7th IAA Planetary Defense Conference – PDC 2021

ANALYSING AND EVALUATING THE POSSIBLE IMMEDIATE AND LONG-TERM HAZARDS OF ASTEROID IMPACT EFFECTS ON EARTH WITH VARIOUS CASE STUDIES OF EARTH'S GREATEST HITS.

Winfrey Paul Sagayam Dennis

Introduction: Asteroids are one of the most engrossing subjects when it comes to our aesthetic sky. These asteroids have even played the most crucial part in the geological and biological part of history. However, these Near-Earth asteroids are potentially hazardous ones that have caused the extinction of dinosaurs which are considered to be the largest and massive creatures of the Mesozoic Era. So, what if the adverse course of events happens again? [Ailor et al., 2013]. Will we be able to overcome the adverse situation? This argument prompts us to address the possible post-impact effect we will face if an asteroid collides with the earth. If an asteroid hit the earth, a huge amount of energy will be released causing shockwaves, earthquakes, tsunami, crater formation, and in the worst-case scenario, it can blow up the entire city causing the death of many living creatures. So, if we want to reduce the post-impact effects, we have to minimize the velocity and the size of the asteroid. Laws of physics play a crucial role in monitoring the asteroid's impact on the earth since the asteroid moving at a high speed will transfer the kinetic energy to the earth causing disastrous consequences. The focus of our work is analyzing the damage caused by the asteroid over people, buildings, and landscape in the vicinity of an impact event. The process included in the analysis is: impact energy, atmospheric entry, impact crater formation, ejecta deposition, seismic shaking, sound intensity, propagation of atmospheric blast wave. The analysis will be done based on the input parameters such as impactor size, impactor density, impactor velocity, impactor angle, and target density.

Description: Let's analyze the impact process and the related global consequences in short. The impact of a Near-earth asteroid on the earth commences when the impactor enters the slender upper atmosphere. Usually, the impactor will be propelled at a speed of between 11 and 72 km/sec. The impactor is usually made of rock (density is around 2000-3000 kg/m3) or iron(density is around 8000 kg/m3) and most likely to collide with the earth's atmosphere at the speed of 12-20 km/sec, in our work we are considering the impactor density to be 2000 kg/m3 and the impact velocity to be 15 km/sec with a probable impact angle of 45° . The target is considered as earth crust hence the target density is taken as 2200 kg/m3.

Impact energy: The basic quantity in evaluating the environmental consequences is the energy produced during the impact, here we are calculating the energy released before atmospheric entry. It is calculated by the formula

$E=mv^2/2=\Pi \rho L^3 v^2/12$

Where m=impactor mass

v=impactor velocity

ρ=Asteroid Density

L=Asteroid diameter

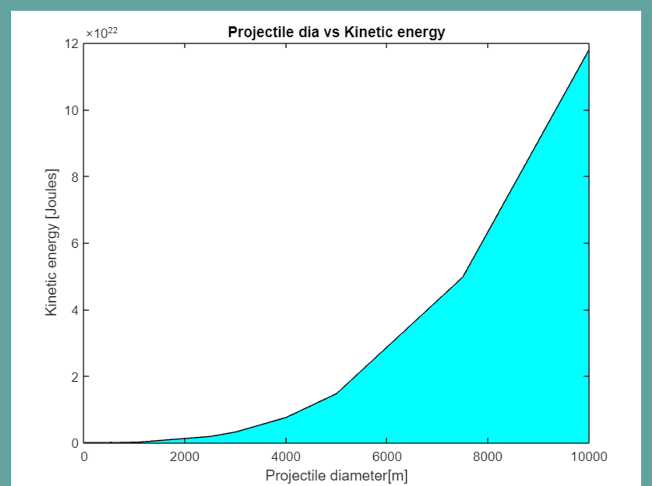

Figure 1: Kinetic energy vs Impactor size
It is clearly seen from the graph, larger the impactor size greater will be the energy produced during the impact.

The atmospheric entry of asteroids: Atmospheric entry is considered to the most complex process in rocket science, for the purposes of a simple program, we have considered that the atmospheric entry has no notable control on the shape, energy, or the momentum of the impacting asteroid with a mass that is much higher than the mass of the atmosphere replaced during penetration. For this grounds, the above-mentioned assumption is applied only for the asteroids that are less than 1 km in diameter.

