## Science & Technologies of the Detonation Process

After-burning

Chemistries dependent on explosive composition and oxygen intake supporting shock transmission

Initiation by thermally induced intense energy input (e.g., hot-wire, impact/shock, radiation)

PRACTICAL IMPLICATIONS
Energy release & rate displaces matter in the direction of the detonation, laterally outward, and behind the process as relief waves.

Shock waves from a large TNT detonation

## Background

System developers and explosive engineers regularly face the demand of making learned decisions concerning the promise of a new explosive, the selection an explosive for a new application, and the characterization of an explosive system. Users and those in command are often challenged to select the components of an arsenal and assess potential hazards and/or investigate an event.

***The types of information critical to these assignments include sensitivity, mechanical properties, cost, availability, and performance.***

## Course Goals

The goals of the course are to

- provide an in-depth and advanced understanding of explosives from theoretical and practical standpoints,
- formulate the bases for evaluating the potential of competitive and alternative explosive systems and their potential utility, and
- provide criteria for treating sensitivity and security .

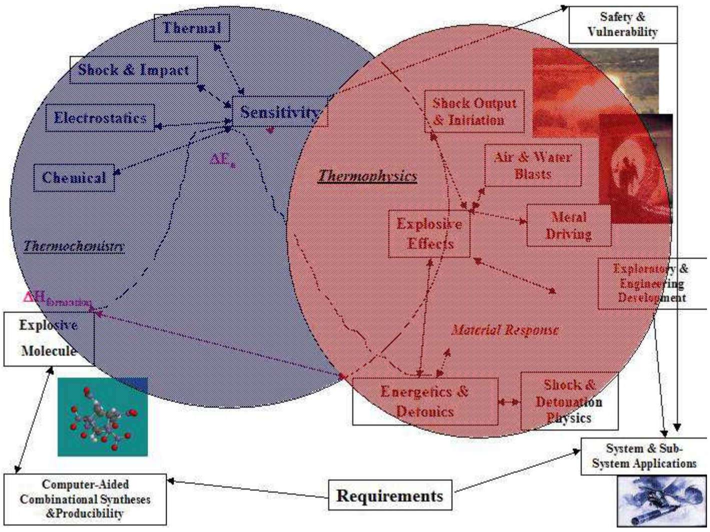


## Learning Outcome

*Upon successful completion of this course, you will be able to:*

- Understand
  - The nature of explosive molecules:
    - Molecular constituents and bonding
    - Classes of pure molecules and compositions
    - Cost to manufacture
  - Stability and sensitivity
  - The detonation mechanism
  - Explosive Effects
- Acquire the tools to estimate critical parameters associated with :
  - Safety
  - Detonation parameters
- Exercise a more comprehensive bases for:
  - ***Assessing on-going research***
  - ***Devising innovation approaches for using explosives***
  - ***Assessing proposals for warhead development***
  - ***Crime scene investigation***

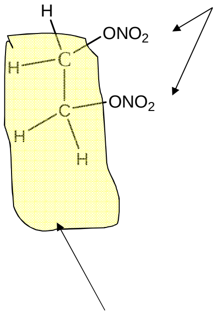
## Overview & Linkages of Topics




1/10/2017 5

# The Explosive Molecule & Utility

# Basic Attributes of a CHNO Explosive



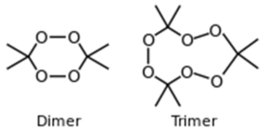

**Fuel**

**Oxidizer carried by Nitrogen**

General Considerations

- A fuel Component
- An Oxidizer Component
- Weak Bonds to Facilitate Dissociation
- High Potential Energy
- Large Molecular Volume of Gas per Explosive
- High Density
- Key Elements
  - Nitrogen

But Terrorists Can Think Differently!

