Low-altitude Airbursts and the Impact Threat

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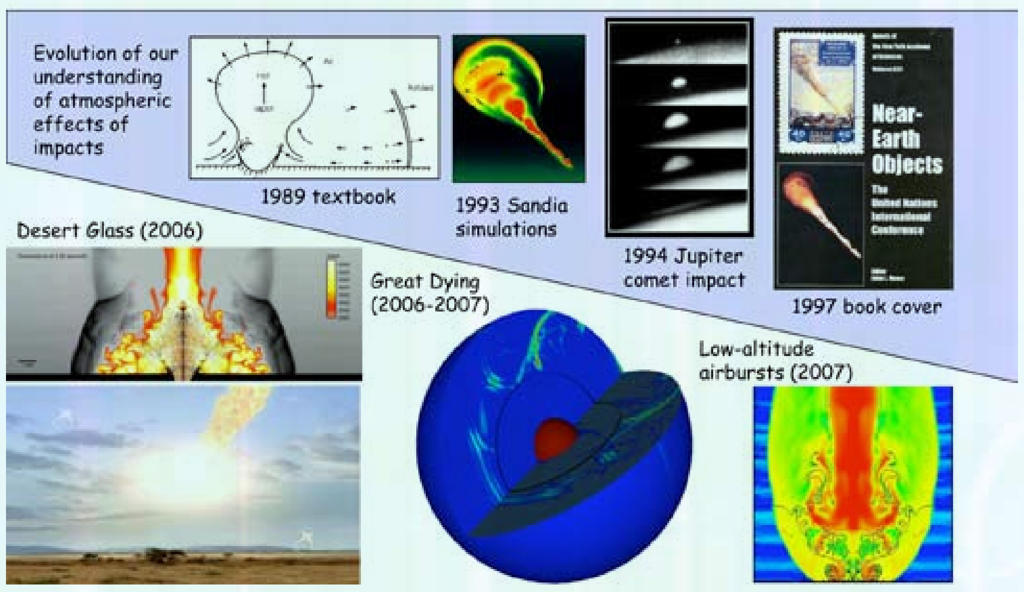
LDRD projects: Planetary impact physics

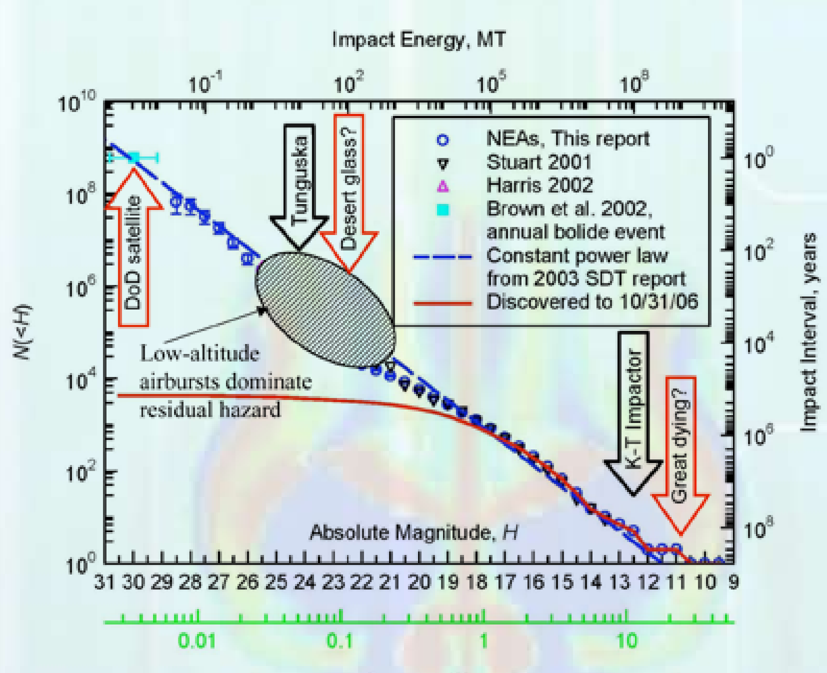
LDRD projects have made use of advanced supercomputing to discover emergent phenomena that were not anticipated from first-principles reasoning.