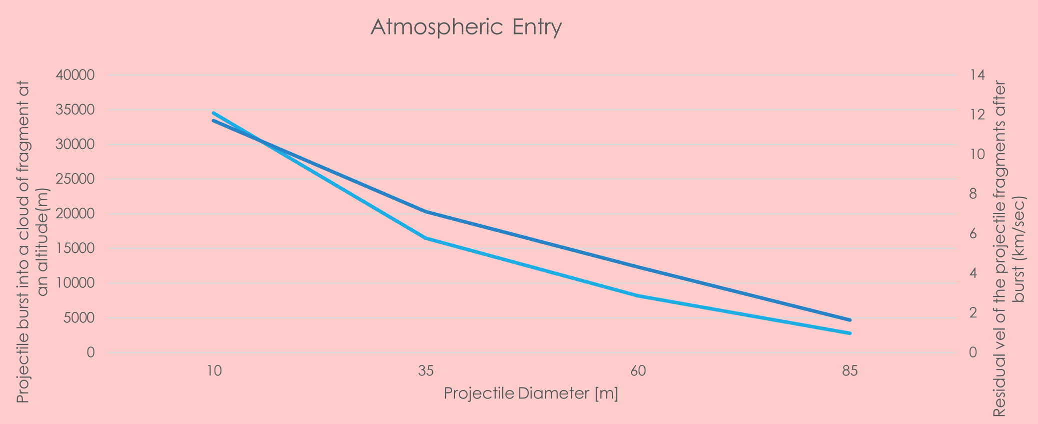

Figure 2: Projectile cloud burst and its residual velocity for smaller asteroids that enter the earth's atmosphere

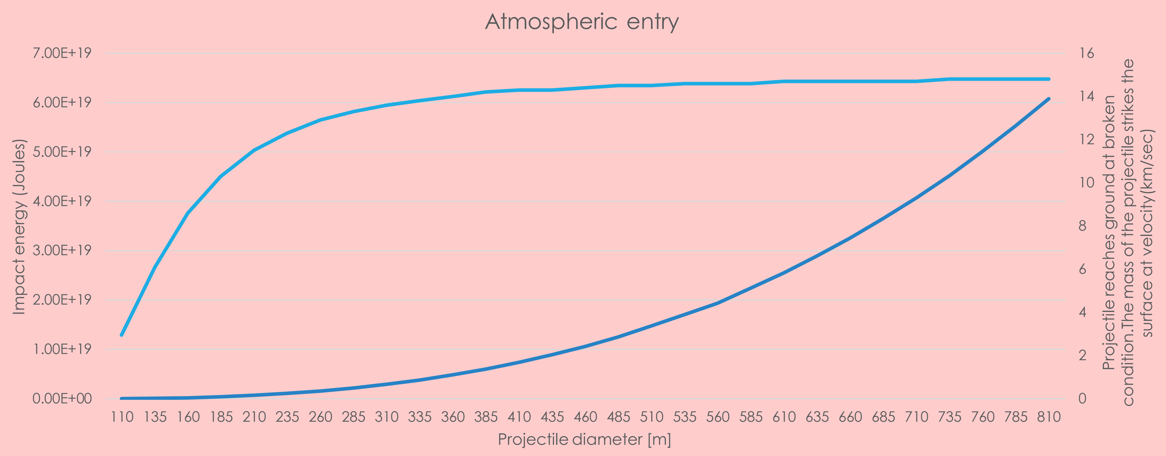

Figure 3: Impact energy and the velocity of the asteroid for larger asteroids that enter earth's atmosphere

Crater parameters: Impact crater formation: When the projectile diameter is large enough to enter the earth's atmosphere, the broken projectile fragment strikes the ground at a hypervelocity speed causing impact crater formation. Craters are nearly circular that doesn't mean that the impactors are circular in shape. The shape due to the projectile fragments flying out on all sides as an outcome of the outburst upon impact. Usually, the size and the shape of the craters depend on the impactor properties such as size and density of the asteroid, impact velocity, the angle at which impact occurs, the geology of the surface at which the impactor strikes. The greater the mass and the velocity of the asteroid, the larger will be the crater dimensions.

