Impact Generated Air Blast

Presented by

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PDC

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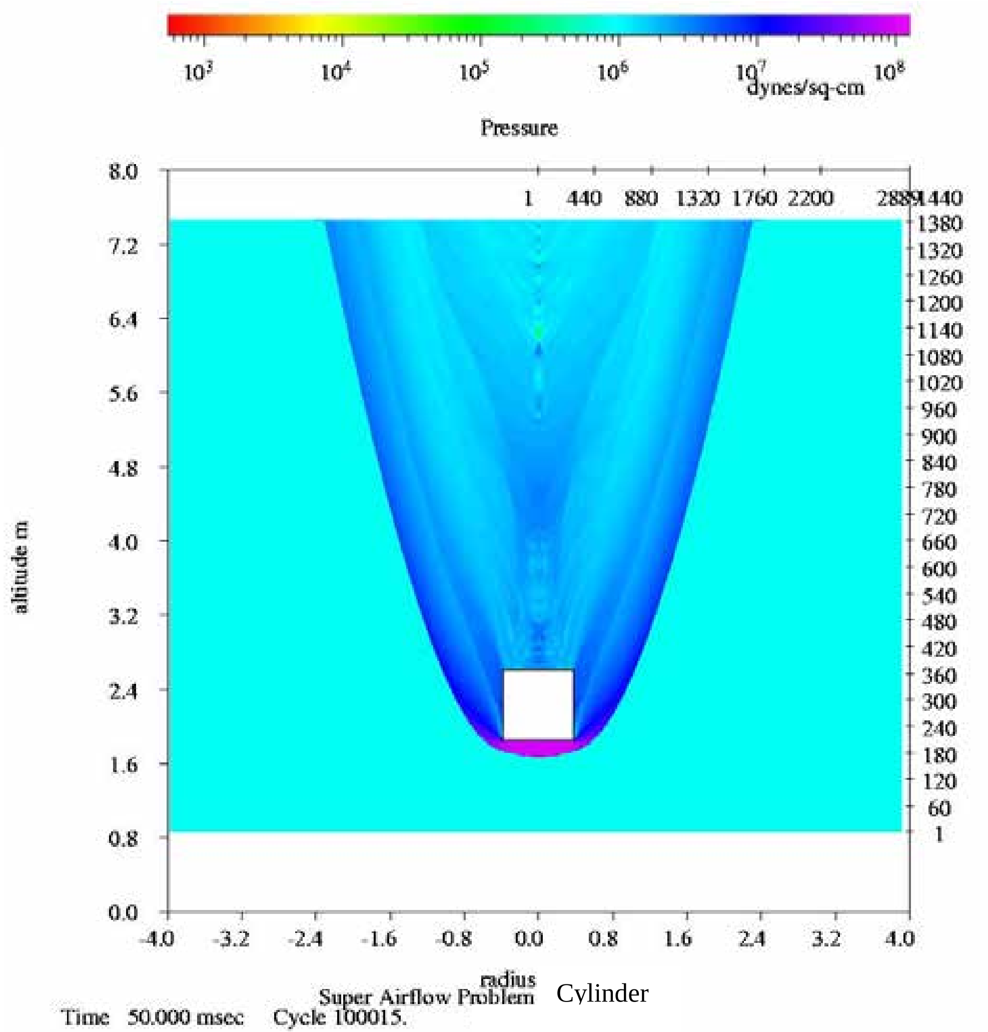
Sources of Air Blast

- Supersonic Incident Velocities
  - "Sonic Boom"
    - Strength of the shock increases with velocity
    - Shape of incoming is secondary
  - Impact Energy Release
    - Is Impactor Geometry Dependent
      - Long Rod vs. Blob
  - Air Column Following the Impactor

