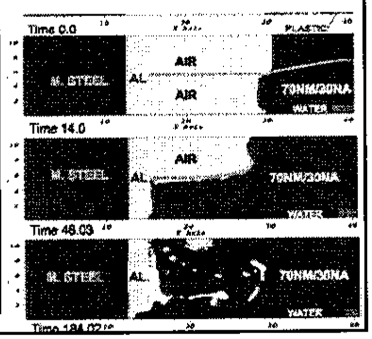






To identify non-ideal explosives a high explosive is used to focus the shock on the insensitive material.

Test #	Size	Inner Mix	Outer Mix	Dent Depth	Width of Dent	
Detonable						
18	4x4	A= 70HP/13EtOH	P	2.81	0.67	0.75
32	4x8	A	P	2.84	0.81	0.78
5	4x4	O =	8/2 NM/NA	2.73	0.68	0.68
9	4x4	P =	7/3 NM/NA	2.74	0.65	0.66
15	4x8	P +	7/3 NM/NA	2.58	0.76	0.70
Questionable						
28	4x4	Oxyclean	P	3.08	0.90	1.07
20	4x4	AN	P	3.14	0.98	1.04
29	4x8	AN	P	3.20	1.10	1.05
19	4x4	Bullseye	P	3.15	1.00	1.32
26	4x4	DNT	P	3.42	1.18	1.00
Non-Detonable						
10	4X4	C = 50HP/5EtOH	98/2 NM/deta	3.14	0.78	1.02
3	4X4	C = 50HP/5EtOH	O	3.04		
4	4X4	H2O	O	3.34	1.08	1.14
7	4x4	C = 50HP/5EtOH	P	3.23	1.29	1.18
8	4x4	Brine	P	3.48	1.18	1.06
14	4x8	C = 50HP/5EtOH	P	3.25	1.10	1.30
31	4x8	C	P	3.28	1.16	1.41
16	4x8	Brine	P	3.55	1.17	1.28
17	4x4	Sand	P	3.14	1.08	0.91
23	4x4	Sugar	P	3.20	1.02	1.13



Publications (URI)

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Oxley, J.C.; Smith, J.L.; Kirschenbaum, L.; Marimiganti, S.; Efremenko, I.; Zach, R; Zeiri,Y Accumulation of Explosive in Hair: Part 3: Binding Site Study in press

Oxley, J.C., Smith, J.L., Naik, S. "Determination of Urea Nitrate and Guanidine Nitrate Vapor Pressures by Isothermal Thermogravimetry," *Propellants, Explosives, Pyrotechnics*, in press.

Gregory, O.; Platek, M.; Oxley, J.C.; Smith, J.L.; Bernier, E. T. "Microstructural Characterization of Pipe Bomb Fragments" accepted Materials Characterization Journal.

Presentations of Characterization Group (URI)

NATAS Short Course in Thermal Stability Studies of Energetic Materials Sept 20, 2009
DHS/URI Detection Workshop Oct 8-9, 2009

~~"Pre- & Post-Blast: What to Look For, What to Look With," Am. Assoc For Sc, Seattle, Feb 23, 2010~~

"What is the Threat?" RI Emergency Management Advisory Council; URI Feb 9, 2010

"DHS Center of Excellence: an Overview;" URI Foundation Board, Jan 30, 2010

"Security: What More Can We Do?" Delta Airline; URI Jan 29, 2010

"DHS Center of Excellence" Homeland Security Science & Tech Adv Co, Wash DC, Jan 28, 2010

"Studying Energetic Materials for Safety & Security; Miami, Florida International U, Jan 14, 2010

"Peroxide Explosives—Hazards & Remedies; Tel Aviv, Dec 9, 2009

"HME—Old Explosives, New Applications, Tel Aviv, Dec 8, 2009

"Characteristic Signatures of VBIEDs Interagency Standoff Explosives Detection & Defeat Working Group, Wash DC, Nov 3, 2009

"Research in Safety and Security, Newark, U Delaware. Nov 2, 2009

"Developing Small-Scale Tests to Predict Explosivity; Sept 21, 2009 NATAS Lubbock Tx

"Explosive Threat; Massachusetts Assoc Hazardous Materials Techs Sept 17, 2009 Plymouth MA

"IED Overview" & "Uses of hair as evidence" Int Crime Scene Conf July 15-17,2009, London, UK

"The IED Threat: What to Look for and What to Look with" National UASI (Urban Areas Security Initiative) Conference; Charlotte; June 10, 2009

"Center of Excellence in Explosives..." URI Research Seminar Series; June 5, 2009

"Toward a Comprehensive Approach to Counter-IED; HME Wkg Gp 29 Palms MarB; May 19, 2009

"Explosive Research at URI Brown University, Ap 9, 2009 Aberdeen, MD; ABL, Ap 21, 2009

"Explosive Residue, Pittcon Mar 11, 2009

DHS University Summit Mar 18, 2009

F1-A1: Vapor liquid equilibria of H_2O_2 mixtures (B. Weeks, TTU)

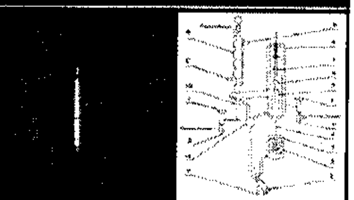
Objective: To determine vapor liquid equilibria (VLE) of $H_2O+H_2O_2$ binary system & $H_2O+H_2O_2$+adulterant ternary system.

Approach:

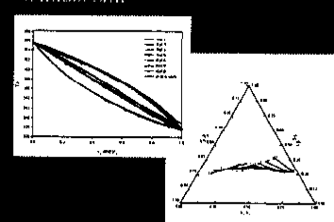
- Expand knowledge of VLE behavior of ternary systems of using adulterants (acetone, ethanol, etc.) mixed with hydrogen peroxide.
- VLE data is collected with a Rose-William still and characterized with a Shimadzu GC (new in 2009)
- Analysis is performed using higher order thermodynamic models (NRTL, UNIQUAC and Wilson)

Significance and relevance:

- Provide inhibitors to distillation of hydrogen peroxide
- Preliminary data has been collected on a methanol + methyl-butanol + propanol ternary system to compare to literature (J. Chem. Engn. Data)



In house constructed pressure-temperature chamber and Rose-William Still



Binary (L) and Ternary (R) for methanol · propanol · methyl-butanol system - comparison to literature data

F1-A1 cont'd: Vapor liquid equilibria of H_2O_2 mixtures (C.S. Yoo, WSU)

H_2O_2-water mixtures: melt, phase transition, decomposition

Progress: **Investigated the phase stability and chemical decomposition of H_2O_2 and its mixture with H_2O using micro-Raman spectroscopy and third-generation synchrotron x-ray at the APS.**

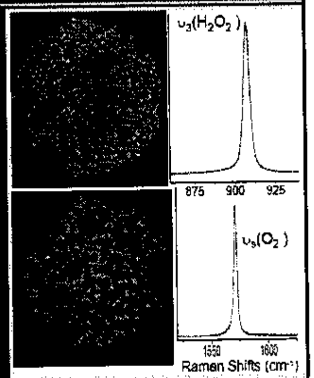
- **Phase transition at 13 GPa**
- **Pressure-induced decomposition: $H_2O_2 \rightarrow H_2O + O_2$ above 20 GPa**
- **Melt-induced disassociation: 2.5 GPa for pure H_2O_2 and 1.5 GPa for 10% H_2O_2**
- **Formation of hydrates at 1.3 GPa in 10 % H_2O_2**

Significance:

- **Unique high-pressure data of H_2O_2 – H_2O mixtures:**
- **First observation of new H_2O_2 phase**
- **Static data that can provide an insight of a cusp on the principle Hugoniot of H_2O_2 at ~5 GPa**

Collaboration: **Drs. Dattelbaum and Sheffield at LANL**

- **Shock initiation experiments in pure H_2O_2**
- **Energetic materials (H_2O_2, AP, AN, IPN, etc.)**

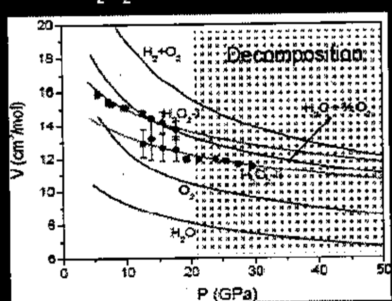


Images and Raman spectra of H_2O_2 at the onset of chemical decomposition at 2.5 GPa.

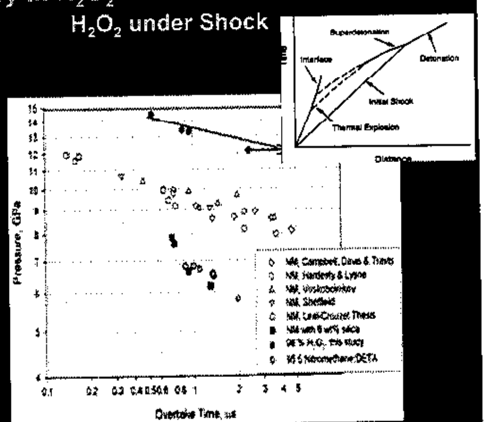
F1-A1 cont'd: Vapor liquid equilibria of H_2O_2 mixtures (C.S. Yoo, WSU)

Static and shock-induced chemistry in H_2O_2

H_2O_2 under Static



H_2O_2 under Shock



- **Structural phase transition from H_2O_2-I (tetragonal) to II (orthorhombic) at 13 GP**
- **Pressure-induced decomposition of H_2O_2-II above 20 GPa: densification driven**
- **Detonation of H_2O_2 above 12 GPa (Det velocity ~ 6 km/s)**
- **Follows an homogeneous detonation model**

F1-A2: Routes to synthesize non-nitrate containing energetic materials (L. Hope-Weeks, TTU)

Objective: The majority of energetic materials contain a high concentration of nitrate groups and can be detected by traditional methods. The goal of this work is to investigate the synthesis and characterization of energetic materials without nitrate groups (primarily non-ideal explosives).

Approach:

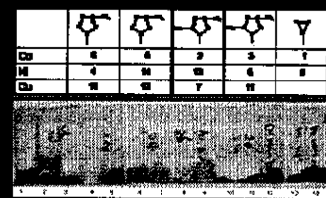
- Synthesis of TATP and other peroxides without the use of hydrogen peroxide (Oxone chemistry)
- Investigated the synthesis of transition metal complexes to determine the effect of the metal on stability.

Significance and relevance:

- By understanding synthetic routes will allow for targets of detecting starting materials
- Metal containing energetics may provide replacement compounds for CP and BNCP
- Products can be used to develop new detection methodology
- Developed a thermal drop hammer for sensitivity tests of less than 10 mg of HE

C_3H_6O + KHSO5 → TATP

Oxone is a commercially available product from DuPont commonly used in denture cleaners, pools and bleach. It can be used to easily convert acetone to acetone peroxides with a yield of ~66% TATP



Range of energetic materials synthesized with various metals and substituants

F1-B: Formation of thin film energetic materials (B. Weeks, TTU)

Objective: To investigate nanoscale properties of energetic materials (ideal and non-ideal) to understand propagation and surface structure.

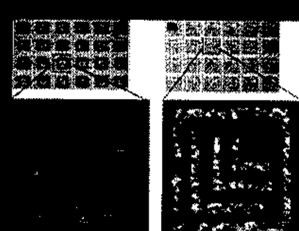
Approach:

- Deposition of thin film energetic materials on the nanometer scale.
- Investigate the structure using AFM, FTIR, and ellipsometry
- Future studies will look at laser initiation for propagation experiments

Significance and relevance:

- Provide data for thermochemical codes (e.g. CHEETAH).
- Understand the sensitivity of non-ideal HEs with a minimal amount of material
- Data is relevant to other areas of research including semiconductor industry and thin film deposition

Research highlighted on the covers of Applied Physics Letters and Scanning



Complex Patterns of PETN formed on a silicon surface (ACS Applied Surfaces and Interfaces)

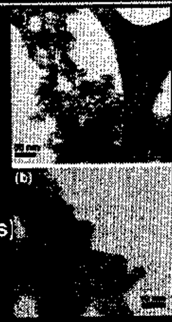
F1-TTU: Yr3 Plans and Metrics

Plans :

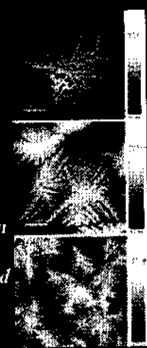
- F1-A1: Continue VLE experiments on peroxide systems with adulterants (long term project)
- F1-B: Investigate the initiability of nanoscale patterned surfaces using laser initiation (determine flame front using both AFM and hydrocodes)
- F1-B: Nanomaterials (aerogels and nanocrystals) for improved detection and mitigation
- F1-A2: Small scale safety tests of energetic materials
- F1-A2: Synthesis of non-nitrate containing energetic materials

Metrics:

- 3 GS + 2 Faculty
- 3 publications
- Collaboration with LLNL and ORNL



ZnS aerogels for improved detection and mitigation (improve material properties)



Nanoscale patterned surfaces of dendritic energetic materials. The fractal dimension and specific surface area can be controlled by deposition parameters

F1-WSU: Yr3 Plans and Metrics

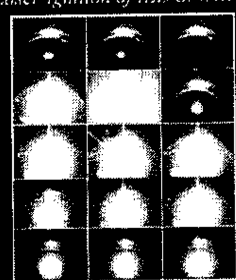
Plans:

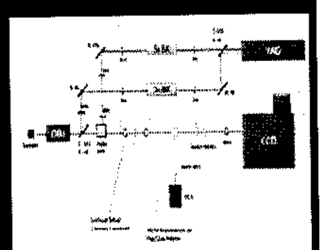
- Investigate the temperature effect on the pressure-induced chemical decomposition in H_2O_2 – to reconcile the difference between static and shock results
- Phase stabilities of heterogeneous AP and AN under pressures
- Proposed study of chemical initiation studies on heterogeneous energetic materials during the deflagration, combustion, thermite, and metathesis reactions (see next slide)

Metrics:

- 2 GS + 2 PD + 1 Faculty
- 1 publication
- 1 abstract for the DHS Summit
- 3 presentations: 2 APS (March 2010), 1 GRC on HE (June 2010)
- Collaboration with LANL

Laser-ignition of IED at WSU





F1-Proposed: Chemical initiation and phase stability of nonconventional explosives (C.S. Yoo)

Objective: To investigate phase stability and chemical initiation of nonideal energetic explosives under relevant pressure-temperature conditions of detonation.

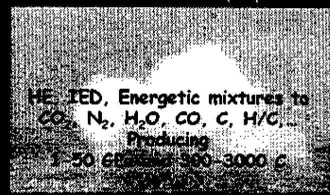
Approach:

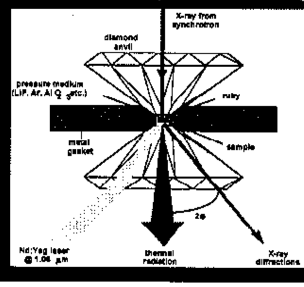
- Determine the phase/chemical stability under static conditions using DAC.
- Investigate chemical initiation by a pump-probe experiments
- Compare shock-initiation and propagation data

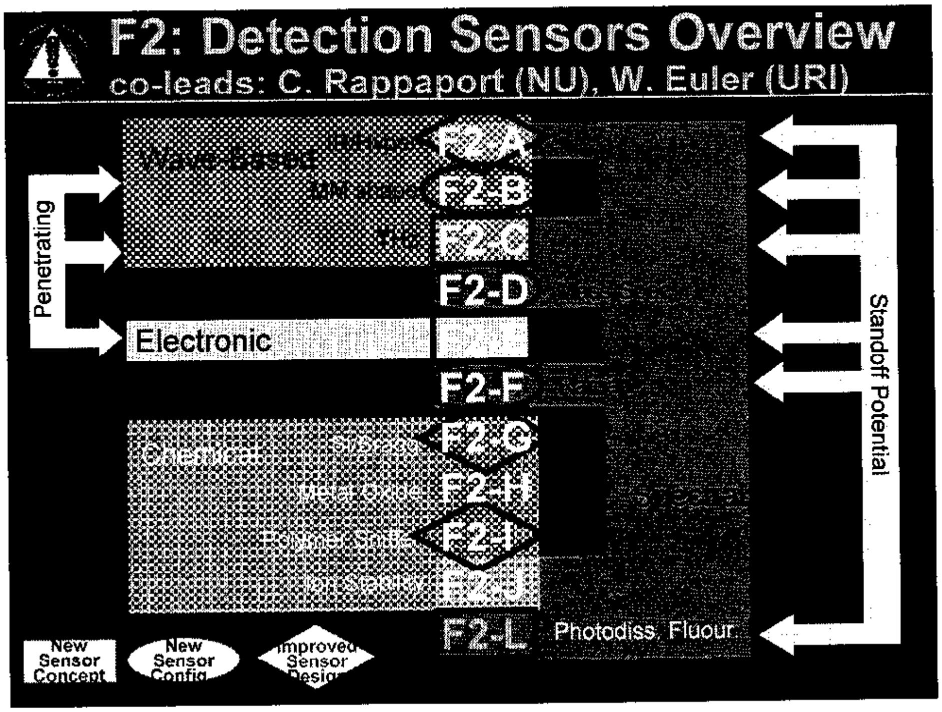
Significance and relevance:

- Understanding fundamental properties of IED's in high values to DHS interest: melting, phase transition, chemical stabilities, EOS, etc.
- Gain insight into shock initiation and sensitivity
- Producing materials/spectroscopic data for characterization and mitigation

Unknown structures and properties







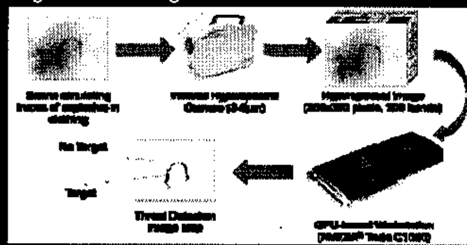
F2-A Explosive Detection using Hyperspectral Imaging

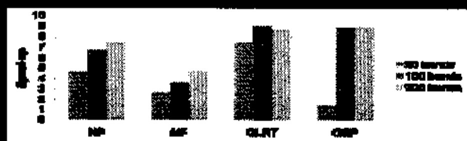
M. Vélez-Reyes, N. G. Santiago, S. Hernández-Rivera (UPRM); M.Diem (NU)

- Motivation and purpose:
  - To develop detection systems for energetic materials (EM) and other chemical threats based on hyperspectral imaging (HSI) and remote IR spectroscopy (RIS).
- Innovative Aspects
  - Target detection methods based on structured models and oblique projections, and multivariate statistical methods. GPU-based implementation for real-time detection.
  - Pre-processing for target/background contrast enhancement based geometric PDEs to improve detection of small objects in complex background.
  - Work supported with strong experimental work.
- Year 1-3 Plans (work started in Jan. 2009)
  - Generate database of phantom images and point data using IR and Raman hyperspectral imagers and stand-off systems for algorithm testing and validation
  - Implementation of standard and proposed oblique projection algorithms for target detection in GPU platform using Jacket Toolbox and CUDA. Establishment of performance metrics and perform evaluation.
  - Assessment of PDE-based image enhancement methods as pre-processing for target detection
- Long range impact
- The expected <u>outcome</u> of this project is to improve significantly the current stage of development of remote detection science of hazardous chemicals.
- Algorithms and spectral and image analyses developed as a result of work will impact other techniques being considered for remote measurements of chemical threats

F2-A Explosive Detection using Hyperspectral Imaging – Current Projects

Implementation of Target Detection Algorithms using GPUs



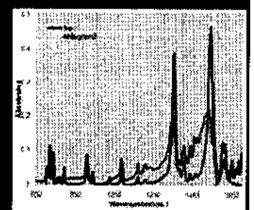


Implementation using the MATLAB GPU Jacket Toolbox shows nearly an order of magnitude speed up for OSP & GLRT. Further performance improvement requires direct implementation in CUDA.