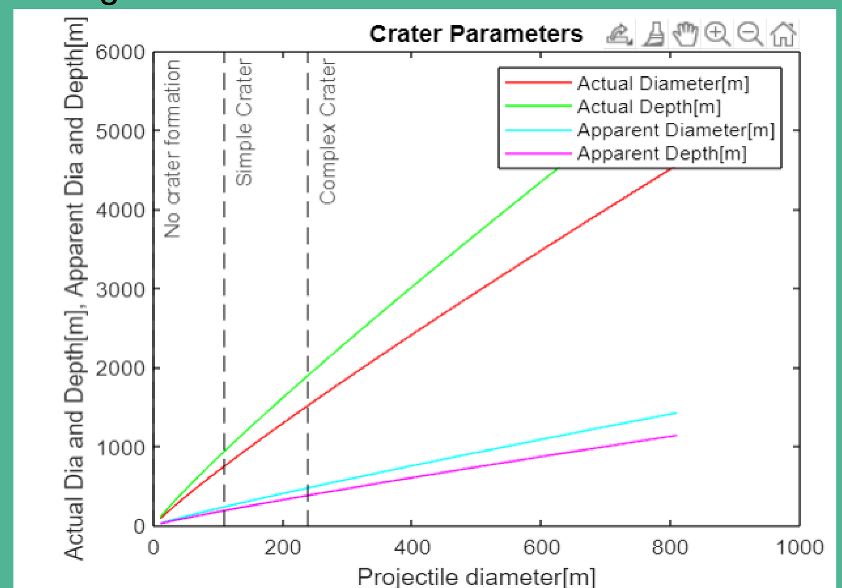

Figure 4: Crater Parameter

The above graph is generated by using the MATLAB software. Where the impact density is considered to be 2000kg/m³, impact velocity is 15 km/sec, impact angle 45°, and target density is 2200kg/m³. These graphs clearly show that increasing the projectile diameter results in larger crater dimensions. From the above graph we can interpret that for the projectile ranging from 0 – 90 m there is no crater formation, and for projectile ranging from 90-250 m the crater formed is a simple crater, and for projectile ranging from 250 and above the crater formed is a complex crater.

Ejecta: The average ejecta thickness(cm) and mean fragment diameter (cm) are calculated using the same input parameters mentioned above and it is plotted as a graph. The ejecta arrival time value for simple and complex crater is calculated as 18.5 min. Ejecta thickness is zero in case if there is no crater formation, and for the simple crater and complex crater the ejecta thickness increases with an increase in projectile diameter. Similarly, the mean fragment diameter is zero in case if there is no crater formation, and for the simple crater and complex crater, the mean fragment diameter increases exponentially with an increase in projectile diameter.

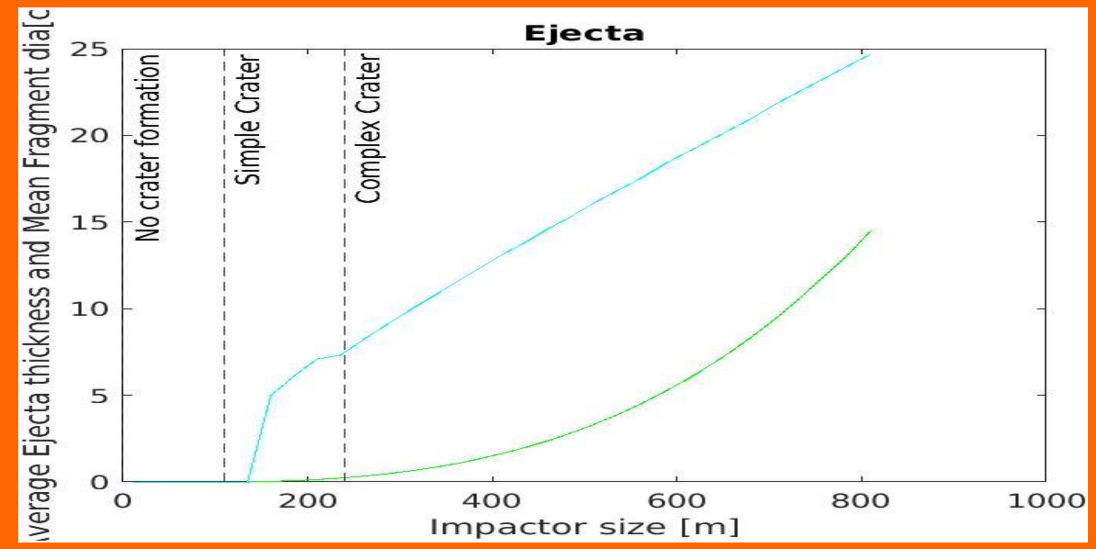

Figure 5: Ejecta thickness (cm) and mean fragment diameter (cm) vs Impactor size (m)

Seismic effects: After the projectile strikes the surface of the earth's crust, like ripples in the pond these seismic waves emit energy outward from the impact area in all directions. The shock wave originated by the impact expands and weakens as it disseminates through the target. It is calculated that the major seismic shaking will arrive approximately **12sec** after impact.