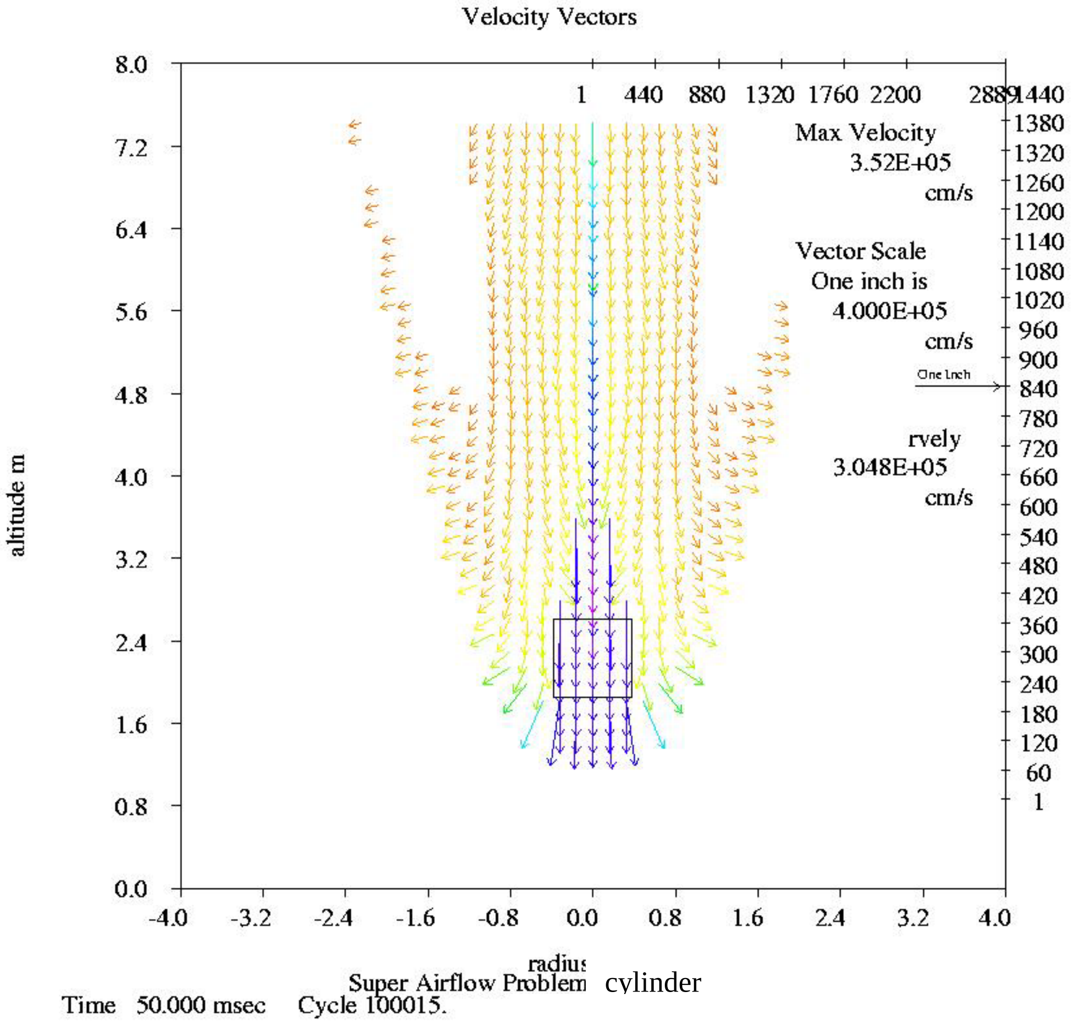
Range of Velocities

- Conventional Penetrating Bombs
  - 700 to 1400 ft/sec (200 to 400 m/sec)
- Boosted Penetrators
  - 1100 to 3000 ft/sec (400 to 900 m/sec)
- Fragments from Munitions and Shaped Charges
  - 1200 to 12,000 ft/sec (350 to 3500 m/s)
- Ballistic Missiles
  - Dependent on re-entry trajectory
  - 3,000 to ~15,000 ft/sec (1 to 5 km/s)
- **Meteors**
  - **To 18 km/s**

