Center of Excellence for Explosives Detection, Mitigation, and Response

change behavior of combatants

block access to resources-finances, knowledge, personnel, **materials, chemicals**

detect
bomb
maker
lab
bomb

mitigate blast effects

find & punish perpetrators

Jimmie Oxley, URI

Center of Excellence in Explosive Detection, Mitigation, & Response

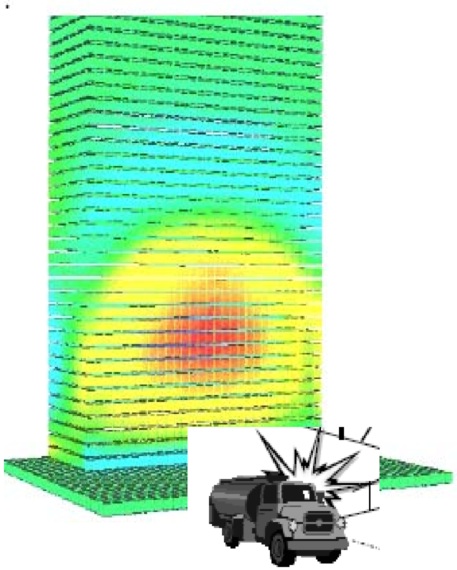
Conventional building design & structural materials should be replaced with blast-resistant ones.

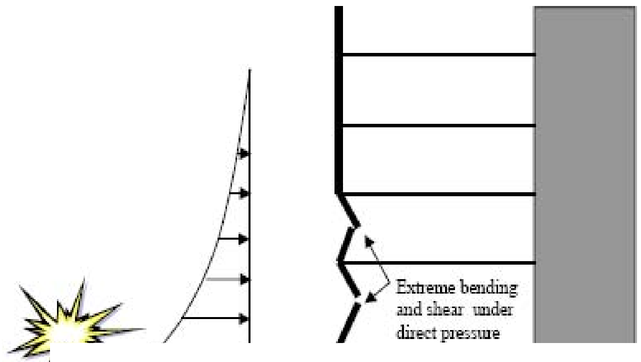
A comprehensive understanding of failure modes of structural elements & materials is necessary for development of blast-resistant structures.

Understanding of progressive collapse is necessary to design of safer structures and evacuation plans.

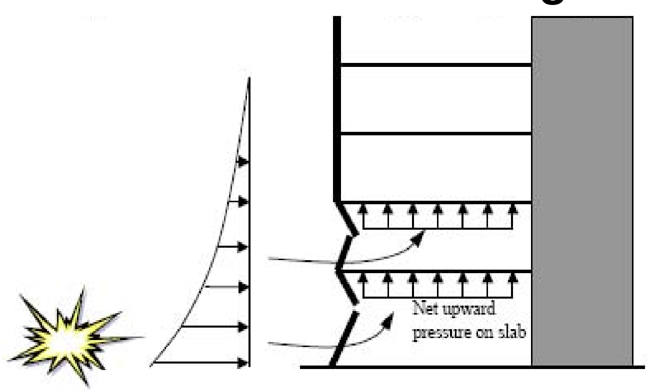
Progressive Collapse of Structures Resulting From Coupled Shock Waves & Thermal Effects Associated with Blast Loads

Design of critical structures must consider the dynamic response to blast & high velocity impact and associated thermal effects on the structure. A predictive model for the progressive collapse of steel structures is an essential design tool.