Standoff IR:EM27 Open Path FTIR

Detection of TNT on SS Surface
Source to target distance: 1 m.

Atmospheric water vapor (between 1250 and 1650 cm^{-1}, blue trace) and distorted bandshapes will be corrected using EMSC by Diem



F2-A Explosive Detection using Hyperspectral Imaging – Yr 2 Accomplishments and Plans

- Phantom Image set using ammonium nitrate (AN) collected in summer 2009 using MWIR Hyperspectral Imager (3-5 μm)
  - Camera exhibits artifact at the center of the field of view (large bright spot with the dark halo) which limits data usefulness. Camera system will be sent to manufacturer for calibration.
- Non imaging spectral data acquisition collected using EM27 Open Path FTIR on surfaces (in active and passive modes): metals, wood, rag, clothes, skin

MWIR Camera Image

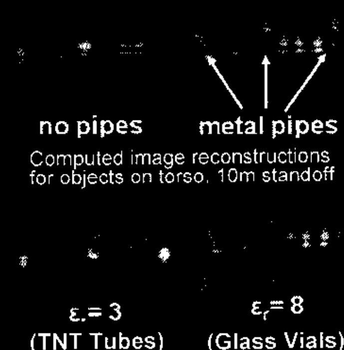
- Completed initial implementation of standard target detection algorithms in GPU using MATLAB Jacket Toolbox.
  - Implementation of proposed oblique projection algorithms for target detection and unmixing algorithm
  - Evaluation of performance is on going using collected data and standard sets.
  - Initial results point out limitations of Jacket Toolbox and need for direct implementation in CUDA for further performance improvement.
  - Atmospheric correction for water vapor and reflective band shape distortions via Extended Multiplicative Signal Correction (EMSC) algorithm by Diem
- Work on GPU implementation an assessment of PDE-based image enhancement for target detection will be started during 2010.

F2-A Project Statistics

Faculty Involved	4
Post-doctoral	1
Graduate Students	1
Undergraduate Students	4
Papers Published/Submitted	2
Presentations by Students	1

F2-B Millimeter Wave Standoff Detection of Concealed Explosives
Carey Rappaport and Jose Martinez, NU

- 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
  - Develop model-based inversion to identify irregularities on skin surface



Computed image reconstructions for objects on torso, 10m standoff

- Year 2 accomplishments:
  - Full wave modeling of FMCW radar system used in experiment
  - New model-based algorithms for detecting dielectric materials as well as metal scatterers
- Long Range Impact:
  - Fast, automatic, standoff alert of objects hidden under clothes
  - Detection optimization using limited view fixed electronically scanned aperture array

F2-B Millimeter Wave Standoff Detection of Concealed Explosives

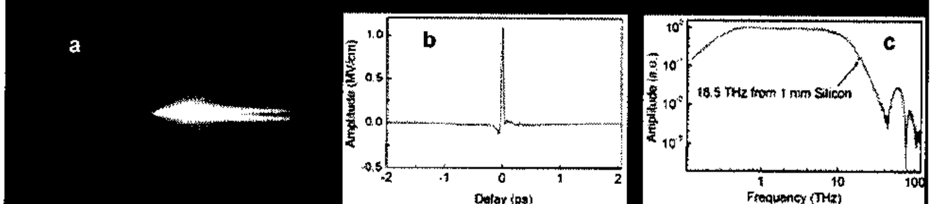
- Year 3 Proposed Work
  - Investigation of multi-bistatic planar 94 GHz FMCW radar to simulate fixed array
    - Experiments in Germany with IAF
    - Extension of ISAR algorithms to bistatic SAR imaging
  - Explore fixed aperture array reconstruction approaches
  - Continue undergraduate research education in modeling, signal processing, and material characterization

Faculty Involved	2
Post-doctoral	0
Graduate Students	2
Undergraduate Students	4
Papers Published/Submitted	2
Presentations by Students	6

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

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

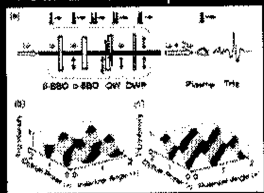
- Purpose and Relevance: Understanding the underlying science of THz wave photonics using air and gases as THz wave emitters and sensors might provide a feasible approach for the concealed items' detection at standoff distance.
- Innovative Aspects: We obtained a pulsed THz field greater than 1 MV/cm with its spectral range over 100 THz.
- Year 2 accomplishments: We develop THz field-enhanced-emission-of-fluorescence (REEF) and THz-enhanced-acoustic (TEA) methods which detect pulsed THz waves with potential standoff sensing capability.
- Long range Impact: The science and technology behind air-plasma 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.



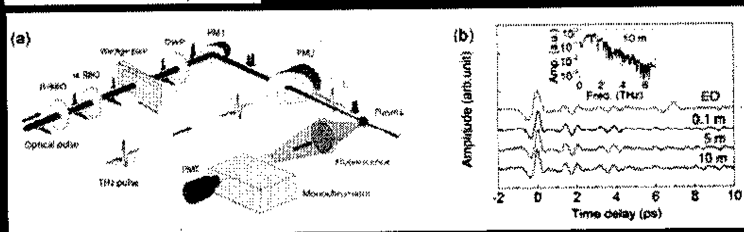
a. Laser induced air plasma. b: THz signal emitted and sensed by dry air. c: THz spectrum.

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

- Year 2 Proposed Work: 1. A quantum mechanical model to describe THz wave generation and detection using air (gases); 2. Experimental verification of the theory; 3. Standoff THz wave generation and detection in ambient air.
- Year 2 Accomplishments (Some Real Data):



(1) A quantum mechanical model has been established, and coherent control of THz wave polarization has been predicted by the model and has been verified experimentally—the polarization of the emitted THz waves can be coherently controlled through the optical phase.



(2) Standoff THz wave detection at a distance of ~10 meters utilizing THz Radiation Enhanced Emission of Fluorescence (THz-REEF) by monitoring at UV light

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

- Year 3 Proposed Work: 1. Investigation of THz Radiation-Enhanced Emission of Fluorescence (REEF) in different gases at different pressures; 2. Improvement of the THz emission efficiency; 3. Remote THz wave generation at a distance over 30 m; 4. Remote THz detection using two-color THz-REEF; 5. Multiple detection schemes of intense THz waves with THz-REEF, THz-ABCD, and plasma sound detection; 6. Undergraduate education (team with Prof. Rockward and his underrepresented minority students).

Faculty Involved	4
Post-doctoral	1
Graduate Students	4
Undergraduate Students	2
Papers Published/Submitted	8
Presentations by Students	2

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 2 Outcomes:

  New techniques for threat source localization using chemical plume tracing (CPT) and computational fluid dynamic (CFD) models.

  Publication describing robotic and CPT techniques for locating and assessing underwater military munitions threats.
- Long range Impact:

  Rapid, accurate identification and localization of multiple threats across wide classes of explosives and toxic chemicals (marine & terrestrial)

Post-doctoral	1
Graduate Students	1
Undergraduate Students	0
Papers Published/Submitted	1
Presentations by Students	2

- Year 3 Proposed research:

  Optimize search methodology as f(chemical specificity, position, update rate, MLOD)

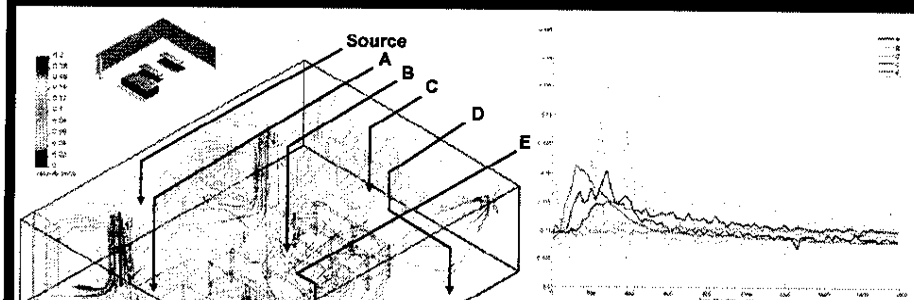
  Integrate sensing onto mobile robots for real-time plume mapping and source localization within complex indoor environments

  Begin developing and evaluating CPT methods for real-time source localization using mobile autonomous robots

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

Year 2 Objectives:
- Develop a portable MS as enabler to rapidly detect, identify threat plumes
- Demonstrate ability to confirm/rule out source at large standoff distances without knowledge of flow field

Year 2 Research Accomplishments:
- Developed new CPT methods using a mobile mass spectrometer for threat detection at large standoff distances
- Using novel CFD models to validate and simplify search strategies within complex indoor environments

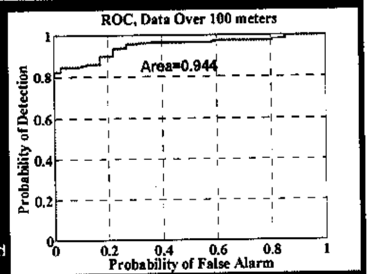


At left: CFD model of air circulation velocity vectors within a 600 ft² room. **At right:** time series measurements of pulsed tracer gas release within the room. Solid colors indicate signal intensity averaged over 20 seconds, dashed lines indicate 95% confidence interval. Letters indicate position of sensor within the room. Data indicate that detector position furthest from source (D) detects plume fastest and with highest average sensitivity; detector position closest to source (A) has the highest variability.

F2-E Detection of Electronically Initiated Explosive Devices

D. Beetner, S. Grant, D. Pommerenke, Missouri S & T

- **Purpose and Relevance**
  - Develop methods to detect, identify, and interrogate electronics commonly used in explosive devices based on their unintended electromagnetic emissions
- **Innovative Aspects**
  - Potentially fast, long-range detection and location
  - Information orthogonal to information generated by many other explosives-detection methods
    - Effective sensor fusion.
    - May provide information when other sensors fail
  - Same physics used to detect devices can potentially be exploited to neutralize device without destroying forensic evidence.
  - Leveraging 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.
- **Long range Impact**
  - Develop firm scientific foundation for methods to detect, identify, and neutralize electronics associated with explosive devices



ROC curve for detection of 5 different regenerative receivers at 150 m from antenna in noisy ambient environment. High detection rate enabled by stimulating change in unintended emissions. No *a priori* characterization of the receiver is required (submitted for publication).

- **Year 1 and 2 Work Summary**
  - Surveyed existing signal processing algorithms used to detect weak signals in significant noise
  - Characterized performance of signal processing algorithms when used to detect unintended emissions
  - Developed methods to detect electronics using stimulated emissions
  - Began characterization of constraints to locate electronic devices using stimulated emissions
  - Explored commercialization or sensor fusion opportunities

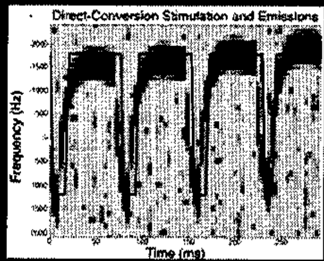
F2-E Detection of Electronically Initiated Explosive Devices

Year 1 and 2 Accomplishments

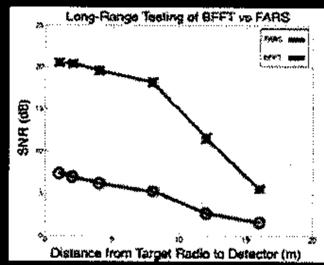
- Characterized stimulated emissions from superheterodyne and regenerative receivers
- Reviewed, developed, and tested signal processing algorithms for detecting wireless receivers
  - Detection of *regenerative* receivers largely complete
  - Completing finishing touches on methods to detect *superheterodyne* receivers
  - Developed measurement/signal processing techniques to reduce ambient noise when measuring weak emissions signal (*added task*)
- Starting development/characterization of methods to *locate* electronic initiators
- Actively pursuing commercializing detection technology
- Beginning characterization of emissions from "other" electronics like electronic timers, microprocessor, IR detectors
- Synergistic efforts:
  - Developed prototype for neutralizing electronic devices
  - Developed instrumentation to locate wireless transmitters

Post-doctoral	0
Graduate Students	5
Undergraduate Students	0
Papers Published/Submitted	5
Patents	2

F2-E Detection of Electronically Initiated Explosive Devices



Unintended emissions (red) from a superheterodyne receiver are modified by a weak stimulation (black)



Detection of receiver is improved by correlating characteristics of weak stimulation with observed emissions

Proposed Work for Year 3

- Complete characterization of algorithms to detect *superheterodyne* receivers
- Continue characterization of theoretical/practical limits to *locating* electronic devices using stimulated emissions
- Continued characterization of emissions from electronic devices like timers, passive IR detectors, and other electronics
- Begin development of algorithms to detect/identify/locate devices like timers, passive IR detectors, etc.

F2-F Remote Raman Spectroscopy Detection of Energetic Materials and other Threat Chemicals

S.P. Hernández-Rivera, UPRM, P. Chen, Spelman

Purpose and Relevance:

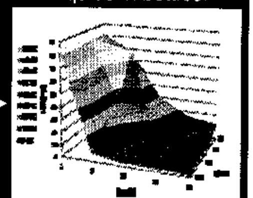
- Develop Remote Raman Spectroscopy (RRS) for detection energetic materials (EM) and other threat chemicals in terms of range (> 100 m), in detection limits (< mg) and in discrimination and quantification studies
- Explore whether resonantly enhanced coherent Raman spectroscopy and/or coherent 2D spectroscopy can be used to better detect NO_2.

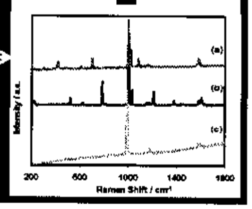
Innovative Aspects:

- Ongoing experiments include detection of EM on surfaces and hazardous liquids in bottles. Experiments include loadings down to several $\mu g/cm^2$.

Year 2 Outcomes:

- First paper to include Raman and IR detection on surfaces.
- First paper including RRS quantification studies of C4.
- RRS detection of hazardous liquids at 7m target-source: e.g.: benzene, toluene, chlorobenzene
- Paper submitted in RRS detection of hazardous liquids.
- Graduated 3 Ph.D. ALERT students, 2 MS ALERT students.
- Began transition from CW to pulsed lasers based excitation.
- Continued discrimination studies
- Acquired most of required instrumentation for CARS





F2-F Remote Raman Spectroscopy Detection of Energetic Materials and other Threat Chemicals

Proposed Strategy for remote CARS detection

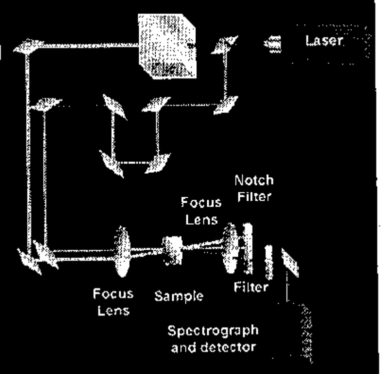
- Targets illuminated at distance using UV laser. If present, nitrogen-containing explosives will release NO_2
- Released NO_2 has a characteristic signal that is detected using 2 other laser beams to generate a coherent Raman signal

Findings

- Experimental setup compares resonantly enhanced with conventional coherent Raman spectroscopy
- In 500-650 nm spectral range, resonantly enhanced Coherent Raman has superior detection

Plans for year 3:

- Additional strategies for further improving the detection limit
- Investigate results in other spectral ranges
- Explore operation in broad daylight without interference from ambient light



Long range Impact:

- The expected overall outcome is to improve significantly Remote Raman Spectroscopy based detection of hazardous chemicals
- Results will impact other techniques for remote measurements of chemical threats.
- Development of CARS remote detection of energetic materials in the vapor phase and on surfaces will revolutionize remote detection based on its specificity and high resolution

F2-G Optical Chemical Sensors using Nanocomposites from Porous Silicon Photonic Crystals & Sensory Polymers

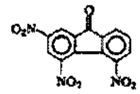
Leads: William Euler, Igor Levitsky, Students: D. Brodeur, C. Latendresse, E. Hwang, Meredith Matoian

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 substrates filled with chemistry selective to explosives

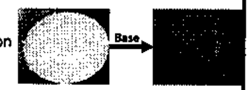
Porous Silicon: An emissive polymer is used to fill the pores, which causes refractive index changes throughout the depth of the sensor. This allows amplification of the fluorescent quenching. The sensor is responsive to both TNT and RDX vapors.