Low-altitude airbursts and the impact threat

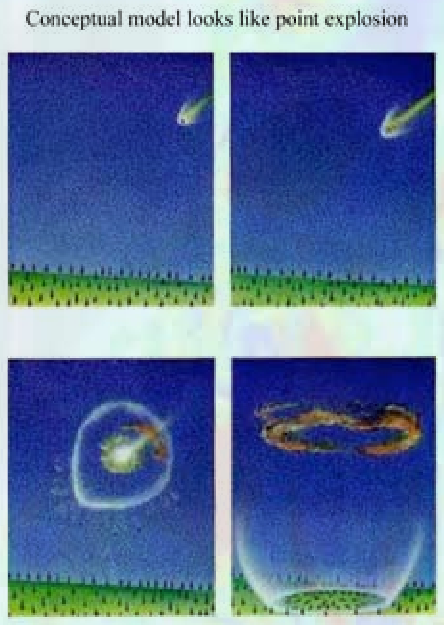
Problem: What is the nature of the threat due to explosions in the atmosphere? How can high-performance computing be applied?

This is the most recent in a series of small LDRD projects with a common theme: to make use of high-performance computing to advance the understanding of the physics of planetary impacts. There is a roughly power-law distribution of Near-Earth Objects (NEOs), which consist primarily of asteroids in orbits that cross the Earth's. The power law is remarkably constant over a size and time range spanning the few-kiloton events that are observed by DoD satellites every year, to the 100 million megaton catastrophe that wiped out the dinosaurs 65 million years ago. Alan Harris (Space Science Institute, and member of the NEO Science Definition Team) maintains the most current data on NEO populations. His graph shows that more than 90% of objects greater than 1 km in diameter — and a significant fraction of those greater than 500 m in diameter — have already been discovered. In 2005, NASA was given a mandate by Congress to discover and catalogue 90% of NEOs larger than 140 meters in diameter by 2020. The remaining threat will be dominated by objects that explode in the atmosphere as low-altitude airbursts. The purpose of this project is to characterize the nature of this residual hazard.

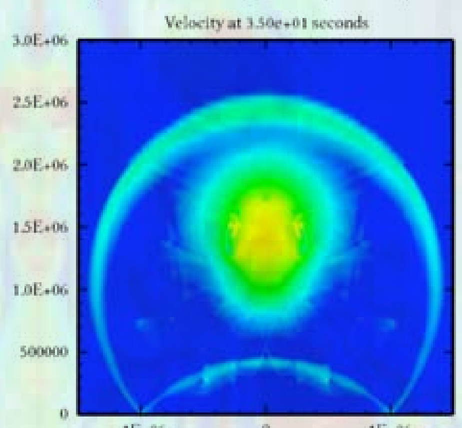


1908 Tunguska explosion: the canonical airburst event

Conceptual model looks like point explosion



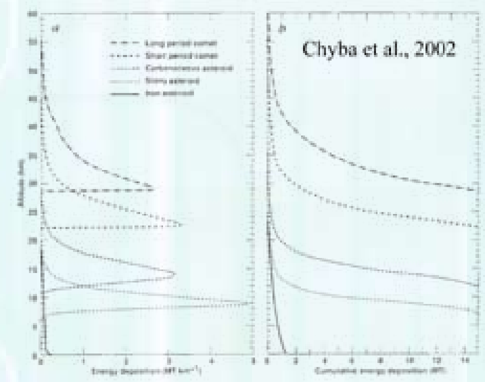
Conventional "point-source" model: 5 Megaton explosion at 10 km altitude. Hydrocode runs support simple concept.



After 35 seconds blast wave extends to 20-km diameter area.

Pancake Model: Earth's atmosphere protects us from low-altitude airbursts

In 1993, Chyba, Thomas & Zahnle published "The 1908 Tunguska explosion: atmospheric disruption of a stony asteroid" in Science. They attributed the event to a 10-20 Mt explosion at an altitude of about 10 km, based on a simple calculations involving ablation, aerodynamic drag, and mechanical deformation called the Pancake Model.