Rectangular Cylinder at 10 kft/sec



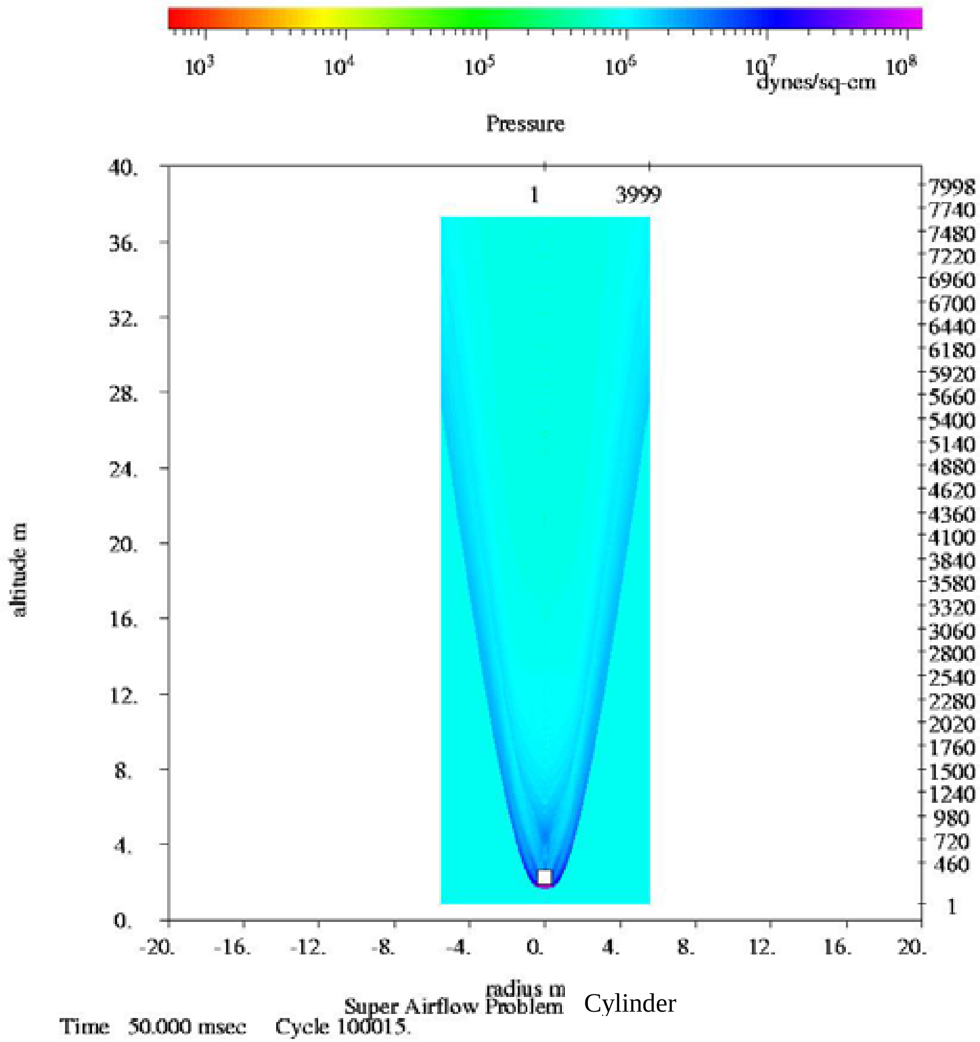
Velocity Field for Cylinder



Shocks from Cylinder

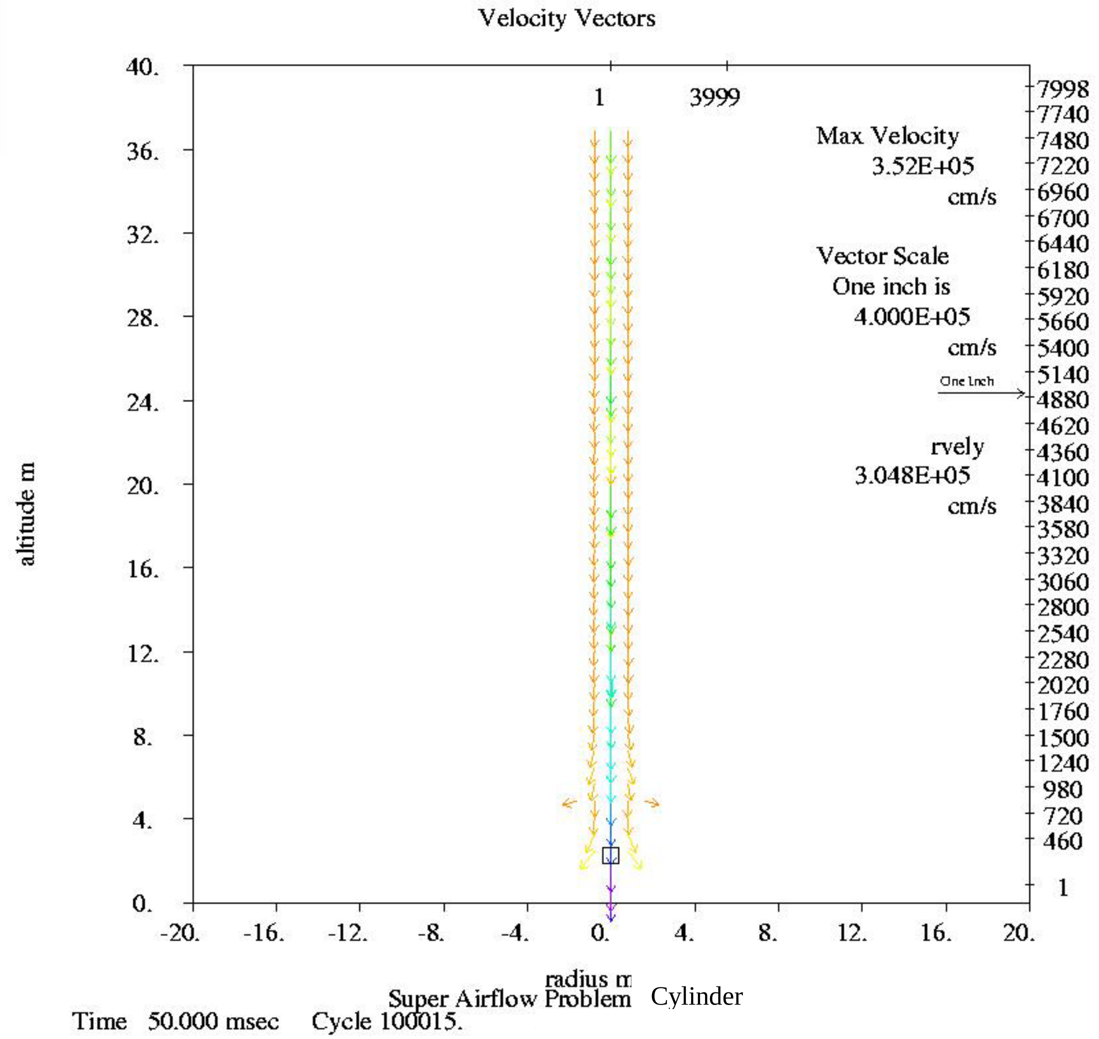
- ~10 bars (150PSI)
  - Extends well behind the cylinder
  - Decays slowly with distance
- Air Kinetic Energy
  - Velocity of ~1.5 km/s (4800 ft/s)
  - Radius of ~twice the radius of the cylinder
  - Extends well behind the cylinder (>50 diameters)
  - Density near ambient