Problem Identified and Next Steps: The fluorescent polymer photobleaches upon exposure to the light source used for the optical measurement. *Solutions*: 1) sacrificial additives, such as trinitrofluorenone (shown at right); 2) new pore structures, such as conical pores to restrict oxygen exposure.



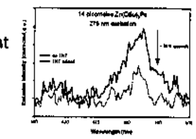
Nafion: porous polymer allowing acid-base chemistry to detect analytes. The sulfonic acid groups in Nafion react with Rhodamine B, causing a color change and suppression of emission. Exposure to bases reverses the effect, allow sensing.[1]

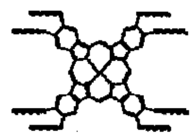
Next Steps: Introduce reducing agents (to form amines) selective to explosives. The reduced analytes can be detected by the sensor.



Sol-gels: porous glasses can be chemically fabricated with transducing components. $Zn(OBu)_8Pc$ is a stable fluorophore that readily quenches TNT and is sensitive to the picomole level.

Next Steps: Introduce $Zn(OBu)_8Pc$ and other fluorescent probes into the sol-gel matrix.





$Zn(OBu)_8Pc$

1. "Gas Phase Sensors for Bases Using Rhodamine B in Nafion Films," Eunhae Hwang, Igor A. Levitsky, William B. Euler, *J. Appl. Polym. Sci.*, 2010, in press.

F2-H Persistent Surveillance Sensor for Detection of Explosive Precursors

Otto Gregory, Michael Platek, August Cote, Thomas Hilfer, Bruce Schaller, Caitlin Hurley

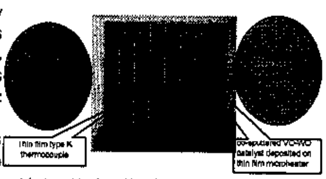
University of Rhode Island

Purpose/ Relevance A robust sensor platform that can unambiguously detect explosive precursors is the goal. Since potential threat molecules accumulate in enclosed, high traffic areas e.g. subway stations, stadiums, tunnels, airplane, highly selective, reliable sensor platform is desired. Sensors must detect minute concentrations of target molecules, e.g. NH_3 without interference effects from related molecules that lead to false positives.

Innovation: Combinatorial chemistry employing combinations of catalysts is used with sensitive screening experiments to optimize sensor response to target molecules, e.g. NH_3, urea. Deposits of VO, WO, FeO, or CoO catalysts and combinations on microheater platforms are capable of detecting the thermodynamic response to target molecules. Enhancement of response through deployment of single wall carbon nanotubes (SWNT) as catalyst support has been demonstrated & is an ongoing aspect of this research. The flow chart (right) provides a roadmap for achieving our goal.

2nd year outcome Experiments were performed using various microheater-sensor platforms to establish thermodynamic response of single oxide catalysts to NH_3 and urea without interference from molecules such as NO_2. Air has replaced other inerts as the carrier gas when testing NH_3. It is representative of field applications & provides better sensor response with less background noise than helium and other inerts with high heat capacities. Testing to determine relative thresholds for detection has been performed for a large number of oxide catalysts using various platforms (Table I).

Long Range Impact The design & fabrication of arrays of microheater sensors containing multiple catalysts, which use pattern recognition to check against a library will be integrated into MEMs platform to provide real time detection of threat indicator molecules. Collaboration with NUWC is creating a MEMs based prototype array which ultimately could be integrated into a wireless monitoring platform or distributed sensor network.



catalyst combinations: V_2O_5-FeO, CoO-Pd, ZnO-Pd, CuO-FeO

Fig 1. Co-sputtering of oxide libraries for screening

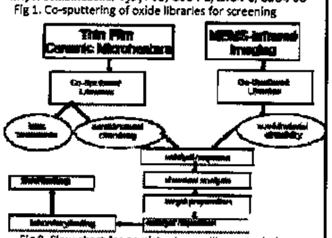


Fig 2. Flow chart for persistent surveillance technique

	NH3	NO2	Urea
FeO	yes	yes	Incomplete
WO	[illegible]	marginal	Incomplete
VO	[illegible]	[illegible]	Incomplete
CoO	yes	marginal	Incomplete
CuO	marginal	[illegible]	Incomplete
PdZnO	yes	yes	Incomplete
PdCoO	yes	yes	Incomplete

Table 1. Catalyst response to various target molecules

F2-H Persistent Surveillance Sensors for Detection of Explosive Precursors

Otto Gregory, Michael Platek, Thomas Hilfer, August Cote, Bruce Schaller, Caitlin Hurley

University of Rhode Island

Results Change in temperature of surface of catalyst coated micro-heater was sensed by measuring power required to maintain temp. of the sensor relative to a reference microheater in absence of catalytic reaction. Thus, thermodynamic response is the power difference due to catalytic reaction with the target gas (Fig. 3). Since detection of NH_3 is dependent on its decomposition at a specific temperature, sensor response can be amplified in the presence of palladium (Pd). Nanocomposite catalysts of Pd & various metal oxides were prepared by co-sputtering & screened for catalytic response using combinatorial chemistry. Pd/CoO_2 and Pd/ZnO nanocomposites were the most responsive catalysts developed to date (Fig 4), and light off condition was shifted to lower temperature while maintaining the selectivity. NH_3 concentration dependence on sensor selectivity & response was established.

The effect of interference or background gases (such as NO_2 on NH_3) on sensor response was investigated to determine threshold concentrations below which discrimination can no longer be achieved. Persistent surveillance is made possible by small, inexpensive metal-oxide gas sensors.

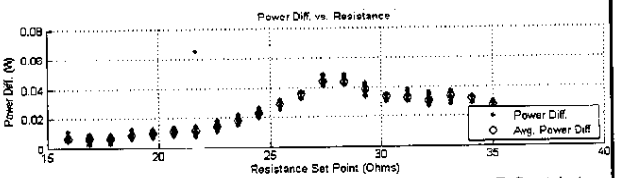


Fig 3: Typical sensor response to NH_3 using FeO catalyst

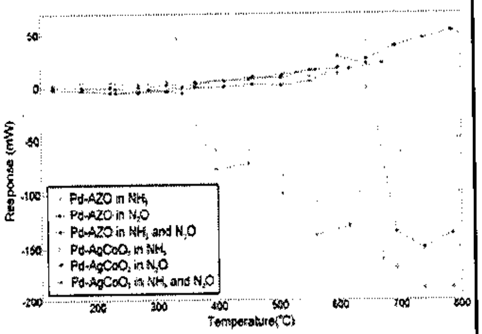
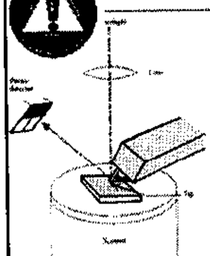


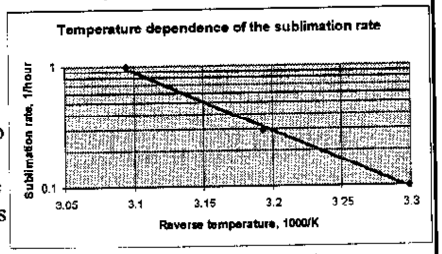
Fig 4 Nanocomposite catalyst response as a function of temperature in NH_3 and NO bearing gases

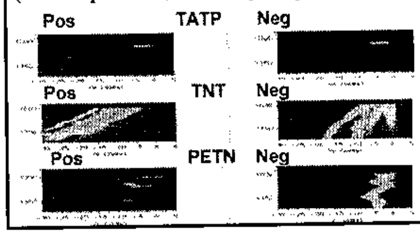
F2-J Explosive Particles Sampling & Detection, Yehuda Zeiri BGU



I. Particle-Substrate Adhesion Forces are being examined using Atomic Force Microscopy (AFM) & aerodynamics. Aerodynamics lifts particles from substrates with short pulse by gas jet. Particle distribution change on the substrate surface yields relative adhesion forces. AFM allows study of soft substrates (i.e. cloth, skin) while aerodynamics will be used to study adhesion of nanometer size particles using Fluorescence microscope.

II. Explosive particle life time measurement
Quartz Crystal Microbalance (QCM) will be used to measure evaporation rate of TNT microcrystals. These measurements allow determination of the life time of explosive particles under various conditions (i.e. temperature, humidity, exposure to UV etc.).





III. Detecting explosives in mixed matrices
We will develop an artificial neural network to enhance the ability of Differential Mobility Spectrometer (DMS) to identify explosives in contaminated matrices with various organic compounds (i.e. oil, gasoline etc.).

F2-K Fragmentation of Gas Phase Ions of Simulants & Explosives in Air at Ambient Pressure; G.A. Eiceman, NMSU

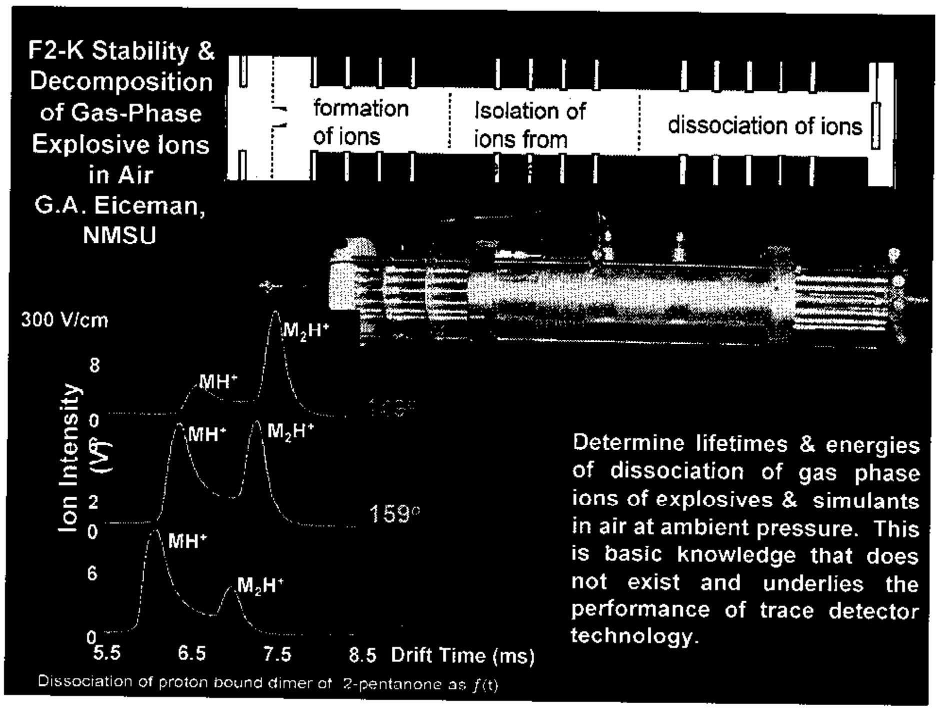
Purpose/ Relevance: Determine lifetimes & energies of dissociation or fragmentation of gas phase ions of explosives & simulants in air at ambient pressure. This is basic knowledge does not exist; yet it underlies the performance of trace detector technology current employed in checkpoint screening and those envisioned for future use.

Innovation: Key technical innovation is ability to determine heats of reactions & free energies with ions under precise control of internal energies; there is no comparable method to obtain such information on physiochemical behavior of gas phase ions of explosives & simulants. NMSU team is the only one worldwide making such measurements.

1st year outcome: An uniqueinstrument was build & proven, along with methodology, using chemical standards. Lifetimes of gas phase ions of chemical standards were determined.

Long-range impact: Concepts & dreams on detecting explosives often conflict with fundamental behaviors which can be overlooked or ignored at risk to development. We seek to fill the gap in understanding this topic for sensible development of future technologies in trace detection.

Next Year: Knowledge will be extended to authentic explosives & simulants.

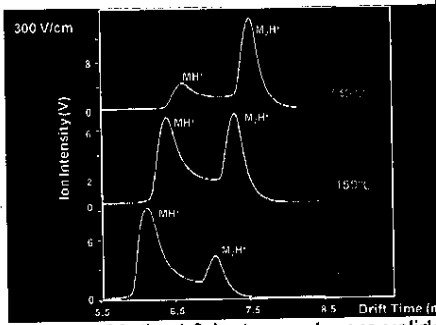


F2-K Stability & Decomposition of Gas-Phase Explosive Ions in Air

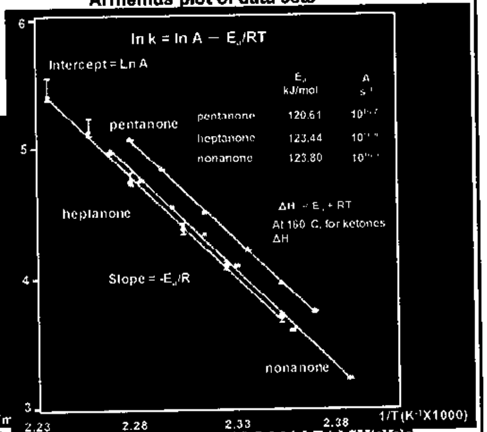
G.A. Eiceman, NMSU

First step in research with new kinetic IMS: validate instrument & methodology

Mobility spectra showing thermal decomposition of proton bound dimer to protonated monomer in new kinetic mobility spectrometer (2-pentanone).



Arrhenius plot of data sets



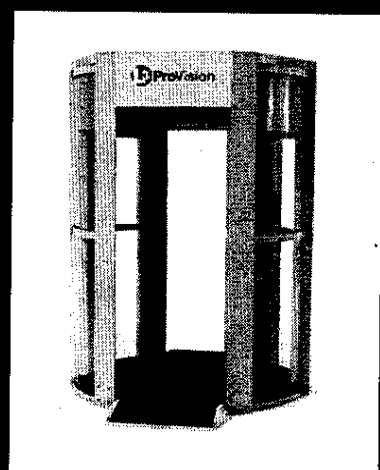
Results: Method & instrument were validated using chemical standards for which reasonably good numbers for comparison existed in literature references. Ketones were chosen for this task and our value for heat of dissociation of the proton bound dimer of ketones was 127 kJ/mole. This was identicial to values of binding energies for oxygen bases such as OH^{+}····O- with heats of ~127 KJ/mol as reported by M.Meotner in J. Am. Chem. Soc. 1984, 106, 1257.

Proposed F2/F3 New Start: Advanced Imaging Technologies (AIT) for Whole Body Imaging

- Objective: Unbiased, academic-oriented testbed for development and evaluation of multi-modal sensors and algorithms for whole body imaging
  - Enable experimentation with new sensing modalities
    - Optimize sensor configurations
    - Optimize scanning modes
  - Explore new algorithm concepts
    - Model based vs. Fourier inversion
    - High resolution fused imaging
    - Automated anomaly detection
  - Develop approaches to information fusion and adaptive multisensor processing

Current State-of-the-Practice Example: L3 ProVision mm-Wave Imager

- TSA qualified Advanced Imaging Technology (AIT) system
- Detects many types of materials based on shape (metallic and non-metallic): liquids, gels, plastics, metals, ceramics
- Uses two linear antenna arrays, scans through 240 degrees
- Limitations
  - "Dead Spots"
  - No spectroscopic info
  - Limited views
  - Poor penetration through leather and metallic clothing
  - No penetration through skin or into body cavities



Whole Body Imaging Sensors with Multimodal Fusion Potential

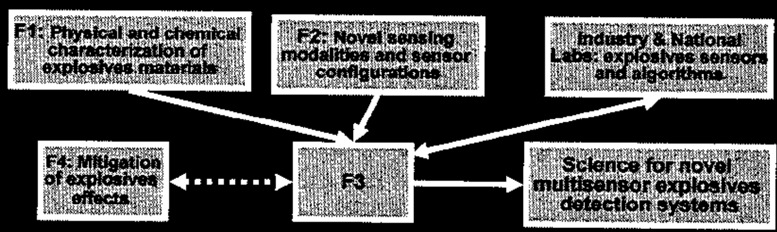
- Mm-Wave
  - Penetrates clothing
  - Distinguishes body-worn objects other than flesh (i.e. metal, explosives, water, plastic)
  - Active system provides target contour info
- THz
  - Spectroscopic responses for explosives characterization
  - Penetrates thin clothing
- X-ray Backscatter
  - Penetrates all concealing layers
  - Dual energy distinguishes foreign materials
  - Ionizing radiation but very low dosage
- IR Thermography
  - Shows unusual heat patterns on body
- NQR
  - Non-localizing, but unique explosive discrimination
  - Penetrates throughout body

Whole Body Imaging Testbed Plan

- Acquire precision portal multi-axis sensor array positioning system
  - Designed to accommodate various types of sensors
    - Separately, for analysis
    - Together, to test fused sensor information
    - Built to be flexible for reconfiguration
- Provide access to raw measurement data
  - Allows specific, modality-based inversion
  - Allows joint modality reconstruction
- Ultimate Goals
  - Establish performance metrics for sensor modalities
  - Develop and evaluate novel inversion and multi-modal threat detection algorithms