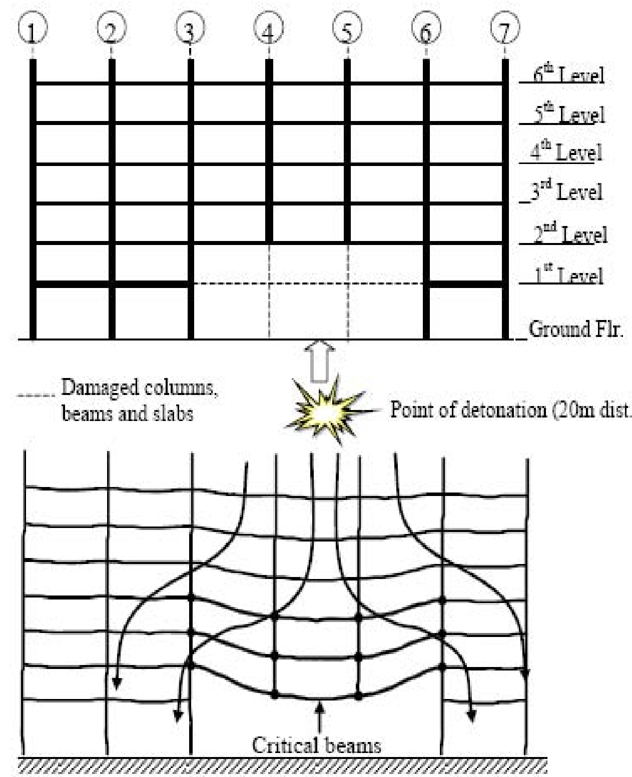


direct column loading

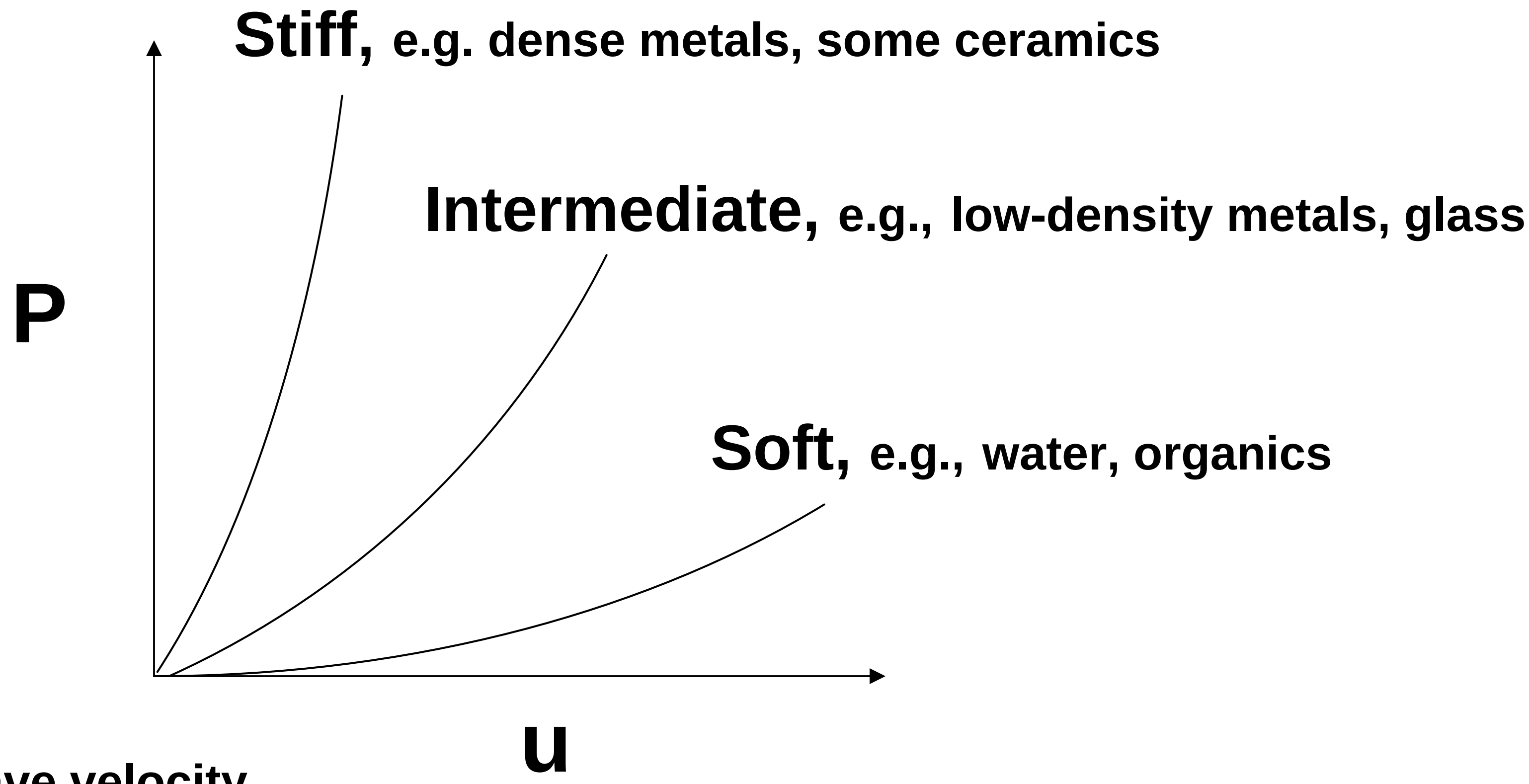


uplifting floor slabs

model of progressive collapse



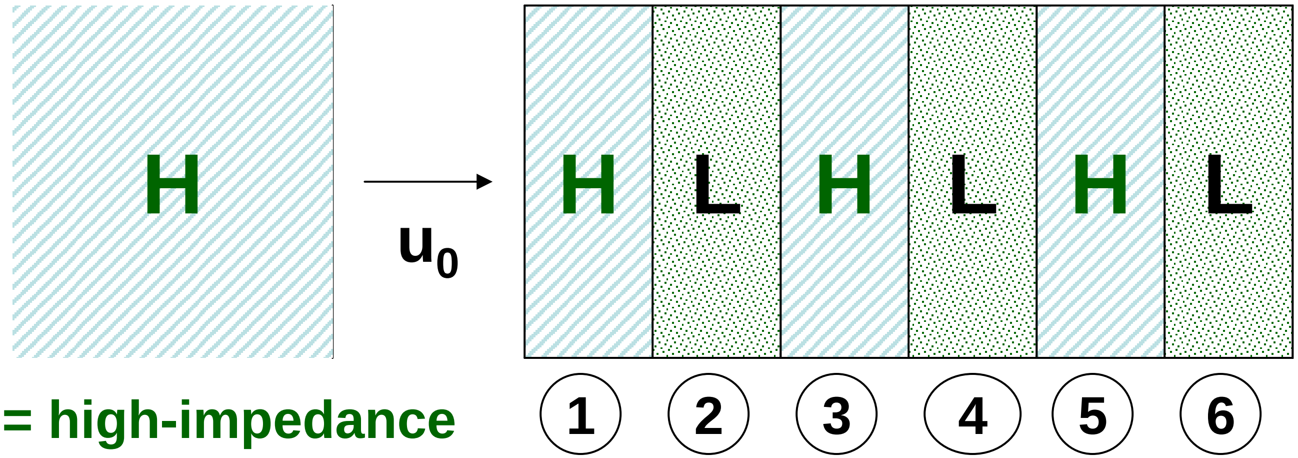
The response of a material to shock loading is described by *Hugoniot* that relates U, u, P, and