Effective Height of Burst Revisited

Mark Boslough

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Effective Height of burst: a valid/useful concept?

“In all cases the height of the apparent airburst is significantly lower than the point of maximum energy deposition.”
– Low-altitude airbursts and the impact threat (Boslough & Crawford, 2008)

“This directed nature of the burst enhances its destructive power relative to a point-source explosion of the same yield at the same altitude.”
– Airburst warning and response (Boslough, 2013)

“Boslough and Crawford (2008) also reevaluated the damage potential of low-altitude airbursts, showing that the effective height of burst for many impact scenarios is much lower than the altitude of peak energy deposition... For many situations, this leads to much more severe damage at the surface than would be estimated using the pancake model and assumptions of Chyba et al. [1993]. “
– Updated Population and Risk Assessment for Airbursts (Boslough, Brown, & Harris, 2015)

“To estimate local blast damage, the PAIR model approximates the airburst as a static burst, taking the point of maximum energy deposition as the burst altitude [Chyba et al., 1993]…”
– Probabilistic Assessment of Tunguska-scale Asteroid Impacts (Wheeler & Mathias, 2019)
2D simulations (PDC 2007)

Low-Altitude Airburst Contribution to the Impact Hazard

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Planetary Defense Conference
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- 5 Mt asteroid explodes 20 km above surface
- 5 Mt asteroid explodes 15 km above surface
- 5 Mt asteroid explodes 10 km above surface

60% KE, 40% IE sourced at specified altitude, under-dense, with fracture and fragmentation, v=20 km/s.
5 Mt asteroid explodes 20 km above surface

From PDC 2007 presentation “Low-Altitude Airburst Contribution to the Impact Hazard”
Altitude of explosion is much lower than altitude of peak energy deposition: 5 Mt events

From PDC 2007 presentation “Low-Altitude Airburst Contribution to the Impact Hazard”
PDC 2007

- 5 Mt asteroid at 20 km
- 5 Mt asteroid at 15 km
- 5 Mt asteroid at 10 km

60% KE, 40% IE sourced at specified altitude, underdense, with fracture and fragmentation, $v=20\ \text{km/s}$.

PDC 2019

- 5 Mt comet at 20 km
- 5 Mt comet at 15 km
- 5 Mt comet at 10 km

98% KE, 2% IE sourced at specified altitude to vaporize and cause total loss of strength, $v=30\ \text{km/s}$.

2019 simulations are instrumented to determine energy deposition curve, energy partitioning, velocity, momentum, and surface damage.
20 km trigger altitude

Temperature (K) at 0.00e+00 seconds
15 km trigger altitude

Temperature (K) at 0.00e+00 seconds
5 Mt comet triggered at 10 km above surface

10 km trigger altitude

Temperature (K) at 0.00e+00 seconds
“Apparent” Height of Burst

20 km trigger

5.7 km burst

15 km trigger

2.3 km burst

10 km trigger

2.8 km burst
Beta Taurid: 5 Mt, trigger height 20 km

- **Energy (Mt)**
- **Altitude (km)**

**Key Points:**
- Trigger point = 20.0 km
- Peak Edep = 15.8 km
- 50% Energy = 15.3 km
- 75% Energy = 13.6 km
- Apparent HOB = 5.7 km
Beta Taurid: 5 Mt, trigger height 15 km

- Kinetic Energy (Mt)
- Internal Energy (Mt)
- Energy Deposition (Mt/km)
- Velocity (%)
- Momentum (%)
- Mass (%)

- Trigger point = 15.0 km
- Peak Edep = 12.4 km
- 50% Energy = 9.9 km
- 75% Energy = 7.2 km
- Apparent HOB = 2.3 km
Beta Taurid: 5 Mt, trigger height 10 km

- Kinetic Energy (Mt)
- Internal Energy (Mt)
- Energy Deposition (Mt/km)
- Velocity (%)
- Momentum (%)
- Mass (%)

- Trigger point = 10.0 km
- Peak Edep = 6.1 km
- 50% Energy = 6.6 km
- 75% Energy = 5.8 km
- Apparent HOB = 2.8 km
Figure 3.73c. Peak overpressures on the ground for 1-kiloton burst (low-pressure range).
Comparison between damage estimation methods

- **Trigger height**: 50% Edep level
  - 20 km: 15.3 km
  - 15 km: 9.9 km
  - 10 km: 6.6 km

- **Static source**: (Glasstone & Dolan)

- **Hypervelocity airburst**: (CTH hydrocode)

- Pressure levels:
  - >1 psi
  - >2 psi
  - >4 psi
  - >10 psi
Modeling Tunguska as a Beta Taurid

Wind speed (m/s)

60 50 40 30 20 10

80 km

60 km

104°
Beta Taurid at 32° entry angle: 5 Mt, trigger height 12 km

- Kinetic Energy (Mt)
- Internal Energy (Mt)
- Energy Deposition (Mt/km)
- Velocity (%)
- Momentum (%)
- Mass (%)

- Trigger point = 12.0 km
- Peak Edep = 10.9 km
- 50% Energy = 10.65 km
- 75% Energy = 10.0 km
Comparison between damage estimates: 5 Mt, 32°

Static burst at 50% Edep (G&D)

3D hydrocode

- >1 psi
- >2 psi
- >4 psi
- >10 psi
Beta Taurid at 32° entry angle: 15 Mt, trigger height 12 km

- Kinetic Energy (Mt)
- Internal Energy (Mt)
- Energy Deposition (Mt/km)
- Velocity (%)
- Momentum (%)
- Mass (%)

Trigger point = 12.0 km
Peak Edep = 8.1 km
50% Energy = 7.6 km
75% Energy = 6.1 km
Comparison between damage estimates: 15 Mt, 32°

Static burst at 50% Edep (G&D)

3D hydrocode

>1 psi
>2 psi
>4 psi
>10 psi
Conclusions: Effective Height of Burst

A valid/useful concept?

Yes, but it’s not that simple. There is no single effective HoB. A superposition of multiple HoB’s based on full energy deposition curve would be a more accurate heuristic.

An approximation that uses static burst at altitude at peak energy deposition (or 50% energy loss) may overestimate damage in some cases and underestimate it in others.

Recommendation:

Probabilistic asteroid impact risk model should be recalculated to account for this effect to determine if it makes a significant difference in the bottom line risk assessment.