F3: Explosives Detection Systems
Lead: David Castañón, BU

- Design and implementation of novel explosive detection and identification systems
  - Multisensor systems
  - Unconventional approaches involving alternative signatures
- Major themes
  - Information fusion from heterogeneous sources
  - Sensor distribution and sensing control
  - Novel algorithms for extracting enhanced signature information and improved explosives detection and classification
  - Human factors both in system design and alternative signatures



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

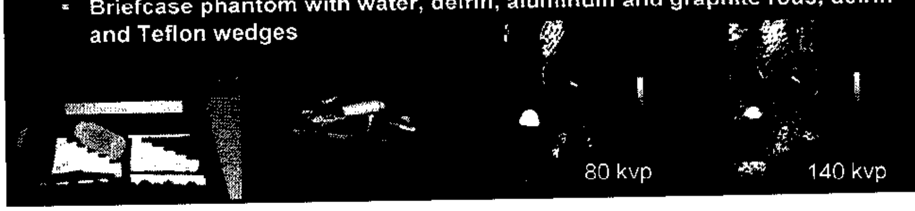
Current Projects

- 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

F3-A1: Next Generation Image Formation: Exploiting Energy Diversity in CT explosive detection

Faculty: W. C. Karl BU; Student: L. Egers, BU

- Motivation and purpose:
  - Reduction of false positive alarms in explosive detection systems by improved quality imaging
- Year 2 accomplishments
  - Acquired LLNL/DHS test phantoms (graphite, delrin)
  - Produced multi-energy data on commercial dual energy scanner (Siemens SOMATOM definition dual-source CT)
  - Implemented published image-domain dual-energy algorithm to estimate effective atomic number and and density.
  - Acquired explosive simulants and produced initial multi-energy data
- Year 2 results
  - Duffle Data set for dual-energy MGH scanner
    - Multi-energy CTs
  - Briefcase phantom with water, delrin, aluminum and graphite rods, delrin and Teflon wedges



F3-A1 cont'd: Next Generation Image Formation: Exploiting Energy Diversity in CT explosive detection

- Publications
  - L. Eger, S. Do, W. C. Karl, H. Pien, "Implementation of an Image-Based Dual-Energy Method for Explosives Detection on Real CT Data," CenSSIS RICC, Oct 2009.
- Year 3 Plan
  - Existing image-domain dual-energy algorithms are fast, but limited to low Z materials. Extend this post-reconstruction approach to high Z materials, which can appear during baggage screening.
  - Existing methods are limited to two energies, biological materials (no k-edge) and usually Compton and photo-electric basis decompositions. We are investigating the value of greater energy diversity (more than 2 energies) as well as optimal, adaptive basis expansion sets to increase sensitivity and specificity.
  - Characterize statistical properties of acquired explosive simulants
- Long range impact
  - Robust, enhanced image formation methods with limited view data sets

F3-A2: Limited Angle Linear Tomography

Faculty: W. C. Karl BU; Student: Z. Sun, BU

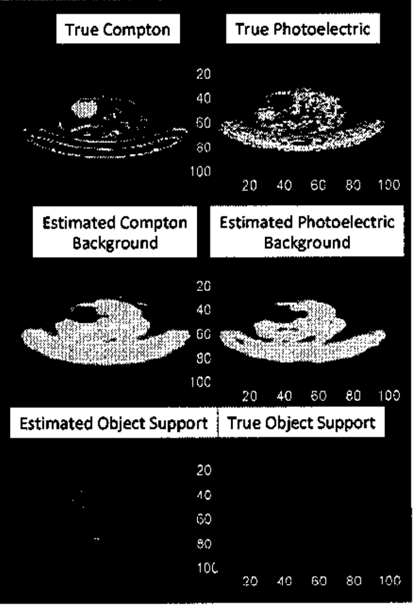
- Motivation and purpose:
  - Development of new reconstruction algorithms with limited angle, limited dose scanners for faster reconstruction
- Year 2 accomplishments
  - Proposed a novel linear-motion-based tomograpic 3-D baggage scanner based on existing carry-on baggage screening hardware.
  - Developed a mathematical model of the new configuration
  - Started preliminary 2-D simulations of the configuration to demonstrate feasibility of approach
- Long range impact
  - Robust, enhanced image formation methods with limited view data sets
- Year 3 Plan
  - Extend 2-D model to fully 3-D system configuration including simulations
  - Develop associated image formation algorithms to perform high quality reconstructions from the corresponding limited data
  - Optimize the system configuration

F3-A3: Object-Based Methods for Dual Energy CT
Faculty: E. Miller, Tufts, Student: O. Semerici, Tufts

- Purpose and relevance
  - Automatic detection of explosives is crucial for aviation security
  - Dual energy, X-ray CT capable of characterizing material properties to identify compounds of interest
  - Current state of the art suffers difficulties recovering photo-electric component
- Innovation: Unified approach to image formation, object detection, and object characterization
- Year 2 Accomplishments
  - Derivation and implementation of imaging/object identification algorithm
  - Initial exploration of performance using simulated data
- Long range impact
  - Increasing the probability of detection of explosive type objects significantly enhances security.
  - By providing accurate material characterization the false alarm rate would decrease which in turn would increase efficiency of the aviation screening process.

F3-A3 cont'd: Object-Based Methods for Dual Energy CT

- Year 2 Results
  - Parallel beam measurements are simulated for 60 points uniformly distributed around a circle outside the object
    - Object structure taken from ALERT-provided imagery
    - Photoelectric and Compton values assigned from literature
  - White Gaussian noise with 60dB SNR is added to simulated measurements
  - The solid object close to the center is an object of interest
- Year 3 Directions
  - Acquisition of more realistic data
  - Continued refinement of algorithm
  - Address more realistic background "clutter"



F3-A3 cont'd: Object-Based Methods for Dual Energy CT

- Publications
  - O. Semerici and Miller, E. L., "A Parametric Level Set Approach for Dual Energy Computerized Tomography," 2009 Gordon-CenSSIS Research and Industrial Collaboration Conference, Oct. 27-28, Northeastern Univ., Boston MA. This presentation was named the Best ALERT posterat the 2009 RICC.
  - O. Semerici and Miller, E. L., "A Parametric Level Set Approach for Dual Energy Computerized Tomography," submitted to - Student Poster Competition at the The Fourth Annual DHS University Network Summit March 10 - 12, 2010
  - O. Semerici and Miller, E. L., "Shape-based methods for vector-valued inverse problems with highly inhomogeneous, unknown backgrounds," accepted, SIAM Conference on Imaging Science, Chicago, April 2010.
  - O. Semerici and Miller, E. L., "Geometric inverse methods for dual-energy CT," in preparation for submission to IEEE Trans. Image Processing

F3- A4: Computationally Efficient Simultaneous Segmentation and Image Formation for X-ray CT EDS (B. Yazici, RPI)

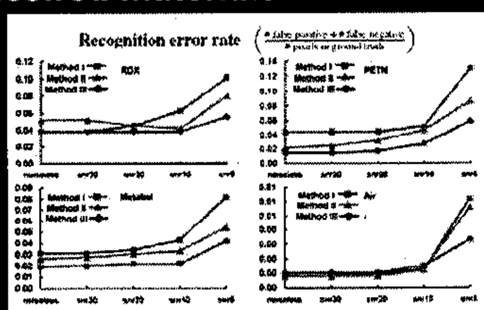
- Year 2 accomplishments
  - Simultaneous image formation and segmentation algorithm applicable to non-ideal imaging conditions including limited view, low dose data and arbitrary source trajectories
- Long range impact
  - Fast segmentation and image formation algorithm applicable to generalized Radon transforms arising in X-ray CT, synthetic aperture imagery and automatic target recognition problems
- Year 3 plans
  - Quantify and demonstrate the performance of the algorithm in real X-ray CT or SAR data

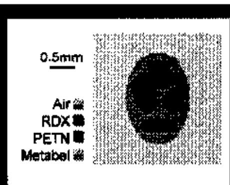
F3-B: Multispectral Methods for Diffraction Tomography (Faculty: D. Castañón, W. C. Karl, BU; Student: K. Chen, BU)

- Motivation and purpose:
  - Increased specificity and sensitivity
  - Reduction of false alarms
  - Increased throughput
- Focus:
  - Enablement of fusion of multiple modalities
- Year 2 accomplishments
  - New theories for multispectral diffraction tomography for increased signal/noise ratio, motivated by THz tomography
  - Techniques for integrated imaging/detection with improved performance
- Long range impact
  - Principled methods for multi-modal imaging with increased signal/noise ratio for explosive detection

F3-B cont'd: Multispectral Methods for Diffraction Tomography

- **Year 2 results**
  - **Born approximation reconstructions for multispectral diffraction tomography**
  - **Developed and evaluated three different inversion approaches to exploit spectral signatures of desired materials**



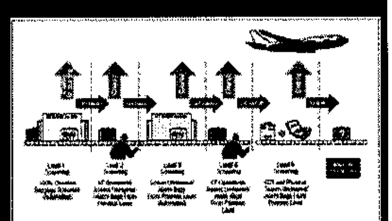


F3-B cont'd: Multispectral Methods for Diffraction Tomography

- Year 3 directions
  - Multispectral tomographic reconstruction in heavy clutter
  - Sparse reconstruction techniques for spectral signature extraction
  - Evaluations with complex scenarios
  - Extensions to include unknown signature clutter, matched field reconstruction
- Publications
  - K. Chen and D. Castañón, Multifrequency tomographic reconstruction in terahertz imaging, 2009 Gordon-CenSSIS Research and Industrial Collaboration Conference, Oct. 27-28, Northeastern Univ., Boston MA

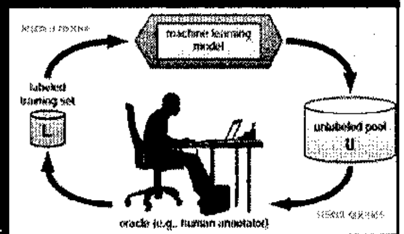
F3-C: Sensor Management for High Throughput Screening (Faculty: D. Castañón, V. Saligrama , BU; Students: K. Trapeznikov, BU)

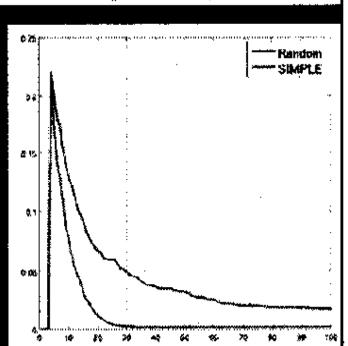
- Motivation and purpose:
  - Increase throughput while maintaining high probability of detection
- Focus:
  - Optimal sensor and algorithm management
  - Sequential design of experiments integrated into detection/classification
  - Increased throughput to remove airport/port bottlenecks
  - System-level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



F3-C cont'd: Sensor Management for High Throughput Screening

- Year 2 results:
  - New concepts for automated classifier design for sequential classification
  - New approach to real-time active learning for fielded classification systems that yield improved performance with less training
- Publications
  - D. Castañón and E. Rodriguez Diaz, ``Support Vector Machine Classifiers for Sequential Decision Problems," Proc. 2009 Conference on Decision and Control,} Shanghai, China, Dec. 2009
  - K Trapeznikov, D Castañón and V. Saligrama, "Active learning and AdaBoost," in preparation
- Proposed Year 3 Work
  - Development and evaluation of active learning for real-time classifier refinement
  - Evaluation on data sets based on luggage screening scenarios
  - Extend results to sequential classification





F3-D1: Compressive sensing for portal screening: Artifact Reduction in Low-Dose Tomography (Faculty: W. C. Karl BU; Postdoc: S. Do, MGH)

- Motivation and purpose:
  - Increased throughput while maintaining specificity and sensitivity
- Focus:
  - Application of compressive sensing to determine enhanced quality reconstructions given limited doses
- Year 2 accomplishments –
  - Developed a novel system model for a commercial medical CT scanner including a new detector response function.
  - Develop new compressed sensing-based reconstruction methods to optimize reconstruction quality despite data quality loss.
  - Demonstrated new models and methods on commercial CT data
- Long range Impact – New, more efficient and less expensive portal-based screening systems

F3-D1 cont'd: Compressive sensing for portal screening: Artifact Reduction in Low-Dose Tomography

- Related Publications
  - S. Do, M. K. Kalra, Z. Liang, W. C. Karl, T. J. Brady, H. Pien, ``Noise properties of iterative reconstruction techniques in low-dose CT scans," Proceedings of SPIE: Physics of Medical Imaging, Vol. 7258, p.725829 Lake Buena Vista, FL, February, 7-12, 2009.
  - S Do, S Cho, W. Clem Karl, MK Kalra, TJ Brady, and H Pien, ``Accurate Model-Based High Resolution Cardiac Image Reconstruction in Dual source CT," 2009 IEEE Intl. Symp. on Biomedical Imaging, Boston MA, June, 2009.
  - S Do, S Cho, W. Clem Karl, MK Kalra, TJ Brady, and H Pien, ``CT system response models in iterative reconstruction algorithms for low-dose imaging," in Proc. of the 10th International Meeting on Fully 3D Image Reconstruction in Radiology and Nuclear Medicine, Beijing, China, 2009
  - S Do,, W. Clem Karl, MK Kalra, TJ Brady, and H Pien,, ``Clinical low dose CT image reconstruction using high-order total variation techniques," in Proc. of SPIE, 2010,
  - S Do, W. Clem Karl, MK Kalra, TJ Brady, and H Pien, ``A variational approach for reconstructing low dose images in clinical helical CT," 2010 IEEE Intl. Symp. on Biomedical Imaging, Rotterdam, The Netherlands, 2010, accepted
- Year 3 Plan
  - Extend methods to multi-energy models and data
  - Demonstrate methods on explosive simulants

F3-D2: Compressed Classification for Distributed Sensor Fusion

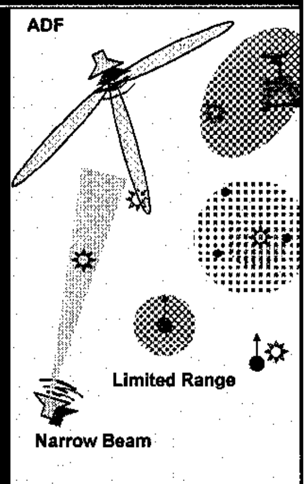
Faculty: D. Castañón, V. Saligrama, BU; Student: D. Motamedvaziri BU

- Motivation and purpose:
  - Increased accuracy with limited communications through compressed sensing
- Innovative Aspects –
  - Extension of compressive sensing concepts to distributed multisensor classification
- Project start: September 2009
  - Proposed work : Exploration of compressive sensing principles for distributed classification
- Year 2 accomplishments
  - Explore randomly selected data from multiple sensors
  - Initial characterization of achievable performance
- Long range Impact
  - Efficient and less expensive multi-sensor screening systems
- Publications
  - D. Motamedvaziri, V. Saligrama, D. Castanon Distributed Compressed Classification, (paper in preparation for submission to ICASSP 2011)
- Proposed Year 3 Work
  - Extension of distributed compressive sensing for classification to tomographic sensors with multiple views

F3-E1: Multi-modal Sensor Networks

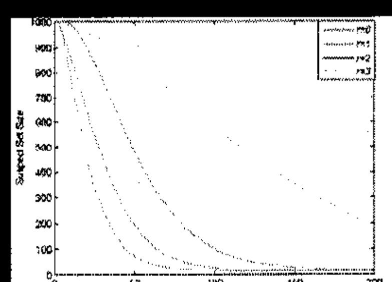
Faculty: D. Castañón, V. Saligrama, BU; Postdoc: G. Atia, BU (Summer '09); Students: E. Ermis, J. Qian, J. Wang, BU

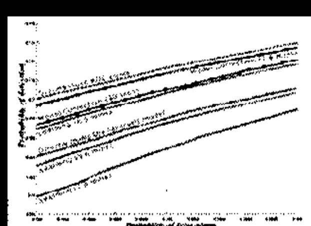
- Motivation and Purpose
  - Pervasive wide-area explosive threat detection
- Innovative Aspects
  - Foundations for optimal sensor network design
  - Theoretical structure for performance limits
  - Multi-modal fusion of distributed/mobile sensors
  - theory for active, adaptive employment of sensors
- Year 2 Accomplishments
  - New Algorithms for group testing in crowds using area sensors
  - Multi-camera Fusion: matching of uncalibrated cameras, decreased training time
  - Performance analysis of algorithms
- Long range Impact
  - Tools for robust, reliable, real-time threat detection, localization & classification
  - Development of novel sensing sensing systems



F3-E1 cont'd: Multi-modal Sensor Networks

- **Year 2 Results in Group Testing and Multi-camera Fusion**
  - **Models of area sensors that can detect explosives in groups**
  - **Characterization of sensors required and number of measurements to isolate threats**
  - **Analysis of time required for classification and training**
  - **Demonstration of reduced training time in multi-camera systems**





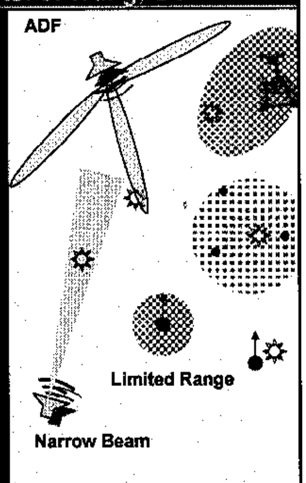
F3-E1 cont'd: Multi-modal Sensor Networks