v. A Hugoniot curve (H) is a locus of shock-jump states for a material. The slope of the Hugoniot indicates stiffness



U – Shock wave velocity
u – Particle velocity
P – Shock pressure
v – Specific volume

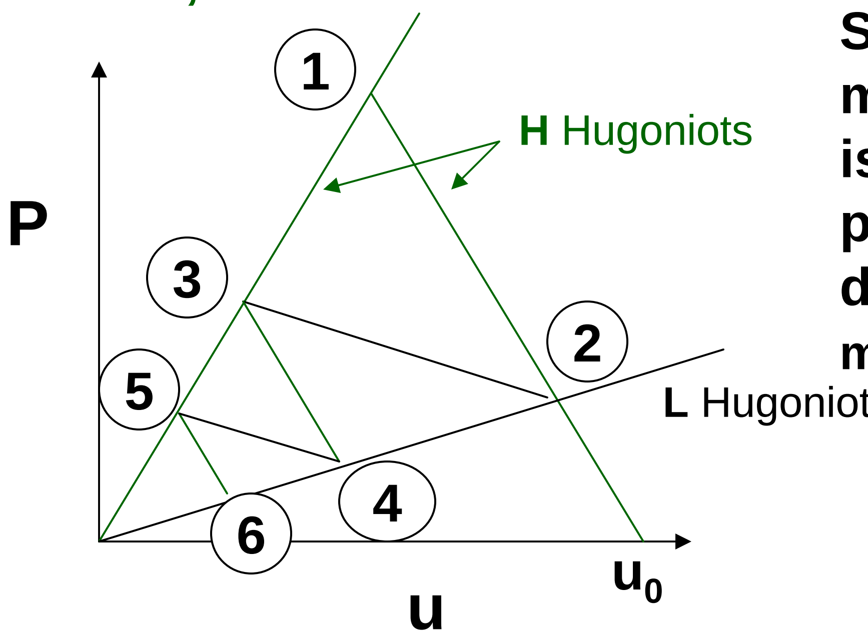
Air is so soft its Hugoniot lies almost on the abscissa.