Pressure for Cylinder, 10kft/s



Expanding the Realm of Possibility

Velocity Field Cylinder, 10kft/s



Shock extent

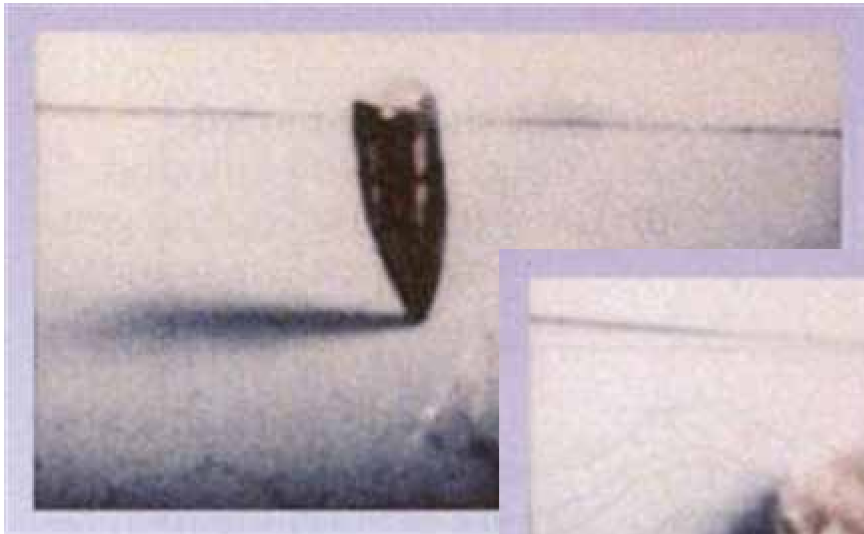
- Pressure ~2 bars at 20 m behind the cylinder
- High velocity column of air extends over 40 m behind the cylinder
  - Kinetic energy of the following air mass
    - Energy = $\pi r^2 L \rho U^2 / 2 = \pi 100^2 * 4000 * 1.2e-3 * 1.5e5^2 / 2 = 1.7e15$ ergs
    - Equivalent of at least 40 kilograms of TNT