- Year 3 Proposed Work
  - Extend results from random motion to fluid motion in crowds
  - Extensions to multi-sensor scenarios, with analysis & design of algorithms
  - Activity characterization in urban cluttered scenes from distributed video
- Publications
  - G. Atia, V. Saligrama, "Noisy Group Testing" Proc. Allerton 2009, UIUC, Urbana, IL
  - E.Ermis P. Clarot, P. Jodoin, V. Saligrama"Activity Based Matching for Multi-Camera Fusion,"(submitted Trans on Image Processing 2010)
  - M. Cheraghchi, A. Karbasi, S. Mohajer, V. Saligrama, "Graph Constrained Group Testing," International Symposium on Information Theory, 2010
  - J. Wang, V. Saligrama, D. Castanon, "Group Testing and Coupled Random Walks (in preparation for submission to Information Theory Workshop, 2010)

F3-E2: Multi-Camera Fusion

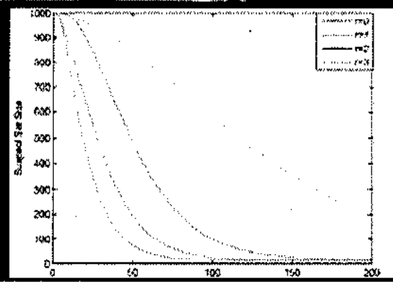
Faculty: D. Castañón, V. Saligrama, BU;
Postdoc: G. Atia, BU (Summer '09); Students: J. Wang, BU

- Motivation and Purpose
  - Pervasive wide-area explosive threat detection
- Innovative Aspects
  - Foundations for optimal sensor network design
  - 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 2 Accomplishments
  - New Algorithms for group testing in crowds using area sensors
  - Performance analysis of algorithms
- Long range Impact
  - Tools for robust, reliable, real-time threat detection, localization & classification
  - Development of novel sensing sensing systems



F3-E2 cont'd: Multi-Camera Fusion

- **Year 2 Results in Group Testing**
  - Models of area sensors that can detect explosives in groups
  - Characterization of sensors required and number of measurements to isolate threats
  - Analysis of time required for classification



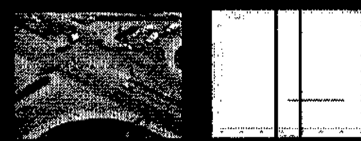
F3-E2 cont'd: Multi-Camera Fusion

- Year 3 Proposed Work
  - Extend results from random motion to fluid motion in crowds
  - Extensions to multi-sensor scenarios, with analysis & design of algorithms
- Publications
  - G. Atia, V. Saligrama, "Noisy Group Testing" Proc. Allerton 2009, UIUC, Urbana, IL
  - M. Cheraghchi, A. Karbasi, S. Mohajer, V. Saligrama, "Graph Constrained Group Testing," International Symposium on Information Theory, 2010
  - J. Wang, V. Saligrama, D. Castanon, "Group Testing and Coupled Random Walks (in preparation for submission to Information Theory Workshop, 2010)

F3-F: Dynamics-Based Detection and Tracking of Explosive Threats

(Faculty: O Camps, M Sznaier, G Tadmor, NU; Students: M Ayazouglu, BL Li, N Ozay, 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":

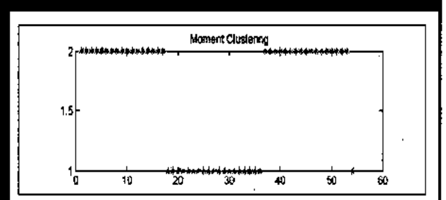


Detecting events via jumps in Hankel rank

- **Year 2 Outcomes:**
  - Activity parsing, contextually anomalous event detection, 3D reconstruction from 2D video.
- **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.

F3-F cont'd: Dynamics-Based Detection and Tracking of Explosive Threats

- Year 2 Results
  - Activity Parsing:
    - Underlying basic science problem: robust identification of hybrid systems (each subsystem corresponds to an event)
    - Efficient solution via moments-based optimization
  - 3-D Reconstruction:
    - Underlying basic science problem: reconstructing the states of a nonlinear system from observation of its output.
    - Solution via rank minimization of Hankel matrices



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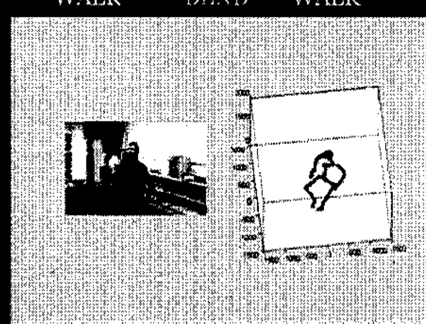


F3-F cont'd: Dynamics-Based Detection and Tracking of Explosive Threats

- Year 2 related publications:
  - M. Sznaier, W. Ma, O. Camps, and H. Lim, "Risk Adjusted Set Membership Identification of Wiener Systems," IEEE Trans. Automatic Control, 54, 5, pp. 1147--1152, 2009.
  - M. Sznaier, "Computational Complexity Analysis of Set Membership Identification of Hammerstein and Wiener Systems," Automatica, 45, 3, pp. 701--705, 2009.
  - Blanchini, F. and Sznaier M., "A Convex Optimization Approach to Synthesizing Bounded Complexity l_∞ Filters," Proc. 2009 IEEE Conf. Dec. Control, pp. 217-222, Dec. 2009.
  - Ozay, N., Lagoa, C. and Sznaier, M., "Robust Identification of Switched Affine Systems via Moments–Based Convex Optimization," Proc. 2009 IEEE Conf. Dec. Control, pp. 4684-4691, Dec. 2009.
  - Sznaier, M., Ayazouglu, M. and Camps, O., "Using Dynamics to Recover 3–Dimensional Euclidian Structure from 2–Dimensional Perspective Projections,", Proc. 2009 IEEE Conf. Dec. Control, pp. 2414-2419, Dec. 2009
  - M. Sznaier, O. Camps, N. Ozay, T. Ding, G. Tadmor and D. Brooks, "The Role of Dynamics in Extracting Information Sparsely Encoded In High Dimensional Data Streams," Dynamics of Information Systems, Hirsch, M.J.; Pardalos, P.M.; Murphey, R. (Eds.), to appear, 2010.

F3-F cont'd: Dynamics-Based Detection and Tracking of Explosive Threats

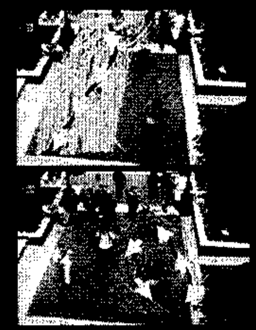
- Year 3 Proposed Work
  - Extracting 3-dimensional information from video sequences (cont.)
  - Tracking/ event detection under appearance changes.
  - Crowd motion models
  - Event detection in crowds

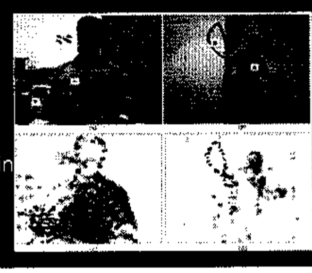
- Underlying basic science problems:
  - Dimensionality reduction via time-varying incremental nonlinear embeddings.
  - State reconstruction from observations for nonlinear systems
  - Finding parsimonious descriptions of dynamic data

F3-G1: Video Analytics Testbed for Detection and Tracking of Suspicious Behavior

Faculty: R Radke, RPI; Students: Z. Wu (Ph.D.), E. Ameres, A. Calcutt (MS), RPI

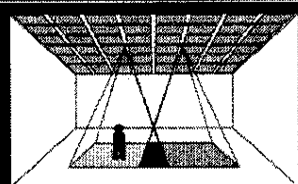
- **Motivation and Purpose**
  - Detection of suspicious, anomalous, irregular behavior in realistic, crowded indoor/urban scenarios
- **Innovative Aspects**
  - Learning, detection of normal vs. anomalous patterns of behavior
  - Many-camera video processing in large, complex environments
- **Year 1 accomplishments**
  - Multi-object tracking and detection of anomalous motion in crowds
  - Automatic segmentation of multiple motions
- **Long range Impact**
  - Large-scale, reconfigurable testbed for research in camera networks, surveillance, tracking, activity recognition, anomaly detection, crowd motion



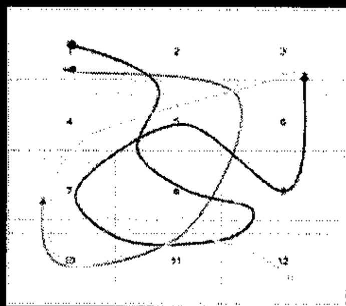


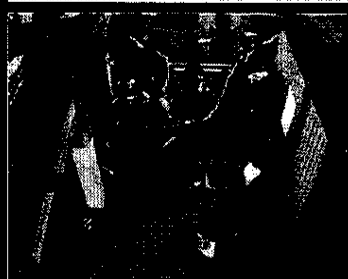
F3-G1 cont'd: Video Analytics Testbed for Detection and Tracking of Suspicious Behavior

- Year 2 Results
  - Indoor tracking testbed: 12 ceiling-mounted fixed-focus network cameras in 50x40x30 ft^3 reconfigurable studio at EMPAC
  - Intrinsic and extrinsic camera calibration; full-floor real-time blended mosaic
  - Preliminary real-time people tracking



F3-G1 cont'd: Video Analytics Testbed for Detection and Tracking of Suspicious Behavior



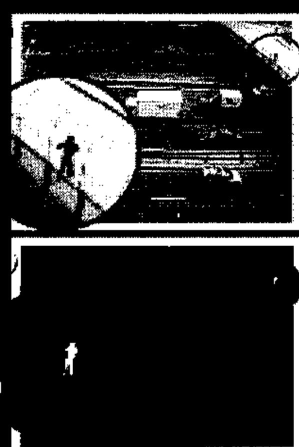


- Year 3 Proposed Work
  - Large-scale environment mock-ups (e.g., airport security screening lines)
  - Real-time multi-object tracking
  - Automatic object-to-person association
  - Change and anomaly detection

F3-G2: Video Analytics: Anomaly Detection

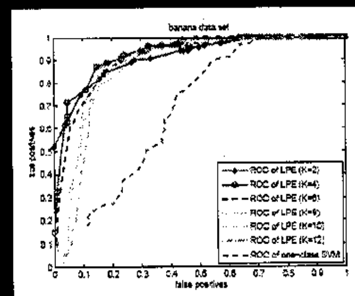
Faculty: V. Saligrama, BU

- **Motivation and Purpose**
  - Detection of suspicious, anomalous, irregular behavior in realistic, crowded indoor/urban scenarios
- **Innovative Aspects**
  - Learning, detection of normal vs. anomalous patterns of behavior
- **Long range Impact**
  - Robust surveillance system for pervasive and persistent detection of anomalies.
  - Creation of framework for optimal analysis of high dimensional data



F3-G2 cont'd: Video Analytics: Anomaly Detection

- Year 2 Results
  - New Approach to Robust Anomaly Detection using K-Nearest Neighbor Graphs
    - Significant improvement in performance vs alternative machine learning techniques
  - Automated Methods for for anomalous pattern discovery in high-dimensional data



(a) SVM vs. K-LPE for Banana Data

F3-G2 cont'd: Video Analytics: Anomaly Detection

- **Related Publications**
  - Y. Benezeth, P. Jodoin, V. Saligrama, C. Rosenberger, "Abnormal Events Detection Based on Spatio-Temporal Co-occurences," CVPR 2009
  - M. Zhao, V. Saligrama, "Anomaly Detection Based on Score Functions on K-nearest Graphs," in preparation for submission to Journal of Machine Learning Research
- **Proposed Year 3 work**
  - Video summarization
  - Anomaly detection in high-dimensional data

F4-A Novel Composite Materials & Structures for Blast Mitigation

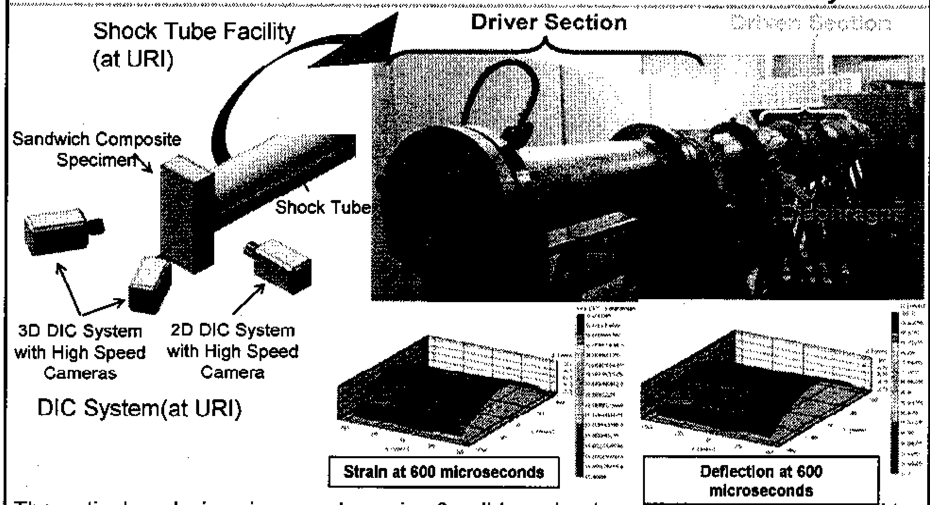
Arun Shukla, Puneet Kumar; Matt Jackson; Andrew Krystinik;Jefferson Wright, URI

Dynamic PhotoMechanics Laboratory

- **Purpose/ Relevance**: Fundamental experiments to elucidate physical mechanisms responsible for damage in composite materials & structures subject to blast & fragment loading, thus leading to new more efficient materials & structures.
- **Innovation**: Highly controlled experiments with real time measurements at extremely high loading rates to give full field load-deformation & damage information at material & structure level.
- **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 response of some selected materials and architectures.
- **Long-range impact**: Design of new multi-functional materials and structures with excellent blast mitigation capabilities.
- To date
- Experiments were conducted to evaluate blast mitigation response of sandwich panel of composite face sheets & energy absorbing core materials.
- Digital Image Correlation was explored in detail & coupled with ultra high speed imaging system to provide deformation & damage information.

F4-A Novel Composite Materials & Structures for Blast Mitigation: Experimental Methods

Dynamic PhotoMechanics Laboratory



Theoretical analysis using gas dynamics & solid mechanics principles was developed to calculate & differentiate between incident, reflected & deformation energy in shock tube experiments. Validation in progress. Experiments were conducted & are being analyzed to understand sequential shrapnel & blast loading effects on structures.

F4-A Novel Materials Proposed 3rd Year

Dynamic PhotoMechanics Laboratory

Response of Structural Glazing Panels to Blast loading:

A comprehensive series of experiments will be conducted under controlled blast loading condition using the shock tube facility to understand the damage mechanism in structural glass panels. After experiments under controlled blast loading, they will be subject to actual blast loading conditions.

Effect of curvature in Structural Panels on blast mitigation.

Effect of curvature in composite, metallic & glass panels on blast mitigation will be evaluated .

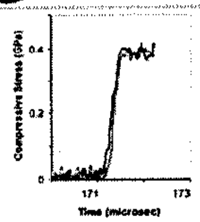
- Experimental Approach: Ultra high-speed imaging systems (3) coupled to optical techniques will provide deformation & damage information in all 3 directions.
- Theoretical Analysis: Gas Dynamics & solid mechanic principles will be used to understand deformation & damage to these structures caused by blast.

A detailed literature review will be continued to better understand the data gaps. Efforts will also be spent on preparations for organizing the IMPLAST 2010 conference in Providence RI.

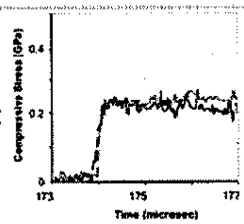
New research collaboration with LLNL, 3TEX Inc. & Wecore will be enhanced.

F4-B Stress Wave Attenuation

Carl-Ernst Rousseau (PI), Bhaskar Ale, Bhaskar Ale, URI

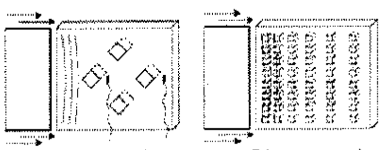


Achieve stress wave attenuation → through particulate reinforcement



Stress attenuation & scattering can be directly correlated to effectiveness of material system in withstanding impact or explosion

Results from model material are directly applicable to other materials featuring similar inclusion geometry & distribution.



epresentative configurations for impact test with embedded stress gages

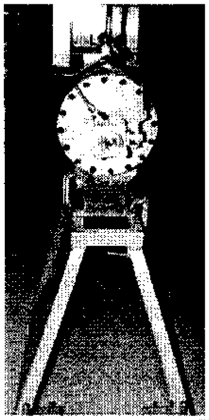
New component: Year 2

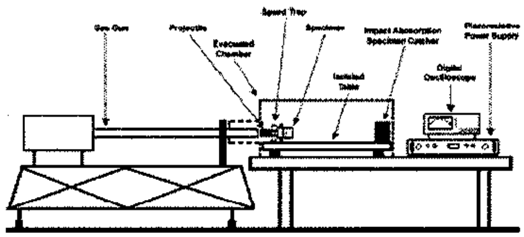
Simultaneous evaluation method consisting of assessment of same material by determining internal friction, thru low-level non-destructive ultra-sonic waves.

New component: Year 3

F4-B Stress Wave Attenuation
Carl-Ernst Rousseau, URI

Method of Investigation:
Impact-generated stress waves & monitoring





Example of damage to structural steel

- Identification of propagating stress wave signature profile, including maximum amplitude & rise time
- Clear delineation between elastic, plastic, shock phases of loading
- Determination of stress attenuation in material tested
- Identification of loading rates effects
- Inference of particle velocity within the material as a result of propagating wave
- Establishment of internal friction within materials being evaluated

F4-C Modeling of Damage & Residual Life of Civil Structures under Blast Loadings – Hamouda Ghonem & Otto Gregory (PIs) Kimberly Maciejewski; Yaofeng Sun; William Visser;Giffard Plume

Purpose/Relevance: Develop a fundamental understanding of mechanics of deformation and failure of the steel reinforcing phase as a function of blast/thermal loading. This understanding is essential in research efforts aiming at predicting the global and local damage resistance of civil structures.