LAMINATED-PLATE (COMPOSITE) MATERIALS DISPERSE A SHOCK FRONT.



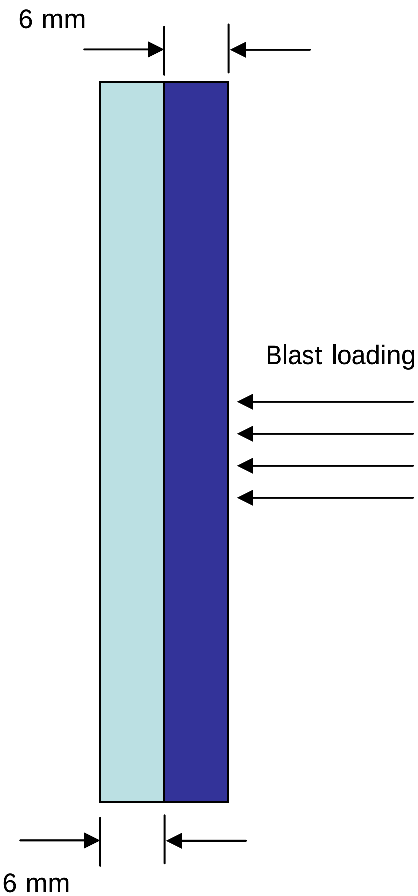
L = low-impedance material, soft

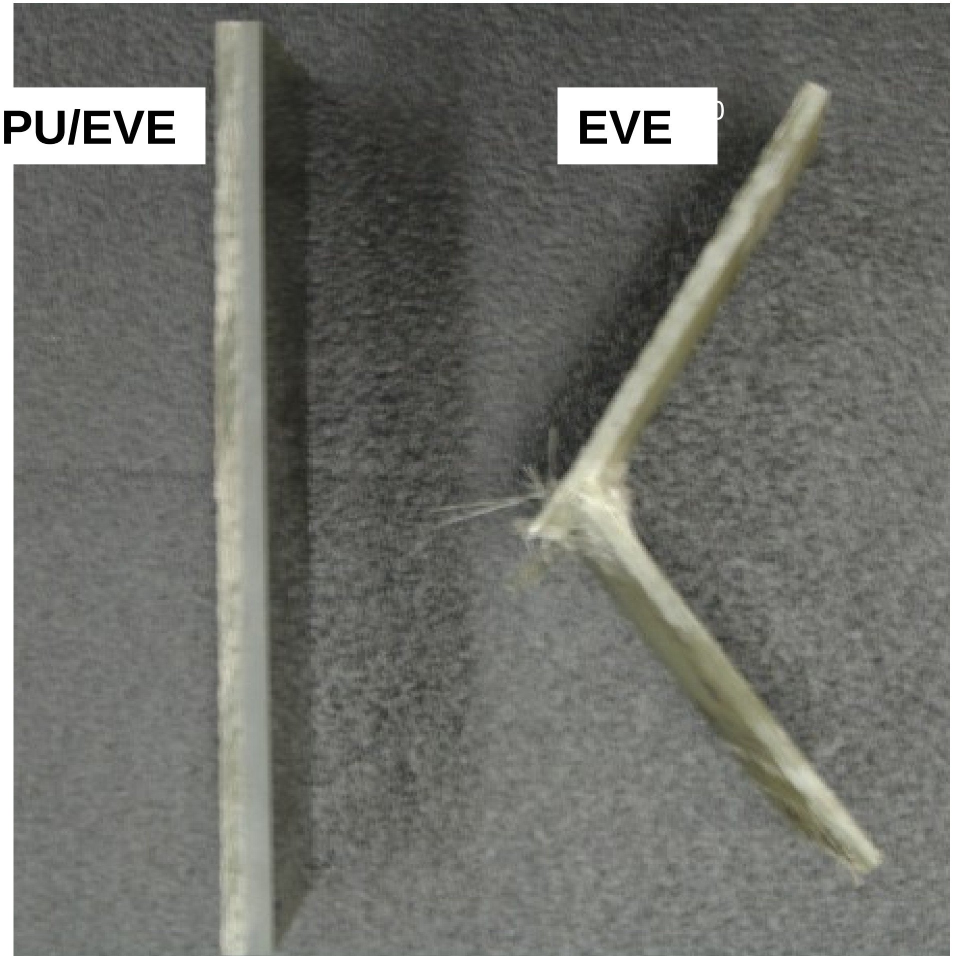
H = high-impedance material, stiff



Shock compression produces more heating than common isentropic compression. It produces more heat in low-density materials (e.g., damaged materials) than in high.

Response to blast single polymer vs. composite





E-Glass Vinyl ester composite coated with Polyurea, a polymer which behaves elastic-plastic.

Undergraduate/Graduate Courses

Sensing

Northeastern University

NE	RS3100	Fund. of Remote Sensing
NE new	HS 3040	Signal Processing and Sensor Management
NE new	HS3080	Chemical & Physical Sensing of Explosive
NE new	HS3090	Man-Machine Interface

Mining

UMR University of Missouri-Rolla

MR	MIN 305	Explosive Handling & Safety
MR	MIN 307	Principles of Explosives Engineering
MR	MIN 351	Demolition
MR	MIN 407	Theory of High Explosives
MR	EE 371	Grounding & Shielding
MR	FF 444	Stochastic Signal Analysis