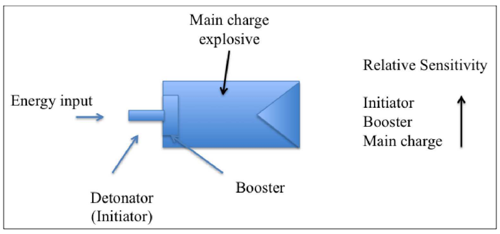


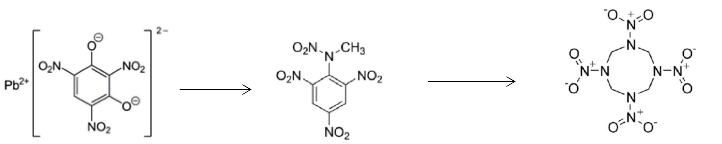

- Easily Made
- Void of Nitrogen
- Weak Bonds
- Dangerous



# Primary to Secondary

Example of an Explosive Train




Lead Styphnate

TETRYL

Plastic Bonded HMX (LX-14, PBXN-9)

Or e.g., low density HMX

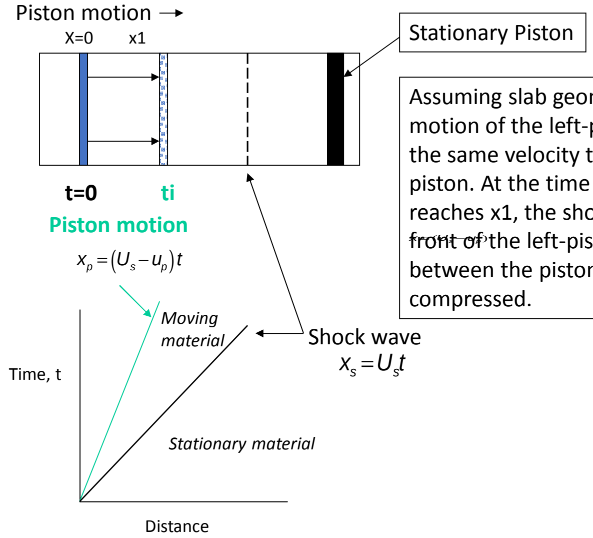
NO2 charge distribution is common

# Shock & Detonation Physics

## Shocking Up To Detonation

- Unique Characteristics of the hydrodynamic state
  - Elastic to visco-elastic to non-recovery
  - Particle versus shock velocities
  - Conservation Laws
- Conditions of Shock Jump
  - Thermal
  - Electronic
- The Hugoniot and Equation of State
- Practical examples & Solutions
- Detonation
  - Deflagration to Detonation
  - Non-steady to Steady-State (Chapman-Jouguet))

## Introduction to the Rankine-Hugoniot Jump Equations




Assuming slab geometry of infinite depth, the motion of the left-piston drives particle flow at the same velocity towards the rigid right-hand piston. At the time that the left-hand piston reaches x1, the shock front that develops is out in front of the left-piston position, and the material between the piston and the shock front is compressed.