Innovation: A damage & residual life assessment program comprising three components:

i. a novel Internal State Variable model capable of capturing detailed inelasticity and instability events of the reinforcing phase subjected to explosion loadings,
ii. a mechanistic based blast deformation criterion formulated in terms of twin volume fraction in impacted steel material, and
iii. a new methodology to determine post blast residual life in terms of ductility reduction and available fracture energy as a function of twin volume fraction.

1st Year Outcome:

- Developed an ISV model and implemented a numerical approach to describe deformation and hardening evolution of the reinforcing phase subjected to blast/thermal loadings.
- Carried out an experimental and numerical program to determine material parameters for the ISV model.

Long Range Impact: Develop a predictive tool to determine the survivability of structures subjected to blast loading and provide criteria for blast mitigation designs aiming at resistance of single and multiple blast events.

F4-C Modeling of Damage & Residual Life of Civil Structures
2nd Year: Blast Damage Criterion (In Progress)

Second Year Goal: Establish a mechanistic based approach to predict twin volume fraction in reinforcing steel members subjected to blast impacts.

Second Year Outcome (in Progress)

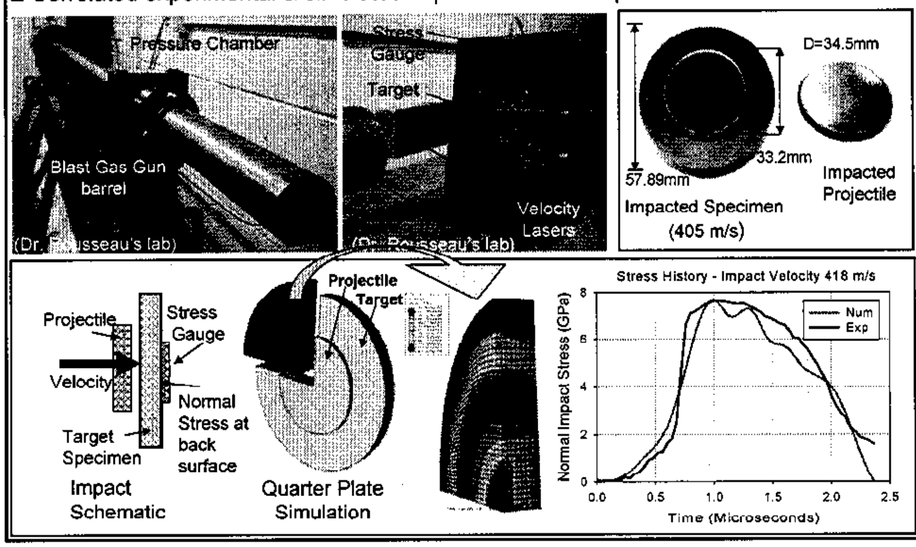
- Completed experimental plate driven impacts using a gas gun, replicating steel members subjected to shock waves yielding a strain rate up to 10^5 s^{-1}. Volume fraction of twins in impacted specimens were measured and correlated with impact stress.

- Developed a numerical model to simulate experimental plate driven impacts in order to calculate wave velocity and corresponding stress field across the test specimen. A successful comparison was made between experimentally and numerically generated stress profiles.

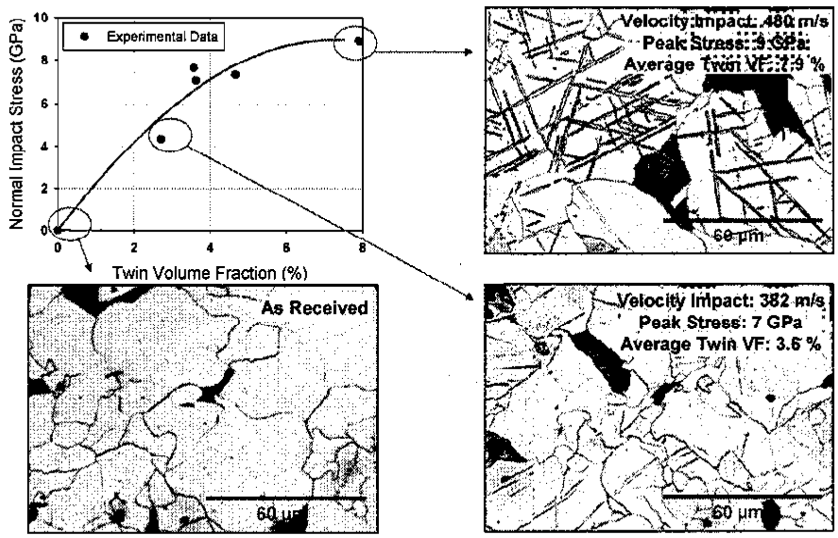
- Developed a constitutive deformation model to calculate the twin volume fraction as a function of blast wave pressure and associated particle velocity. This model is coupled with blast simulation to provide a relationship between impact history and developed twin volume fraction.

F4-C 2nd Year: Blast Damage Criterion (In Progress)

- Carried out plate driven impacts with velocities ranging from 200 to 500 m/s
- Correlated experimental & simulated impact stresses to optimize the numerical model



F4-C 2nd Year: Experimental Volume Fraction of Twins vs Impact Stress in Low Carbon Steel (In Progress)



➤Experimental twin volume fraction acts as an indicator of blast history

F4-C Proposed 3rd Year: Modeling of Damage & Residual Life of Civil Structures

Damage Criterion as a Function of Blast Loading:

❑ Combine SEM & image analysis techniques to analyze the twin volume fraction in test specimens with different blast damage histories.

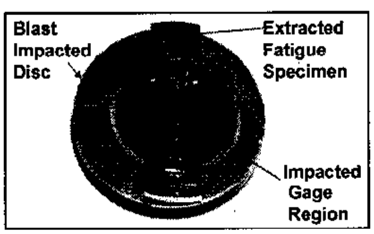
❑ Examine mechanisms for twin nucleation and propagation during impact in order to establish physically based model for blast damage.

❑ Correlate impact conditions and slip/twining deformation in corresponding test specimens in order to optimize established blast damage criterion.

Residual Life of Post Blast Conditions:

❑ Fatigue specimens are to be extracted from blast impacted discs & tested to measure residual life as a function of twin volume fraction.

❑ An integrated model will be established to correlate residual life with blast loading conditions.



Publications & Presentations URI

>E. Wang; N Gardner; A. Shukla, The blast resistance of sandwich composites with wise graded cores, Int J Solids & Structures, 46, 3492-3502, 2009.

>E. Wang; A. Shukla, Analytical & Experimental Evaluation of Energies during Shock Wave Loading, Int J Impact Engineering, submitted .

>A. Shukla et. al. Performance of Novel Composites and Sandwich Structures Under Blast Loading, with Srinivasan Arjun Tekalur, Major accomplishments in composite materials and sandwich structures, Springer, ed I. Daniel, E. Gdoutos; Y.D.S. Rajapakse.

>E. Wang; N. Gardner; A. Shukla, "Experimental study on the performance of sandwich composites with stepwise graded cores subjected to a shock wave loading", SEM Ann Conference on Experimental & Applied Mechanics, ABQ, NM , June 1-4, 2009.

>N. Gardner, "Blast performance of sandwich composites with discretely layered core", SEM Annual Conf on Experimental and Applied Mechanics, student paper, ABQ,NM June 1-4, 2009.

>S.A. Tekalur; E. Wang; M. Jackson; A. Shukla, "Failure Behavior & energy absorption of sandwich composites under dynamic loading", SEM Ann Conf on Exp & Appl Mech, ABQ, 6-09.

>K. Maciejewski, Y. Sun, O. Gregory; H. Ghonem, "Deformation and Hardening Characteristics of Low Carbon Steel at Elevated Temperature: Thermal and Post Thermal Behavior and Numerical Applications", submitted to Journal of Structural Steel , *in review.*

>Y. Sun, K. Maciejewski; O. Gregory; H. Ghonem, "Numerical Applications of Viscoplastic Deformation of Structural Steel", Journal of Structural Steel, *in review.*

>O. Gregory, J. Oxley, J. Smith, M. Plateck, H,Ghonem and E. Penirie, " Microstructural Characterization of Blast Fragments, J. Material Characterization, *in press.*

> 'Self Healing Concrete ', M.Pelletier, A. Bose, MRS Annual Meeting, Boston, Dec 3, 2009

>K. Maciejewski, Y. Sun, O. Gregory; H. Ghonem, "Deformation & Hardening Characteristics of Low Carbon Steel at Thermal Exposure", MS&T Conf 2008, PA

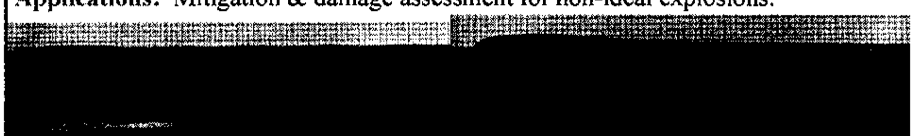
>Safety and Security Engineering, 2009"- Wessex Institute of Technology, August 2009

>Four Papers are being submitted for the upcoming 2010 SEM and IMPLAST meetings

F4-D Structural Response to Non-ideal Explosions

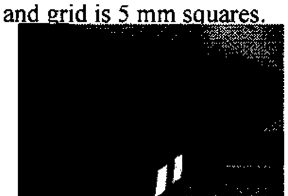
PI: JE Shepherd, Students: JK Karnesky, J. Damazo Caltech

Goals: Develop a comprehensive model of plastic deformation, rupture, & blast wave generation for both gaseous detonation and deflagration loading in piping and tubes.
Applications: Mitigation & damage assessment for non-ideal explosions.



(a) (b)

Plastically deformed tubes after (a) five 2-bar initial pressure detonations; (b) three 3-bar initial pressure detonations. Marks are 2 cm in length and grid is 5 mm squares.



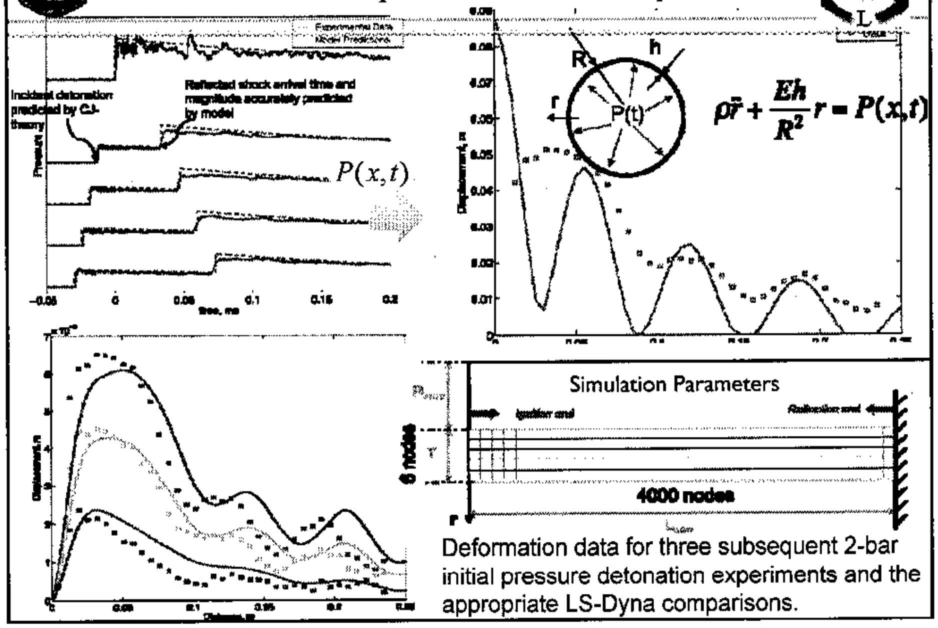
Highlights: Discovered periodic deformation mode (right) & explained origin with wave interference & material response models.

•Measured reflected pressure history & developed pressure time loading model

•Applied pressure loading model to single degree of freedom model

•Performed 2-D finite element calculations in LS-Dyna to obtain a more accurate numerical comparison

F4-D Structural Response to Non-ideal Explosions



Deformation data for three subsequent 2-bar initial pressure detonation experiments and the appropriate LS-Dyna comparisons.

F4-D Structural Response to Non-ideal Explosions Future Work

- FY 10
  - **Extension to other materials**: Carry out testing with better characterized materials including austenitic stainless steel.
  - **Collaboration:** Develop collaboration with other organizations, such as LANL, so that we can use their test capabilities for rupturing tubes.
- FY11 and beyond
  - **Fluid-Structure Interaction**: Pursue coupled fluid-structure computations to account for the feedback between deformation and gas dynamics.
  - **Characterize failure process:** Observations of burst process, strain to failure, comparison with damage accumulation models.

Publications & Presentations:

Plastic Deformation of Tubes due to Detonation, J. Karnesky, J. Damazo, J. E. Shepherd, 22nd ICDERS July 27-31, 2009 Minsk, Belarus (Extended abstract & talk)

A Model for the Spatial and Temporal Distribution of Pressure During Ideal Detonation Reflection, J. Karnesky, J. Damazo, J. E. Shepherd, Paper # 09F-42, Fall Technical Mtg Western States Sect Combustion Institute, U Calif, Irvine, CA, Oct 26 & 27, 2009. (conf paper & talk)

2010: Paper "Detonation Driven Plastic Deformation of Thin-Walled Steel Tubes" proposed for ASME 2010 pressure vessel and piping conference.

F4-E Water Blast Mitigation

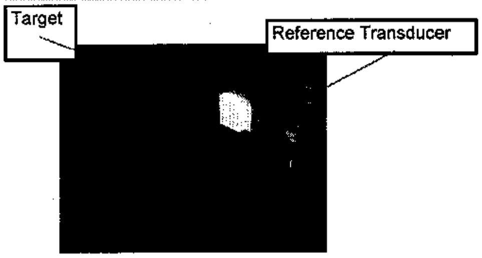
PURDUE UNIVERSITY

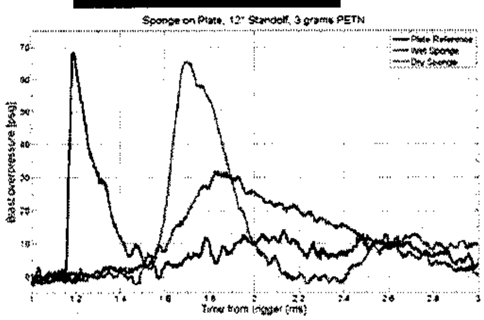
Steve Son (PI); Erick Miklaszewski

- **Purpose/ Relevance**: Conduct fundamental experiments to elucidate physical mechanisms responsible for blast mitigation using water in the form of sprays or sheets. We are systematically studying the effectiveness, and hope to develop a fundamental understanding, of the interaction of blast waves with water (sprays, sheets, etc.) so that this approach to blast attenuation can be exploited.
- **Innovation**: Highly controlled laboratory-based experiments with dynamic time measurements at realistic blast profiles from a unique explosively-driven shock tube.
- **Initial Results**: This project began this fall. We have found that a container of water provides very little blast mitigation. In contrast, a water-filled sponge is much more effective at blast mitigation. We have designed a test fixture to test sprays and mists.
- **Long-range impact**: The mechanisms of water blast mitigation will be be elucidated. This data will be useful to modelers and designers that are interested in using water to mitigate blast.

F4-E Explosively-Driven Shock Tube for Water Mitigat Experiments

PURDUE UNIVERSITY





Shock tube

Shadowgraph of Explosive Blast

F4-E 1st Year (In Progress) & Proposed 2nd Year — PURDUE UNIVERSITY

This Year

✓A series of experiments were conducted to evaluate blast mitigation response of water filled barriers.

✓A series of experiments were conducted to evaluate blast mitigation response of water-filled sponges.

✓Design of spray and mist system done. Parts ordered.

✓Preparation for the upcoming GRC 2000 meeting begun.

✓Research collaboration was established with AgileNano™ (http://www.agilenano.com/).

Next Year

✓Water additives, including salt will be considered.

✓Single droplets in a blast will be considered to exam role of droplet breakup vs. evaporation.

✓Initial multiphase modeling of shock interaction and comparison with collected data will begin

F4-F Self-Healing Materials for Mitigation of Blast Damage **N.R. Sottos(PI), S White, J Patrick** — ILLINOIS

- **Purpose/relevance:** To develop self-healing materials capable of autonomous protection and recovery from blast induced damage.
- **Innovation:**
  - Extension of self-healing technology blast resistant composite structures.
  - New self-healing materials development for blast damage.
- **First year outcome (since Aug. 09):**

– Literature review of blast protective structural composites.
– Selection of sandwich composite structure for self-healing.
– Initial Target: Microcapsule based self-healing foam core
– Encapsulated 2 of 3 components necessary for foam healing: isophorone diisocyanate (IPDI) & foaming agent.

- **2nd Year Plan:**

– Determine stability of capsules containing foam healing agents.
– Integrate capsules into foam core.

Self-healing foam core

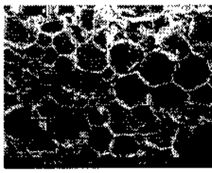
– Develop protocol to damage & heal foam core, e.g. 3 pt bend testing.
– Begin investigation of microvascular healing in face sheet panels.

Yang, J., Keller, M.W., Moore, J.S., White, S.R.; Sottos, N.R. *Macromolecules*, 41, 9650-55, 2008.