MR	FF 373	Antennas & Propagation

BS, MS, PhD Mining Engineering
BS, MS (new) Explosive Engineering
Certificate in Explosive Engineering

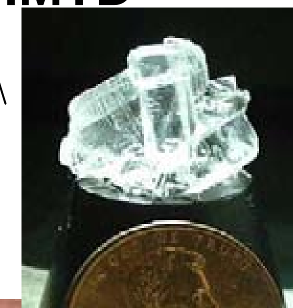
Engineering & Explosives

University of Rhode Island

RI	MCE 440	Mechanics of Composite Materials
RI	MCE 464	Vibrations
RI	MCE 576	Fracture Mechanics
RI	MCE 679	Theory of Plasticity
RI	CVE 560	Structural Design
RI	CVE 596	Numerical Methods in Structural Engineering
RI	CHE 333	Engineering Materials
RI	CHE 464	Industrial Reaction Kinetics
RI	CHE 468	Microscopy
RI	CHM 661	Introduction to Explosives Chemistry & Physics
RI new	CHM 662	Explosive Operations & Regulations
RI new	CHM 663	Analysis of Explosives & Other Energetics
RI new	CHM 664	Explosive Hazards Analysis

Characterization of Energetic Materials
What's its density?
What's its performance?
What's its signature? vapor pressure?
What are its decomposition products?
What are its safety parameters?
Is it an explosive? at what scale?
Edward AFB 1999
13,700lb propellant with
1700 lb C4 booster