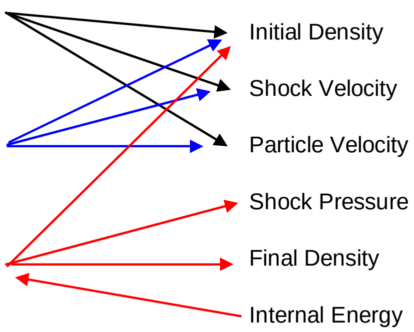


## Application of Conservation Equations

$$v_0 / v_1 = \rho_1 / \rho_0 = U / (U - u_1)$$

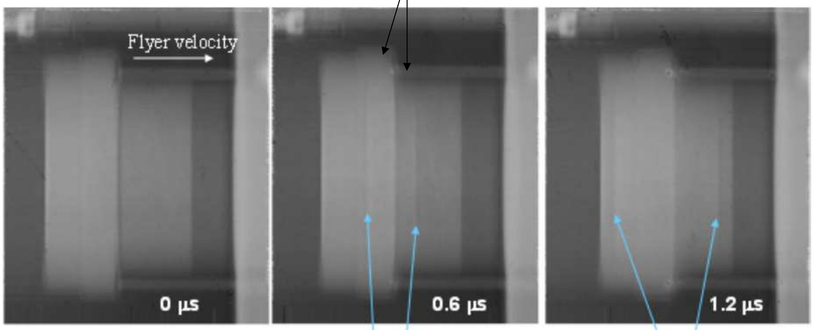
$$P = \rho_0 u_1 U$$

$$\Delta E = \tfrac{1}{2} P_1 \cdot (v_0 - v_1)$$



## Shock Setup and Transmission Resulting from Hypervelocity Impact of Aluminum Slabs

**Material compression**




**Shock Front** **Shock Front**

Shock fronts moving at the same absolute rate in opposite directions

Hixson, LANL



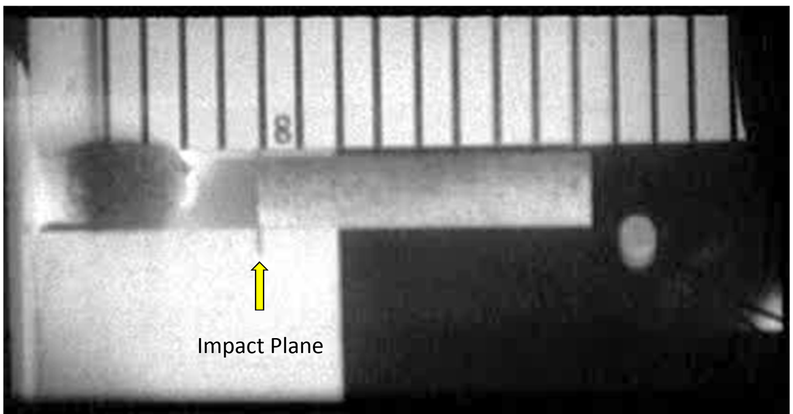
## IMPACT TO INITIATION

High velocity jet impact against TNT-Rod

Immediate compression & thermal heating

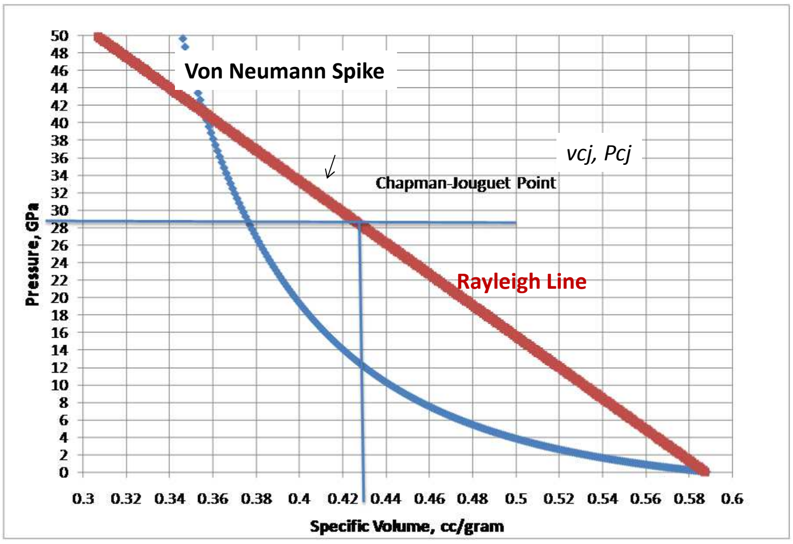
Chemical reaction and pressure build-up in small volume about the impact

Shock formation/detonation




Appearance of shock reflections

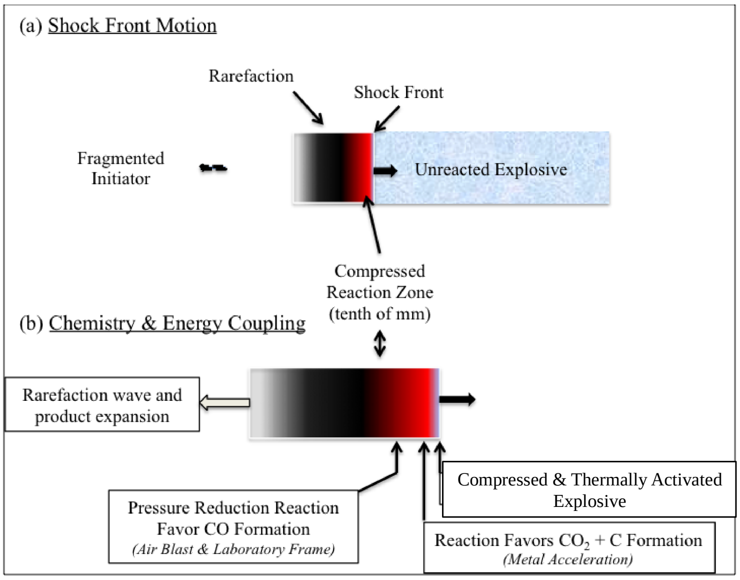
## Relevant Detonation Parameters Derived from Conservation Equations and Experiment




Example: Composition B



## Explosive Detonation & Utility




Directed Energy
- Overpressure & Blast
- (e.g., EFP, Shaped Charge)

Cylinder Expansion
- Overpressure & Blast
- Cylinder Expansion
  - Fragmentation