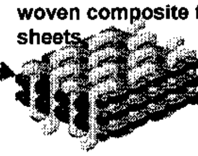
F4-F Self-Healing Structural Sandwich Panel

Transonite® Sandwich Composite

Year 1: Develop self-healing polyurethane foam core to recover shear damage

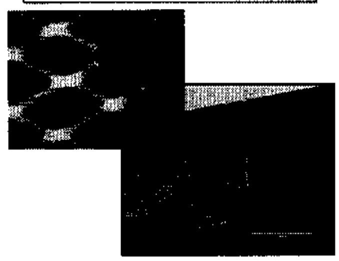


Year 2+: Integrate self-healing into 3D woven composite face sheets



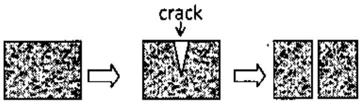
Microvascular Based Healing Approach

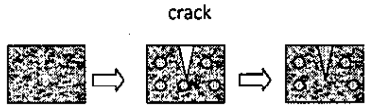
Microcapsule Based Healing Approach



✓ Successful encapsulation of reactive (IPDI) healing agent for foam core

F4-G Self-healing concrete Arijit Bose; Michelle Pelletier URI

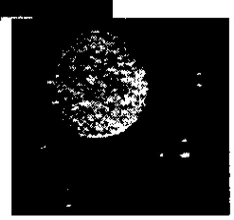




Partial mechanical recovery, reduced water ingress

- **Water in oil emulsion (surfactant stabilized)**
- **Interfacial polymerization of diisocyanate (MDI) and water, surfactant catalyst**
- **Results in polyurethane shell with aqueous center**
  - **1M Sodium silicate in aqueous phase**
  - **Capsules from 40-800 um, Average ~ 372 um**
- **Add ~1% v/v in cement**

$$Na_2O \cdot SiO_2 + Ca(OH)_2 \rightarrow CaO \cdot xSiO_2 \cdot H_2O + 2Na^+$$
$$CaO \cdot xSiO_2 \cdot H_2O + 2Na^+ + CO_2 \rightarrow CaCO_3 + xSiO_2 + NaOH$$
$$Na_2O \cdot xSiO_2 + Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + xSiO_2 + 2NaOH$$

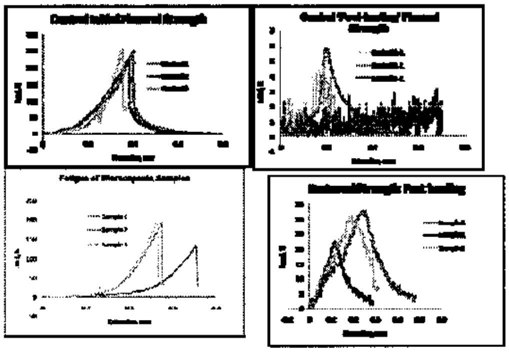


Paper presented: 'Self Healing Concrete ', M.Pelletier, A. Bose, MRS Annual Mtg. Boston, Dec 3, 2009

F4-G Self-healing concrete

Weakened with a controlled load of 0.2mm/min

Allowed to heal for 2 days before retesting for restoration of strengtl



Control Sample	Restored Strength
1	1.9%
2	1.0%
3	2.3%

Capsule Sample	Restored Strength
1	17%
2	17%
3	17%

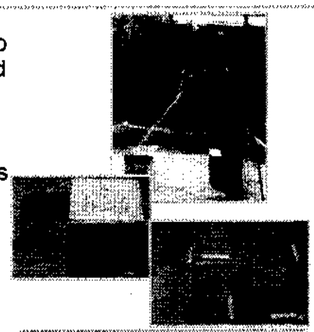
2nd Year Plan: Mechanical property characterization of aged samples eg flexural strengt
Characterization under impact loading (SHPB apparatus)

Evaluate filler shell characteristics and optimize polyurethane shell thickness, size, concentration of fillers filler is gel

Examine water ingress & corrosion resistance recovery after development of microcracks
Electrochemical cell

F-4-H Optimal Design and Use of Advanced Structural Materials to Mitigate Explosive and Impact Threats J.J. Myers, J. Baird Missouri S&T

- Purpose/relevance: To develop advanced materials to mitigate explosive and high velocity impact with reduced fragmentation.
- Approach:
  - Physical experimental evaluation of advanced technologies using sacrificial and multi-layer systems
- Second year outcome (since Sept. 09):
  - Optimization of randomly distributed reinforced polyurea coating systems for reduced fragmentation and enhanced blast and impact resistance of structural elements / material characterization (coupon testing), screening and optimization.
- Future work:
  - Phase I – (in-progress, continues) – experimental evaluation of beams and cylinders for multi-hazard evaluation.
  - Phase II – Panel blast testing using discrete fiber-reinforced polyurea systems, multi-hazard evaluation / testing of beams and cylinders for confinement and fragmentation reduction.



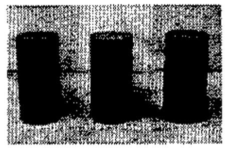
Discrete Fiber-Reinforced Polyurea Systems

Protective Coating Systems for Blast Mitigation Barrier Systems

F4-H: Optimal Design and Use of Advanced Structural Materials to Mitigate Explosive and Impact Threats (ACTIVITY #2, Myers Lead)

J.J. Myers, C. Greene, N.L. Carey, and J. Baird / Missouri S&T

Purpose: Evaluation of fiber-reinforced polyurea coating systems to provide multi-hazard enhancement (i.e. blast, fragmentation reduction, impact, seismic, general strengthening) including column confinement, flexural and shear strengthening for repair-retrofit applications.



Concrete Cylinders

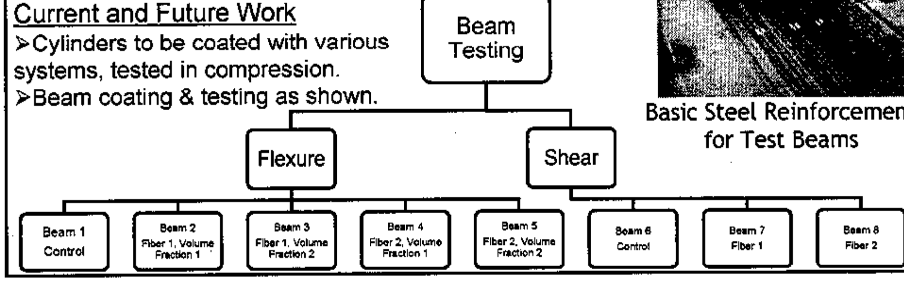
Accomplishments:

- Concrete cylinder specimens at 3 strength levels prepared for coating and experimental testing.
- Beam specimens prepared for coating / flexural & shear testing evaluation.

Basic Steel Reinforcement for Test Beams

Current and Future Work

- Cylinders to be coated with various systems, tested in compression.
- Beam coating & testing as shown.

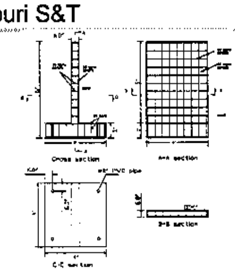


F4-H: Optimal Design and Use of Advanced Structural Materials to Mitigate Explosive and Impact Threats (ACTIVITY #3, Baird Lead)

J.J. Myers, C. Greene, N.L. Carey, and J. Baird / Missouri S&T

Purpose:

Demonstrate the use and performance of enamel-coated rebar in cantilevered barrier walls under blast loads. The cantilevered walls signify the criticality of the anchorage detail of vertical reinforcement into the base of the walls. In this case, the bond strength of steel reinforcement embedded in the wall base becomes critically important.



Instrumented barrier details

Accomplishments:

- Reactive enamel-coated rebar was successfully produced for use in full-scale blast testing.
- Two full-scale barrier walls blast-tested, each approximately 6 feet tall, 4 feet wide and 6 inches thick; one barrier with coated rebar, and the other barrier with conventional uncoated rebar.
- Instrumentation acquired strain, acceleration, and pressure data for each of three shots against each wall – 4 lb NEW of TNT, 10 lb NEW of TNT, and 30 lb NEW of TNT.
- Result – Rebar bond to concrete was stronger when coated.

Two barrier walls after three blast tests each: front side; uncoated rebar L, coated rebar R

F4-I: Optimal Design and Development of Advanced Materials and Structures (PI: Choong-Shik Yoo)

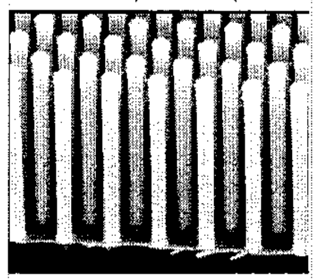
Purpose/relevance: To investigate the shock wave propagation in advanced materials and structures
- Oriented CNT and multi-layers with large shock impedance anisotropy
- High strength monolithic amorphous and composites

Approach: Dynamic experiments in time (ms to μs) and stress (1-30 GPa) scales relevant to explosive detonation using a gas gun and a short pulse laser

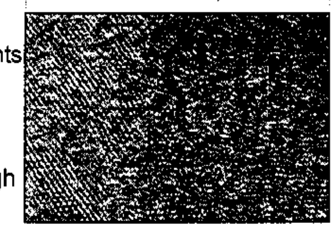
Progresses:
- Determined mechanical strength of CNT in quasi-hydrostatic conditions (published in CPL (2009)
- Discovered a new form of carbon from compressed CNT
- Preparing oriented CNT for plate impact experiments (Collaboration with the FTC)

Future work:
- Determine Hugoniot of oriented CNT by a gas gun
- Examine fragmentation and blast propagation in high strength metallic alloy by a short-pulse laser

Shock dissipation/dispersion



Shock absorption



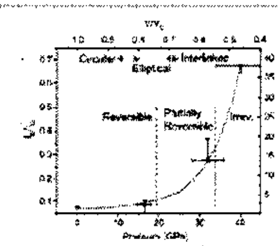
F4-I: Static strength of CNT and new extended carbon

Motivation: CNT has highly anisotropic mechanical strength in nm – offering a window to reveal how shock wave propagates through in an atomistic scale

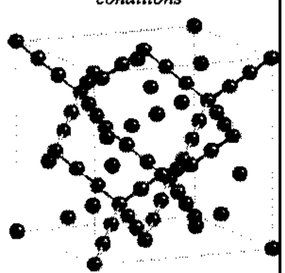
Results:
- Strength of CNT strongly depends on hydrostaticity
- In quasi-hydrostatic conditions, CNT is stable to 30 GPa – higher stability than any other form of carbon (published in Chem. Phys. Lett. (2009))
- Discovered a new form of diamond-like extended carbon (in preparation for publication)
- Preparing oriented CNT in both Si and Al_2O_3 substrates for plate impact experiments

Significance and relevance:
- Fundamental static properties critical to basic science and shock-wave propagation
- Enabling collaboration for materials fabrication

Next step:
- Determine the Hugoniot of oriented CNT



SWNT in quasi-hydrostatic conditions



New extended carbon in diamond-like structure

F4-I: Dynamic responses of structured metal alloys

Motivation: Structured metallic alloys and composites offer advanced mechanical properties encompassing those of metals and ceramics

Approach: Investigate dynamic responses of high strength metallic alloys using a short-pulse laser and a micro-impactor

Significance and relevance:

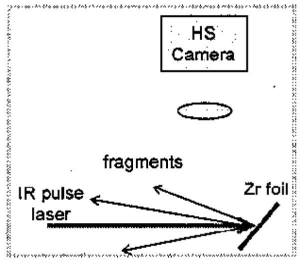
- Understanding interatomic mixing, thermal and chemical diffusion, fracture and chemical mechanisms across the interface and grain boundaries
- Critical to designing high strength materials structures that are resistive to blast waves

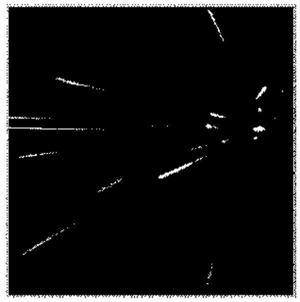
Progress:

- Complete a setup for impact- and/or laser- ignition experiments

Next step:

- Study thermal, chemical, mechanical responses of monolithic Zr-alloys during laser-ignitions



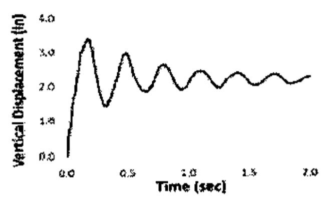


F4-K: Fundamental Science of Progressive Collapse Resistance of Reinforced Concrete (RC) Structures
(Faculty: Mehrdad Sasani, NU; Postdoc: Yaser Mirzaei, NU)

- Purpose and Innovative Approach
  - Advanced modeling and numerical simulation of response of full-scale structural systems following member loss due to explosions
  - Unique and pioneering experimental program on actual structures
  - Complements Joe Shepherd's work on confined structures (pipelines)
- Near term and Long range Objectives
  - Achieve fundamental system-level understating and develop advanced modeling methods of primary collapse resistant mechanics and mechanisms (Catenary & Vierendeel actions)
  - Develop a probabilistic framework for design of innovative structures and evaluation of existing structures against explosion
- Impact
  - Drastic improvement of integrity evaluation of complex RC structures

F4-K cont'd: Fundamental Science of Progressive Collapse Resistance of Reinforced Concrete (RC) Structures

- Purposed work/accomplishment in Year 2
  - In order to carry out analytical and experimental studies proposed in year 2 (first slide), we study progressive collapse resistance of flat slabs/plates (i.e. RC slabs without beams) , which are economical structural systems used particularly in parking garage structures and are susceptible to manmade hazards (explosions in parking garages such as 1993 WTC bombing)
  - Response of an actual two-story parking garage with flat slab following column explosion is experimentally evaluated (recorded deformation below)

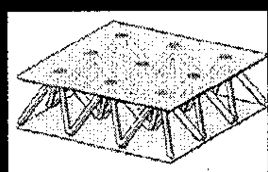


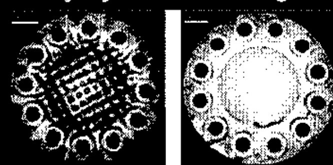
F4-K cont'd: Fundamental Science of Progressive Collapse Resistance of Reinforced Concrete (RC) Structures

- Current (2nd year) and future (3rd year) analytical activities
  - Development of advanced local failure models including:
  - Fracture in sections without tensile reinforcement
  - Geometric distribution of cracking
  - Punching shear
  - Implementation of local models to account for system response including effects of:
  - Floor growth and additional axial compression
  - Local brittle and ductile failure
  - Catenary action (axial tension)
  - Development of advanced modeling methods of primary collapse resistant mechanics and mechanisms in flat slab/plate structures and reliable evaluation of their progressive collapse resistance

F4-J: Modeling of Explosion – Resistant Structures
(Faculty: A. Vaziri, NU; PhD Student: A. Ajdari, NU)

- Purpose and Innovative Approach
  - Advanced modeling and numerical simulation of response of structures under blast and shock loading at different scales: from structural components to full-scale structural systems
  - Development of robust failure material models for structures capable of simulating material fracture under dynamic loading
  - Development of novel energy absorbent structural materials based on the concepts of activity, heterogeneity and hierarchy
- Near term and Long range Objectives
  - Achieve fundamental understanding of failure mechanisms of structures under blast and shock loading
  - Develop high-performance explosion-resistant structural systems
- Impact
  - Development of novel materials with superior energy absorption characteristics
  - Construction of robust computational platform for simulating the response of structures under high intensity dynamic loading

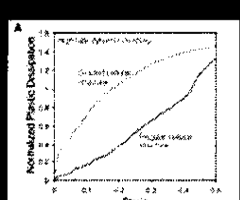

Sandwich panel with all-metal cores for explosion resistant structures


Small-scale structural specimens subjected to shock

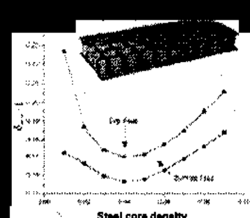

Detailed 3D numerical simulations of structural failure under blast

F4-J cont'd: Modeling of Explosion – Resistant Structures

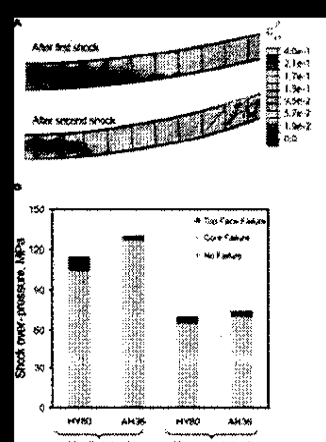
- Year 2 Research Accomplishments
  - Fundamental study of response of sandwich structures under high intensity dynamic loading
  - Development of computational models for investigating the response and failure of structures subjected to multiple blast loadings
  - Studying the energy absorption of heterogeneous and functionally graded materials
  - Introduction of functionally graded cellular structures as novel energy absorbent materials



Graded cellular structures with enhanced energy absorption



Optimization of metal shock – loaded sandwich panels



Detailed 3D numerical simulations of structural failure under two consecutive blast loadings

Al on

F4-J cont'd: Modeling of Explosion – Resistant Structures

- Year 3 proposed work
  - Simulation of structures subjected to multiple shocks
  - Studying the residual structural capacity of shock-loaded panels
  - Biomimetic Energy Absorbent material systems (BEAMS)
- Metrics
  - <u>Journal article:</u> A. Ajdari, H. Nayeb- Hashemi, A. Vaziri, "Dynamic crushing of regular and Voronoi cellular structures with constant and functionally graded relative density", in prep.
  - <u>Conference Abstracts</u>:
    - A. Vaziri, A. Ajdari "Homogenization and failure of metal sandwich panels subjected to air shocks", *IMPLAST 2010.*
    - A. Ajdari, S. Babaeezadeh & A. Vaziri, "Dynamic crushing and energy absorption of cellular structures", *IMPLAST 2010.*
  - <u>Additional Accomplishments</u>:
    - AFOSR YIP 2010
    - Organizing and Co-organizing symposiums and mini-symposiums in the area of Impact Engineering in the following conferences:
      - 10^{th} US National Congress on Computational Mechanics
      - IV European Conference on Computational Mechanics
      - International Conference on Computational and Experimental Engineering and Sciences (ICCES10)