sugar salt AN HMX RDX TNT PETN TATP HMTD



Flame Test is a quick way to assess hazard on small quantity

RDX

Sugar

TATP

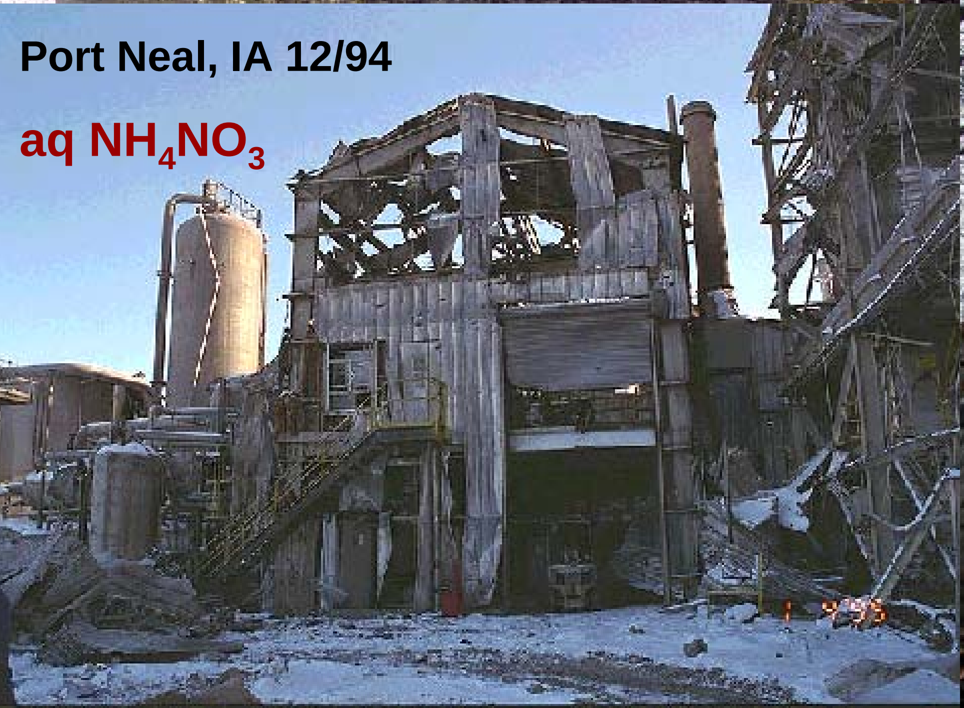
Explosives are characterized by visual appearance, spectroscopy (IR, Raman, MS), melting point, performance, density & vapor pressure. Vapor signature may be contaminant or decomposition product.

Explosive & Propellant Properties		MW g/mol	m.p. C	vapor pres torr @25C	state
AN, NH4NO3		80	169	salt	S
HMX		296	280d	3E-09*	S
RDX		222	204d	2E-09	S
Picric acid		229	122	1E-09	S
PETN		316	141	3E-08	S
Tetryl		287	129	3.5E-05*	S
TNT		227	81	4.5E-06	S
NG, nitroglycerin	AN →	227	13	2.3E-04	L
DMNB^, 2,3-dimethyl-2,3-dinitrobutane	UN →	176		2.1E-03	L
2,4-DNT, 2,4-dinitrotoluene		182	69	1.9.E-02	S
EGDN^, ethylene glycol dinitrate	TATP →	152	-23	4.8E-02	L
p-MNT^, 4-nitrotoluene	DADP →	137	55	4.1E-02	S
o-MNT^, 2-nitrotoluene		137	-3	1.5E-01	L
Nitromethane, CH3NO2		61	-29	37	L

^ ICAO taggants *100C, ** 150C


Allentown, PA
Feb. 19, 1999
H_2NOH


Manchester, CT 7/01
Phoenix, AZ 8/00
$Ca(OCl)_2$


Port Neal, IA 12/94
aq NH_4NO_3


Danvers, MA 11/06
hexanes

1996-8	Aug. 2006	Nov. 2006	Dec. 2006	Ap 2007	Feb-07
Nation Research Council	Natural Resources Canada	Australia	Singapore	DHS	EU
nitric acid	nitric acid	nitric acid		2000	nitric acid
ammonium nitrate	AN	AN	AN	2000	AN
potassium nitrate	KNO_3	KNO_3	KNO_3 >5%	2000	
calcium nitrate					
mix NaNO3, Ca(CN)2, NH4Cl	$NaNO_3$	$NaNO_3$	$NaNO_3$ >5wt%	2000	
sodium chlorate	$NaClO_3$	$NaClO_3$	$NaClO_3$	2000	$NaClO_3$
potassium chlorate	$KClO_3$	$KClO_3$	$KClO_3$	2000	$KClO_3$
hydrogen peroxide	H_2O_2 >30wt%	H_2O_2	H_2O_2 >20wt%	>30%, 2000	H_2O_2
potassium perchlorate	$KClO_4$	$KClO_4$	$KClO_4$	2000	$KClO_4$
		$NaClO_4$	$NaClO_4$		
		NH_4ClO_4	NH_4ClO_4	2000	NH_4ClO_4
urea				2000	
	nitromethane	nitromethane		2000	
dinitrotoluenes					
nitrobenzene					
$Ca(OCl)_2$					
$Na(OCl)_2$					
$KMnO_4$					
sodium chlorite					
calcium carbide				anhy NH_3 7500	
halogenated biocides				NH_3 >20% 15000	
nitroparaffins					
picric acid					
acetylene				7500	
		sulfuric acid			sulfuric acid
				anhydr any amount	HCl

Government agencies are beginning to worry about chemical precursors, but there is little data to guide choices.