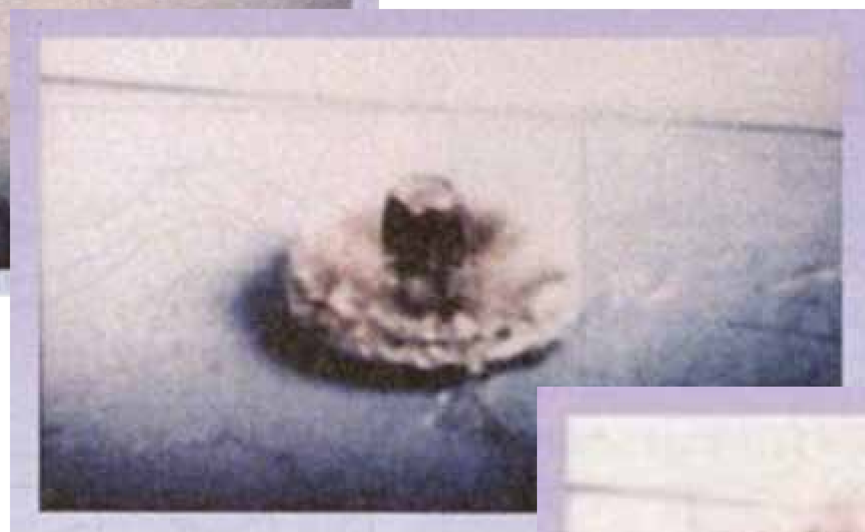
Full 3-D Calculation of Guided Bomb with Turbulence, 1.4 kft/s

Impact Energy Conversion

- Change in kinetic energy is converted to internal energy
  - Dependent on relative material density
    - Square root of impactor density to surface material density
    - Small scale experiments indicate crater volume goes as the 1.74 power of V
  - Assume this is proportional to energy in the target
    - Shock, ejecta, motion, heating
- Assume the excess energy goes into air blast
  - $E_{blast} = 0.5M(V^2 - V^{1.7})$