Education Program

Graduate and Professional Development

Undergraduate Programs

K-12 and Community College Outreach

Training for First Responders

Initiatives to Increase Diversity

New Start: Energetic Materials Safety Awareness

Education for Professions (URI-lead)

Professional classes	Dates	# studen
Fundamentals JHU APL	Feb 4-6, 2009	10
Unintended Ignitions Sources, NJ	Feb 17-19, 2009	28
Combustion, NJ	Feb 23-23, 2009	29
Safety Protocols, Picatinny NJ	Ap23-24, 2009	20
Air Blast, Picatinny, NJ	Ap 27-29, 2009	19
Fundamentals of Explosive, RI	May 5-7, 2009	55
Explosive Material Characterization, NJ	May 12-14 2009	16
Fundamentals, Valcartier, QB	May 26-28 2009	17
Fundamentals, Crane, IN	Jun 1-3, 2009	16
Fundamentals of Explosive, NJ	Jun 23- 25, 2009	22
DDT, Picatinny, NJ	July 28-30, 2009	23
Thermal Hazards of HE, NJ	Aug 3-4, 2009	16
Fundamentals, Ottawa	Sept 8-10 2009	16
Material Response to Blast	Sept 29,30	21
Explosive Devices, NJ	Oct 27-29, 2009	25
Environmental Aspects of Explosives, NJ	Nov. 3,4, 2009	28
Fundamentals, Edwards AFB, Ca	Jan 19-21, 2010	26
Fundamentals of Explosive, NJ	Feb 1-3, 2010	24
Unintended Ignitions Sources, Ottawa	Feb 3-5, 2010	13
Fundamentals of Explosive, ABQ	Feb 17-19, 2010	12
Systems Hazards, ABQ	Feb 17-19, 2010	12
Warhead Mechanics, NJ	Feb 23-25, 2010	17
Nanomaterials, NJ	Mar 8-9, 2010	
Materials Response under Impulsive Loading, Ottawa	Mar 22-23, 2010	
Air Blast & Structural Response, Ottawa	Mar 24-26, 2010	
Terrorism Issues, NJ	April 26-27, 2010	
Fundamentals, RI	May 4-6, 2010	
Explosive Operations: Safety & Protocols	May 26-28, 2010	
		463

Over 450 professionals served in explosive courses--nine 1st-time classes.

Workshops in September 09 for North American Thermal Analysis Society & October for Vendors of Explosive Detection Instruments.

University Students—Grad & Undergrad

Research experience & employment for undergraduate (9 in 2009)

New Present safety class could be available to CoE participants in early March. An enhanced program should be ready by May or June.

Educational Activities K-12

URI supported
Lego robotics program
WBCA 3rd to 8th 30 students
in 1st competition took 27 out of 50
Narragansett 5th/6th & 7th/8th 60 students

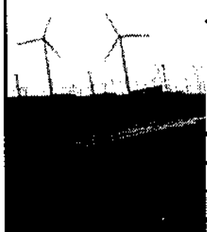
Chemistry "magic shows" 5 schools

Feb. 2 "shadowing 8th graders in chemistry lab—3 in 2009 & 2 in 2010

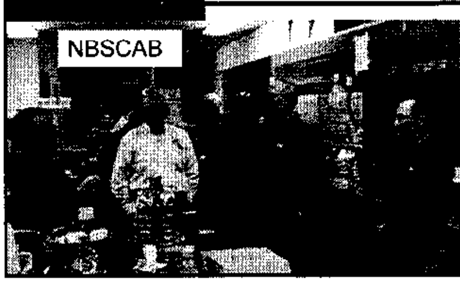
Research Experiences for Teachers:
2 teachers in summer 2008
7 teachers in summer 2009
1 teacher will go to URI grad school Fall 10
Teachers' research presented at Oct 2009 URI Detection Workshop

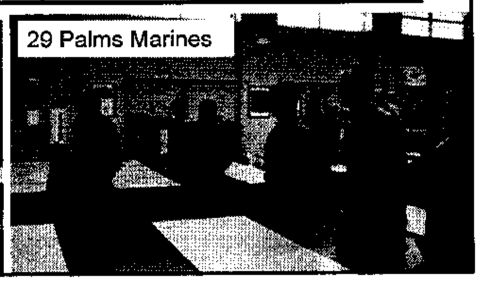
Educational Activities for First Responders

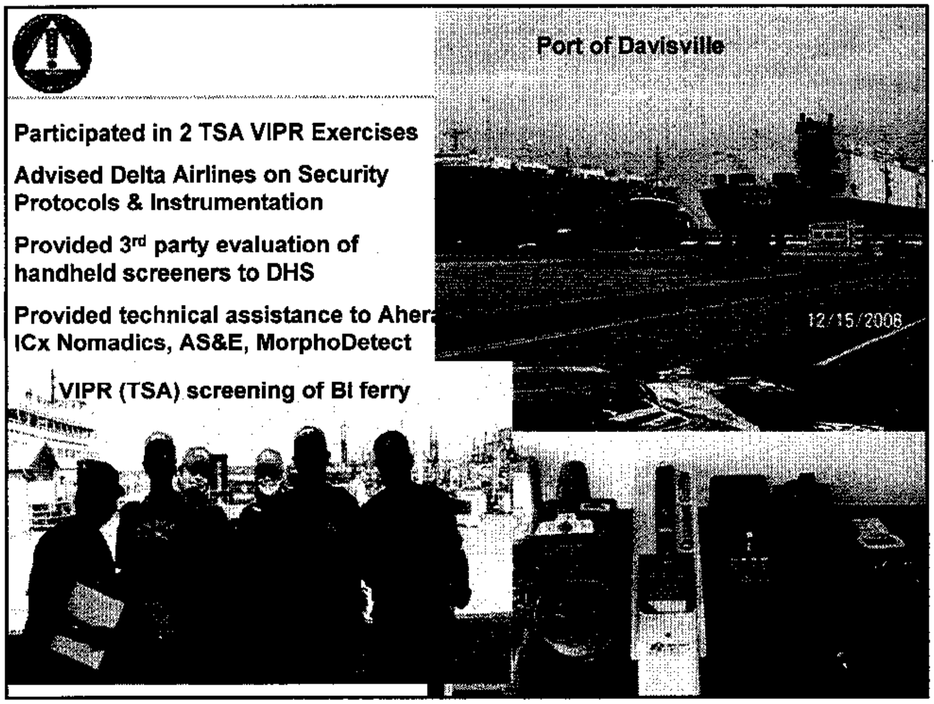
First-responders, themselves, guide our program. Training ranges from formal lectures to informal advise and practical exercises.



Group	Location of Exercise	Date
US Marines	29 Palms, CA	Dec 08
" " "	29 Palms, CA	Feb 09
" " "	29 Palms, CA	Apr 09
" " "	29 Palms, CA	May 09
NBSCAB	URI	Feb 09
RI Bomb Squad	URI	TBA
NYPD CBRN	NYC	May 09


NBSCAB


29 Palms Marines


Port of Davisville
Participated in 2 TSA VIPR Exercises
Advised Delta Airlines on Security Protocols & Instrumentation
Provided 3rd party evaluation of handheld screeners to DHS
Provided technical assistance to Ahera
ICx Nomadics, AS&E, MorphoDetect
12/15/2008
VIPR (TSA) screening of BI ferry

Education Program at NU-led ALERT
Year 3 Work Plan

Graduate and Professional Development

- ALERT-Relevant Courses for Distance Education – Identify (Spring 2010) and Disseminate (Fall 2010)
- MS for HS Professionals – Study Viability/Marketability (2010/2011)
- Short Course on Security Screening Technologies – (August 2010)

Undergraduate Programs

- High Tech Tools and Toys "Hands On" modules – Disseminate IR Spectroscopy Module (Spring 2011)
- Research Experiences for Undergraduates – Host 10 undergraduates (Summer 2010)
- Co-op and Capstone Experiences – Plan for a Co-op Student (2011) and develop ALERT Capstone (2010/2011)

K-12 and Community College Outreach

- Research Experiences for Teachers- NU STEM Center – Host 3 Teachers (Summer 2010)
- Young Scholars Program (High School)- NU STEM Center – Host 6 HS students (Summer 2010)
- NU Collaboration with 3 CCs - Workshop for CC Instructors using HTTTL module (Summer 2010)
- MS&T Collaboration with Missouri Community Colleges – Continue ALERT presentations (2010/2011)
- DHS Scientific Leadership Bridge Awards for Minority Serving Community Colleges (proposal pending)

Education Program at NU-led ALERT
Year 3 Work Plan (continued)

Training for First Responders

- Explosives Training Short Course Training (MS&T) – 30 officers and Senior NCOs from Ft. Leonard Wood (Feb 22, 2010) – Missouri S&T)
- Explosives Awareness Training (MS&T) - Continue in 2010/2011
- "Hands-on Explosives Training" for Midwest Research Inst. (TTU) - Summer of 2010

Initiatives to Increase Diversity

- Implementation of Strategic Plan – Task Force Teleconference (June 2010)
- DHS Summer Research Team for Minority Serving Institutions - (2 proposals pending)

New Start: Energetic Materials Safety Awareness Education Program

- Define Year 3 Work Plan - (March 2010)

Graduate and Professional Development Programs at NU-Led ALERT

Year Two Results

- Short Course on "Shock Wave Propagation and Physics" (Aug 2009) at NU attended by ~25 Faculty, Grad Students, HS professionals
- Gordon Fellow John Banzhaf is supported by Pacific Northwest National Laboratories to lead the "Research and Development Roadmap for VBIED Detection" collaboration between PNNL and NU (Fall 2009/Spring 2010)
- DHS Fellow, Michael Sechrist, worked at NU with Dr. Michael Silevitch and John Beaty on *"Strategic Vulnerability Study of the East Coast's Underwater Cable Infrastructure: Protecting from an Explosive Attack."*(Summer 2009)

Year Three Plans

- Identify ALERT-Relevant Courses for Distance Education (Spring 2010)
- e.g "Chemistry of Energetic Materials" (UPRM), "Theory of High Explosives" (MS&T), "Computational Methods and Algorithms in Imaging" (RPI)
- Study Viability/Marketability of MS for HS Professionals (2010-2011)
- e.g., MS in Homeland Security Technologies
  - "Security Screening Technology" track
  - "Explosive Detection Technologies" track
  - "Multisensor Systems" track
- Pilot: 5- Day Short Course on Security Screening Technologies (Aug 2010)
- Topics to be covered include Threats, Chemical Spectroscopies, and Imaging and Detection
- Recorded for Distance Education
- Identify a DHS-related Gordon Fellow for 2010/2011 class

Undergraduate Programs at NU-led ALERT

Year Two Results

- High Tech Tools and Toys "Hands On" Modules
  - Developed IR Spectroscopy module - Distinguishing olive oil from motor oil
- Co-op Experience
  - NU ChemE Madeline Wrable co-op with Prof. Samuel Hernandez of UPRM (Spring 2010).
- Research Experiences for Undergraduates Program
  - 10 students at NU, RPI, TTU, UPRM (Summer 2009)
  - All 21 students in REU

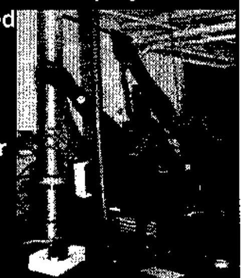
Year Three Plans

- High Tech Tools and Toys "Hands On" Modules
  - Use IR Spectroscopy module with Young Scholar and RET participants (Summer 2010)
  - GE1111 – "Engineering Problem Solving and Computation" (Spring 2011)
  - Ultrasound Imaging in the Diffraction Limit (Fall 2010)
- Research Experiences for Undergraduates
  - Program to continue with 10 undergraduates (Summer 2010)
- Co-op and Capstone Experiences
  - One ALERT co-op student planned (2011)
  - Develop ALERT Capstone Group (2010/2011)

K-12 Outreach at NU-led ALERT

Year Two Results

- Research Experiences for Teachers – NU STEM Center
  - 6-week research and professional development experience for secondary teachers and Community College Faculty
  - High School Teacher Mark Casto worked with Prof. Mehrdad Sasani on the "Progressive Collapse of Reinforced Concrete Structures" project
  - High School Teachers Mike Wall and Alex Perez worked on the "Failure Modes of Light-Weight Sandwich Structures" project
  - 21 Teachers and Community College Faculty participated in ALERT-related seminars
- Young Scholars Program (High School) – NU STEM Center
  - 24 students participated in 6 weeks of research at NU and 6 participated in ALERT-related research
  - All 24 students attended ALERT-related seminars
- Other K-12 Outreach
  - Exxon Mobil Bernard Harris Summer Science Camp – 4[illegible] 7th, 8th and 9th grade students were introduced to research work of DHS field testing of "Lookout!"magazine
  - ALERT students assist with university field trips and summer camps at NU



K-12 Outreach at NU-led ALERT cont'd.

Year Three Plans

- Research Experiences for Teachers- NU STEM Center
- Program to continue and expand to include additional teachers (Summer 2010)
- Up to four Community College Faculty will be recruited (Summer 2010)
- All RET participants will participate in ALERT-related seminars
- Young Scholars Program (High School)- NU STEM Center
- Program to continue with 24 students participating in ALERT-related seminars and 8 students placed in ALERT-related research labs (Summer 2010)

Community College Outreach at NU-led ALERT

Year Two Results

- **Research Experiences for Teachers- NU STEM Center**
  - Four Community College Faculty engaged in research and were introduced to HTT&T
- **Community College Outreach**
  - Collaboration with STEP Program – Implementation of High Tech Tools and Toys Modules with Partner Community Colleges (MassBay Community College, Middlesex Community College and Northern Essex Community College)
    - Two workshops held for Community College Faculty (Fall 2008, Summer 2009)
    - Two CC RETs conducted research in the High Tech Tools and Toys laboratory at BU for six weeks (Summer 2009)
    - Planning Meeting between NU, NU STEM Center and CC Partners to incorporate HTT&TL Modules into CC curriculum (January 29 , 2010)

  - Missouri S&T conducted program analysis (Engineering, Science & Technology, Math, Criminology, and Sociology) of partner CCs to develop recruiting material (Fall 2009)

Community College Outreach at NU-led ALERT cont'd.

Year Three Plans

- **Research Experiences for Teachers- NU STEM Center**
- Up to four Community College Faculty will be recruited (Summer 2010)
- **Community College Outreach**
- Expanded Two-Week HTT&T Workshop for CC faculty working with NU (Summer 2010)
- Expansion to new CC Partner - DHS Scientific Leadership Bridge Awards for Minority Serving Community Colleges between ALERT at NU and Roxbury Community College (proposal pending)
- Share ALERT/DHS research through CC STEM Seminars and Clubs (Summer 2010/Fall 2010)
- MS&T Collaboration with Missouri Community Colleges – Continue ALERT presentations (2010/2011)

Training for First Responders at NU-led ALERT

Year Two Results

- **Explosives Training Short Course (MS&T)**
  - 30 members of Jefferson City SWAT/Bomb Squad (Nov 19, 2009)
  - Ft. Leonard Wood Personnel - 75 officers and Senior NCOs (Dec 15, 2009)
- **Explosives Awareness Training (MS&T)**
  - 4 deputies Phelps County Sheriff's Dept. (Jan 8, 2010)
  - 25 police officers Phelps County Sheriff's Dept .(Jan 28, 2010)

Year Three Plans

- **Explosives Training Short Course (MS&T)**
  - 30 Ft. Leonard Wood Personnel - (Feb 22, 2010)
- **"Hands-on Explosives Training" for Midwest Research Inst. (TTU)**
  - Four-day on-site course for US Government Personnel (Summer 2010)
  - Synthesis and testing
  - Available for HS professional, ALERT grad students

Initiatives to Increase DIVERSITY at NU-led ALERT

Year Two Results

- Year Two Base-line Data

	[illegible]	[illegible]	[illegible]
Faculty	10% (4)	20% (8)	40
Graduate Students	15% (6)	23% (9)	40
Undergrad Students	32% (5)	25% (4)	16

- 2009 Research Experiences for Undergraduates Program
- 10 undergraduate students participated in research projects at ALERT partner locations (NU, RPI, TTU, UPRM) including 3 Hispanic students, 2 African-American students and 3 female students
- HBCU Collaborations
- Prof. Zhang (RPI) / Prof. Rockward (Morehouse College): "Continuous Wave Terahertz Imaging"
- Two Morehouse students engaged in REU experiences in Summer 2009
- Prof. Samuel Hernandez (UPRM) / Prof. Peter Chen (Spelman): "Coherent Raman Detection"
- UPRM graduate student Hilsamar Felix spent 6 weeks in summer 2009 working at Spelman

Year Three Plans

- Strategic Planning Process
- Task Force Teleconference- June, 2010
- Establish workable strategies for increasing diversity among faculty, graduate students and undergraduate students.
- DHS Summer Research Teams with MSIs (2 proposals pending)
  - Collaboration between Prof. Max Diem of NU and Prof. Shanti Rywkin of Borough of Manhattan Community College
  - Collaboration between Prof. Brandon Weeks of TTU and Dr. Pamela Auburn of University of Houston Downtown