EDUCATION: Students & Teachers

screeners | **1st responders** | **government regulators** | **industry** | **certificates workshops**

graduate students | **degrees**

teachers | **undergraduate students** | **HBCU & MSI**

teachers | **high schoolers**

Funding allows exchange of students and faculty. This will provide minority students a wide range of opportunities & experiences.

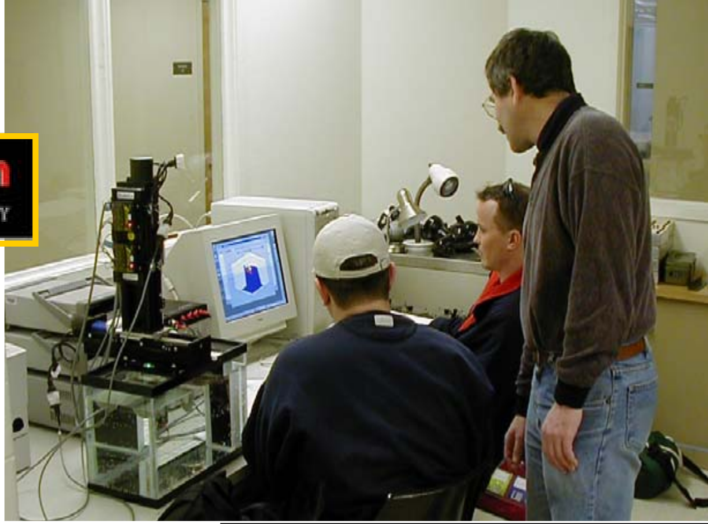
Center research programs brings students—graduates & undergraduates into contact with potential employers in law enforcement, counterterrorism, etc.

Laboratory discovery, association with a dynamic research team, & publications encourage students to endure and excel in science & engineering.

Overall Education Program

Undergraduate Programs

High-Tech Tools & Toys Lab
Undergraduate Research
ALERT Scholars
Co-ops & Internships



Full-time students: PhD & MS research
Part-time: MS & Certificate, Distance learning
DHS Scholarship and Fellowship Program

Responders, Security Professionals, Government

Workshops
Certificate Short Courses
23 Explosive short courses since 2004
MS & Advanced Degree Studies
Web-training resources
Employer Sponsor & Faculty Mentor

Pre-college Programs

Boston Public Schools partnership
Troy Children's Museum (RPI)

Provide training, support and technology to first responders.

Two day, 25-30 person response (fire, hazmat, bomb squad, police, forensic lab & 1 URI professor for 1 talented 17-yr-old amateur chemist.

Improvised Explosive Laboratory

External Advisory Boards

10 members from responders community & appropriate government agencies

1 representative each from industrial partners in detection community

5 member super advisory board to aid directors in program coordination

Role of Boards

- Identify technology gaps
- Educate CoE as to new needs & technical responses
- Provide guidance on integration on technology & human response
- Provide recommendation and guidance in development of and relevance of educational & research programs
- Advise as to allocation of resources

DHS Explosive Center of Excellence

University of Rhode Island

CALTECH

Northeastern University

Boston University

Rensselaer

UMR University of Missouri-Rolla

NM State University

Texas Tech University

Washington State University

Awareness and Localization of Explosives-Related Threats

ALERT

Detection

Mitigation

Response

Explosive Short Courses 2004-08

Military

NAVSEA, Indian Head & Stump Neck, MD	9/04, 6/06, 2/08
NAVSEA, Crane, IN	3/07
Waterways Experimental Station, Army, MS	11/04
Picatinny Arsenal, NJ	6/07, 4/08
Hill AFB, UT	3/05
Eglin AFB, FL	6/06

U.S. Government Agencies

FAA/TSA Technical Center, NJ	6/05
U.S. Customs	2/04, 8/04
CIA, Wash DC	4/07
Sandia National Lab, NM	12/06
Los Alamos National Lab, NM	8/05
Defense Nuclear Facilities Safety Board, Wash DC	9/07
DoE/Honeywell, MO	6/05, 8/05

Industry

Lockheed Martin, NY	2/05
Raytheon, MA	3/07
John Hopkins Applied Physics Lab, MD	7/05, 4/08
Swales Engineering, MD	3/04

