Fragmented Asteroid Airburst Ground Effects

Custom C++ Code for shockwave and optical pulse modeling

Extremely promising
The Acoustical effects of these blasts are modeled using the Friedlander blast propagation equation:

\[ P = P_0 e^{-t/t_0} \left( 1 - \frac{t}{t_0} \right) \]

The Time Decay constant \((t_0)\) is extrapolated from nuclear data as a function of overpressure at any given location:

\[
t_0 \begin{cases} 
-0.07755 \ln(P_0) + 1.051 & P < 200 \text{ kPa} \\
0.01246 \ln(P_0) - 0.07758 & P > 200 \text{ kPa}
\end{cases}
\]

The Overpressures\((P_0)\) for any given location is calculated using the following equation:

\[
P_0 = p_n \left[ r(E_{ast-kt}/\epsilon) \right]^{-1/3} + p_f \left[ r(E_{ast-kt}/\epsilon) \right]^{-1/3}
\]

The Optical pulses are calculated for each fragment including atmospheric propagation for every path.

For the Acceptable Threshold we chose \(~2\text{ kPa}\) of acoustical pressure and \(~0.2 \text{ MJ/m}^2\). These values represent the average strength of commercial windows and the approximate energy at which grass catches fire.

Examples shown for 200 meter with 10 day prior and 800 meter with 60 day prior, both with 20 km/s. These are extremely aggressive intercepts. Longer time scale intercepts are always desired and have less ground effects. Mean fragment size is \(~10\text{ m}\). Smaller mean fragment sizes are even better and have less ground effects.
50m Asteroid in 1000 Fragments - Acoustical

Intercept = 1 days | Speed = 10 km/s | Angle of attack = 45° | Disruption = 1m/s | Density = 2.6 g/cc

Time since burst = 84.0 s | Time since first blast arrival = -5.0 s

Real-time pressure

Maximum pressure

Real-time pressure distribution

Real-time max/min pressure

Cumulative distribution w/ weighted avg = 570.87

Frequency

Pressure (Pa)

Time (s)

Pressure (Pa)
200m Asteroid in 10000 Fragments - Acoustical
Intercept = 10 days | Speed = 20 km/s | Angle of attack = 45° | Disruption = 1m/s | Density = 2.6 g/cc
Time since burst = 65.2 s | Time since first blast arrival = -5.0 s

Real-time pressure distribution
Real-time max/min pressure
Cumulative distribution w/ weighted avg = 1164.01
800m Asteroid in 500000 Fragments - Acoustical
Intercept = 60 days | Speed = 20 km/s | Angle of attack = 45° | Disruption = 1m/s | Density = 2.6 g/cc
Time since burst = 95.1 s | Time since first blast arrival = -5.0 s
800m in 500000 Fragments - Optical

Intercept = 60 days | Speed = 20 km/s | Angle of attack = 45° | Disruption = 1m/s | Density = 2.6 g/cc
Time since burst = -2.000 s

Optical Power Flux Distribution in W/m²

Optical Energy Flux Distribution in J/m²

Real-time power flux distribution

Real-time max power

Cumulative Distribution of the final energy
Conclusions

- Threat mitigation feasible with as little as 60 days intercept before impact for 800m and lower for smaller diameters.
- Pressures under 2 kPa and optical flux under 0.2 MJ/m$^2$.
- Little to no damage from threats as large as a kilometer, PDC 2023 threat (800m) can be managed with minimal ground effects with an intercept time > 60 days (1 m/s mean disruption speed)
- Note that the product of the intercept time and the mean disruption speed is the key metric as it sets the fragment cloud size. We choose a modest 1 m/s mean disruption speed in the models shown.