Impact Generated Air Blast

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PDC
April, 2013

This work was not sponsored by any government contract or agency.
Sources of Air Blast

- Supersonic Incident Velocities
  - “Sonic Boom”
    - Shape 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

n Conventional Penetrating Bombs
  l 700 to 1400 ft/sec (200 to 400 m/sec)

n Boosted Penetrators
  l 1100 to 3000 ft/sec (400 to 900 m/sec)

n Fragments from Munitions and Shaped Charges
  l 1200 to 12,000 ft/sec (350 to 3500 m/s)

n Ballistic Missiles
  l Dependent on re-entry trajectory
  l 3,000 to ~15,000 ft/sec (1 to 5 km/s)

n Meteors
  l To 18 km/s
Rectangular Cylinder at 10 kft/sec
Expanding the Realm of Possibility

Velocity Field for Cylinder

Max Velocity
3.52E+05 cm/s

Vector Scale
One inch is 4.000E+05 cm/s

v_{cylinder}
3.048E+05 cm/s

Time 50,000 msec Cycle 100015.
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
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
    - $\sqrt{\text{Density of impactor density to surface material density}}$
    - 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
  - $E_{\text{blast}} = 0.5M(V^2 - V^{1.7})$
Expanding the Realm of Possibility

.30 Caliber bullet at 850 m/sec

Copper jacketed lead bullet, impacting a steel plate. Essentially Disintegrates (melts) on impact, no significant crater

Photos courtesy of and with the permission of the Heflin steel division of the ESCO Corp.
Energy Excess to Air Blast

Air blast energy vs velocity

Specific Energy (ergs/gm)

TNT Detonation energy

Velocity (cm/sec)

Expanding the Realm of Possibility
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
    - ŷ 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
  - ŷ 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 = $1.2 \times 10^{10}$ gm
- $V = 18$ km/s = $1.8 \times 10^6$ cm/s
- Total Kinetic Energy = $1.94 \times 10^{22}$ 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

n Air Blast Shock Contributions
  l Bow shock
    ŷ Limited range and pressure
  l Air Column
    ŷ May be comparable to impact energy
      n Supersonic expansion

n Impact excess Kinetic Energy
  l Could be 2 to 3 times the equivalent mass of TNT
  l Currently based on centimeter sized impactors and Mach 3 Sled tests

n Need larger scale experiments to confirm these claims