Explosive courses presently available

1 Fundamentals of Explosives
- Basic Definitions and Principles
- Chemistry - Conventional Explosives
- Chemistry - Unconventional Explosives
- Explosive Safety
- Shock-wave Physics
- Detonation Physics: theory & phenomena
- Initiation, hot spots, shock, DDT
- Explosive Devices and Applications
- Explosive Effects

2 Explosive Operations: Regs & Protocols
- A walk through the safety manuals
- Commercial Storage Regs: BATF & NFPA 495
- Federal Regulations Relevant to Gov. Agencies
- Personnel protection, training, mishaps, SOP prep.
- Required tests (ESD, shock, friction, impact, thermal)
- Specifics of Handling Explosives
- History of explosive accidents

3 Stability, Compatibility, & Surveillance
- Thermal safety--small & large, use of results
- Analysis of thermal stability & compatibility
- Surveillance issues
- Cook-off - thermal explosion models

4 Material Response to Impulsive Loading
- Detonation as driver; shock interactions
- Material structure & mechanical behavior
- Experiments
- Inelastic continuum mechanics & damage
- Modeling and wavecodes

5 Explosive Systems Hazards & IM
- Fundamentals of explosives related to hazards
- DDT phenomenology & testing
- Flame spread in damaged explosives
- Ignition sources: mechanical, electrical, frag impact
- Insensitive munition policy and test requirements
- Design techniques to reduce violence responses
- Insensitive high explosives (IHEs)

6 Explosives: Environmental Issues
- l General issues & toxcity
- Explosive residue from blast
- Fate & transport: HE in soil, water, plants
- Sampling protocols & analytical methods
- Analytics protocols by specific explosive

7 Laboratory Analysis & Forensics
- Operational safety
- Case studies from forensic scientists
- Particle morphology-characterization & effects

Working With First Responders

Identify technology gaps with the practices and tactics of first responders in mind

Gather field validation data through these organizations

Provide training, support and technology

Create national & international links to relevant organizations

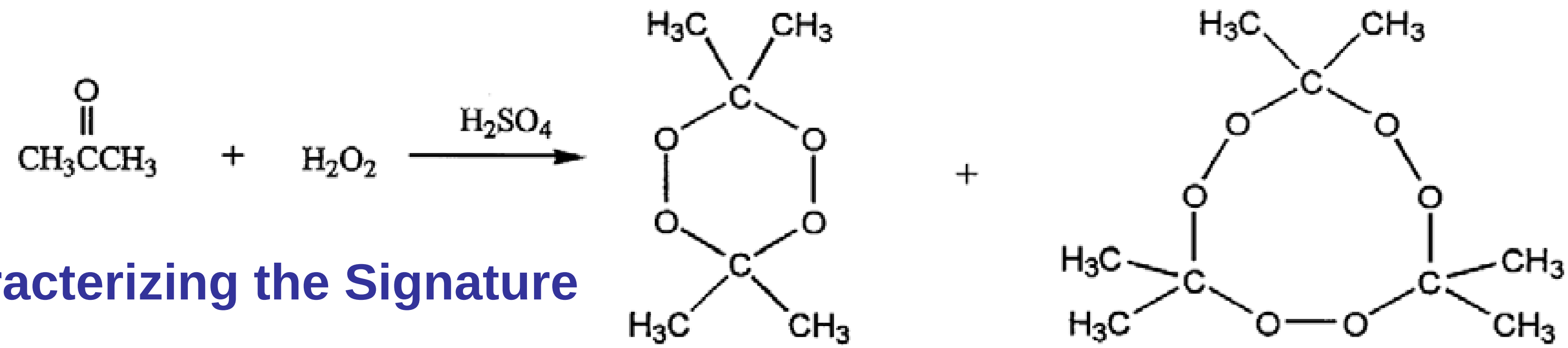
Explosives Detection Technology

- Current state
- Emerging technology in explosive devices, detection, mitigation

The Response Advisory Board Ensures Relevance

Danvers, MA

Nov. 22, 2006



DADP

mp = 126-128°C

TATP

mp = 93-95°C

Characterizing the Signature

visual appearance, density, spectroscopy (IR, Raman, MS), vapor pressure, melting point, decomposition products, performance.

detonation velocity ~5290 m/s
density ~1.20 g/cc