.30 Caliber bullet at 850 m/sec



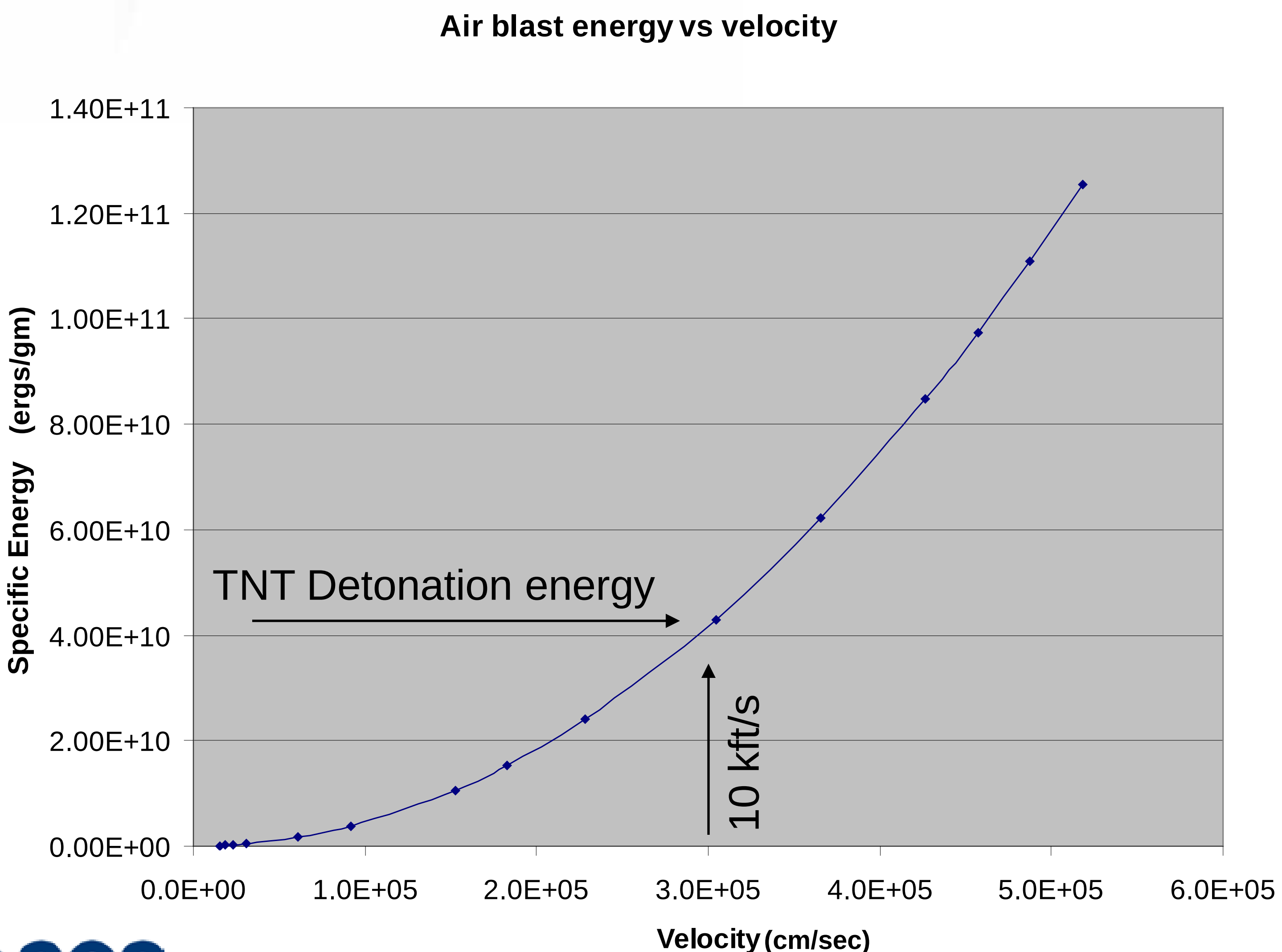


Photos courtesy of and with the permission of the Heflin steel division of the ESCO Corp.

Copper jacketed lead bullet, impacting a steel plate.

Essentially Disintegrates (melts) on impact, no significant crater

Energy Excess to Air Blast



Air Blast Implications

- At ~ 3 km/s the air blast energy will be the equivalent of the impactor mass of TNT
- At ~ 4 km/s the air blast will be the equivalent of twice the impactor mass of TNT
- Air column impact ~ ¼ impactor energy
- Additional energy from burning of aluminum and steel may contribute to Air Blast
- All are above the energy in ground shock and cratering

Experimental Confirmation

- 1973 Sandia sled test, Jack Reed pressure measurements
- Measured pressure of the sonic boom
  - Array of gauges on a line parallel to the sled track
  - Secondary signals not related to sled passing
  - Used arrival times to determine the signal origin
    - target at the end of the track
- Used pressure peaks, impulse and rate of decay
- Able to determine the effective yield of the air blast
    - Found a "good fit" when he used the **TOTAL** kinetic energy of the sled, motor, fuel and test object
- **The energy in the blast wave was indistinguishable from the total kinetic energy of the impacting mass**

Meteor Example

- M = 12,000 metric tons = 1.2e10 gm
- V = 18 km/s = 1.8e6 cm/s
- Total Kinetic Energy = 1.94 e22 ergs ~462 kt
- Cylindrical source ~30 km long, 16° slant angle
  - Uniform or finite number of “point” detonations
    - Makes little difference
- Height centered ~30 km
- Use square root scaling, gives ~1.5 PSI incident on the ground
  - ~ 3 PSI reflected

Conclusions

- Air Blast Shock Contributions
  - Bow shock
    - Limited range and pressure
  - Air Column
    - May be comparable to impact energy
      - Supersonic expansion
- Impact excess Kinetic Energy
  - Could be 2 to 3 times the equivalent mass of TNT
  - Currently based on centimeter sized impactors and Mach 3 Sled tests
- Need larger scale experiments to confirm these claims