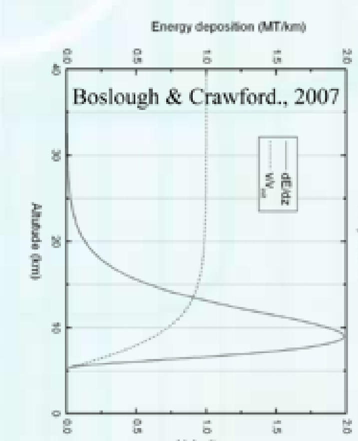


A stony asteroid in this scenario deposits essentially all of its kinetic energy above 7 km. The energy deposition curve is sharply peaked because of the mutually-reinforcing effects of atmospheric drag and deposition. Subsequent modeling has been based on point-source explosions and nuclear weapons effects. This has been the paradigm for the past 1.5 decades.

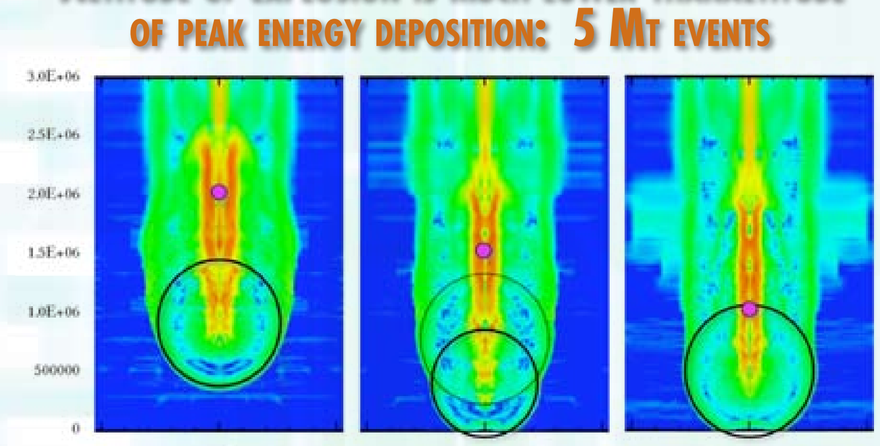
Pancake Model: Earth's atmosphere protects us from low-altitude airbursts

Approach: We perform high-resolution hydrocode simulations that do not make simplifying assumptions about energy deposition

Revisiting the pancake model demonstrates that at the altitude of maximum energy deposition, the asteroid still has most of its mass and more than half of its initial velocity. When it explodes its mass is converted to a hot vapor jet which continues downward at hypervelocity. The "point source explosion" model is therefore a poor approximation.



Altitude of explosion is much lower thanaltitude of peak energy deposition: 5 Mt events



20 km source 9 km explosion	15 km source 4 km explosion	10 km source 5 km explosion

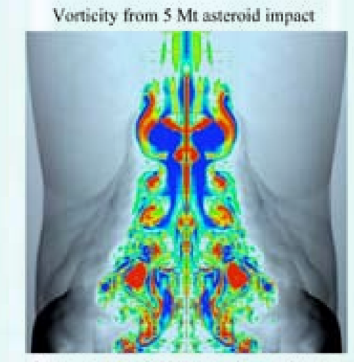
Results: Jet is carried downward by its momentum. Ring vortices from that "lubricate" flow by reducing drag coefficient

Airburst contribution to impact hazard

Significance: Surface damage from low-altitude airbursts is much greater than for nuclear explosion of same yield. These conclusions have already been incorporated into NASA white paper.

- Tunguska yield estimates of Chyba et al. may be too high by factor of 3-4.
- Tunguska-class events are more frequent, but less damaging than conventional estimates (because of yield over-estimate).
- Momentum coupling to atmosphere, solid earth and tsunami is higher because of plume ejection.
- Radiative coupling based on nuclear weapons effects literature is underestimated (impact fireball moves downward, nuclear fireball moves upward).
- Small cratering events are large airburst events with incandescent fireball in contact with surface over hundreds of square kilometers for tens of seconds. This may explain anomalous glass and glass-coated clasts in the geologic record.

Vorticity from 5 Mt asteroid impact



Large ring vortices reduce drag, enhance downward flow, and increase coupling of energy to surface of the Earth.

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