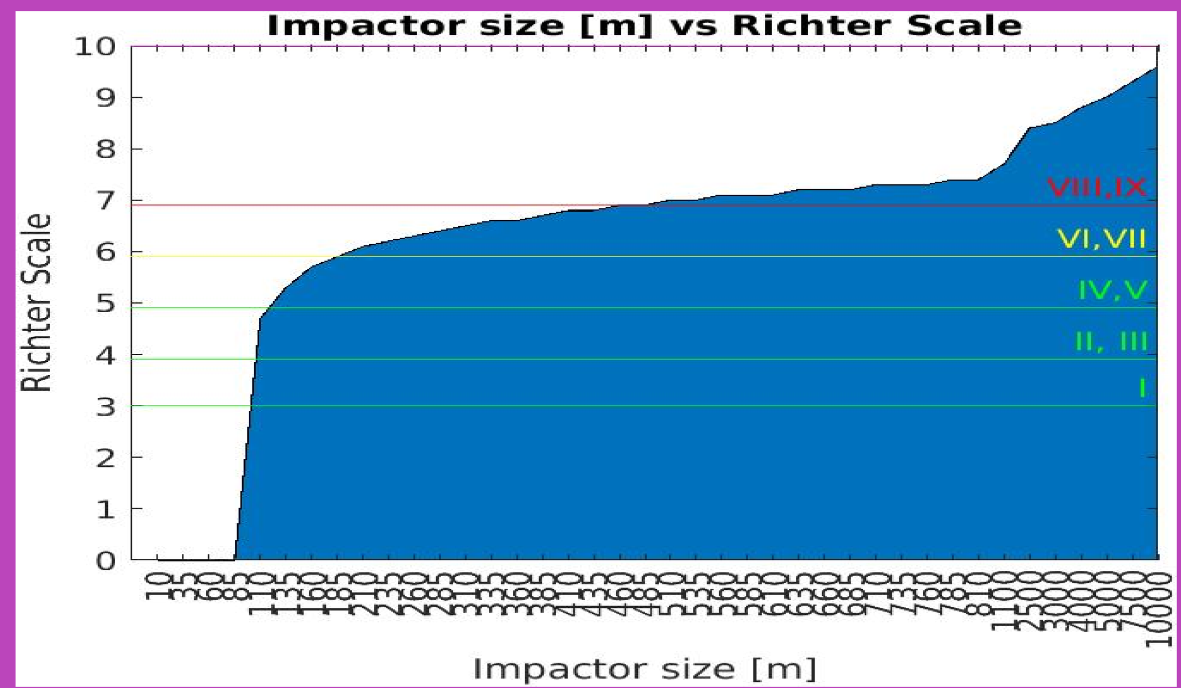

Figure 6: Richter Scale

Richter Magnitude	Modified Mercalli intensity	Earthquake effects
0-2	I	Not felt by people
2-3	II	Felt by little people
3-4	III	Ceiling lights swing
4-5	IV, V	Wall's crack
5-6	VI, VII	Furniture moves
6-7	VIII, IX	Some buildings collapse
7-8	X	Many buildings destroyed
8-Up	XI, XII	Total destruction of buildings, bridges and roads

Table1: Richter scale

Airblast: The energy due to the impact-induced shock wave in the atmosphere causes a distortion in the air which is generally known as air blast or blast wave. The intensity of the blast wave depends on the energy which is released during the impact and the break-up altitude which is either zero where a crater is formed or the burst altitude for airbursts[3]. This distortion propagates in the form of a wave. If the impact energy is very high, the wave may initially be a strong pressure wave known as a shock wave, moving at a velocity greater than the speed of sound in the air. Then the waves in due course slump.

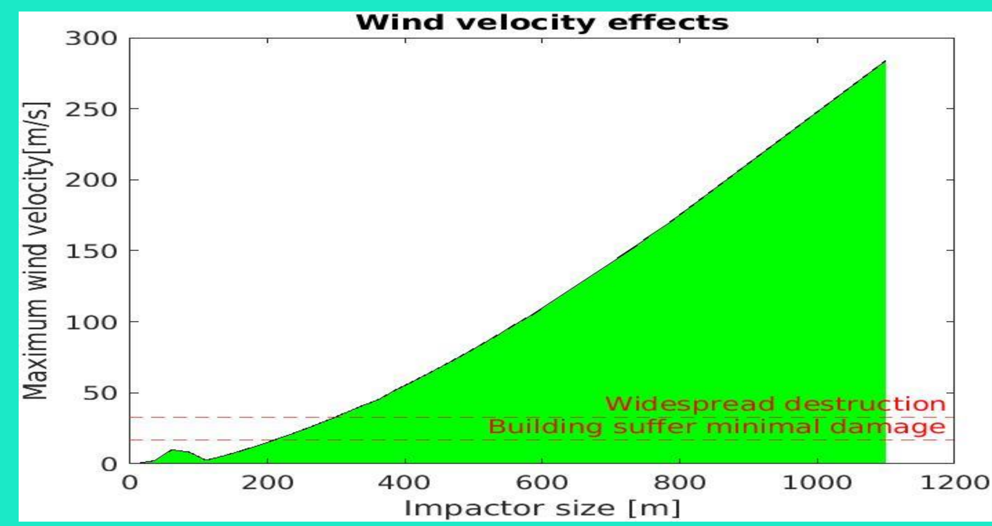

Figure 7: Wind velocity effects

Peak overpressure: For crater forming impact, in order to evaluate the peak overpressure, we presume that the shock wave generated in the air due to the impact is directly similar to that generated by an explosive detonated at the ground surface(surface burst). Peak overpressure is a measure of how much the pressure in the blast wave exceeds the atmospheric pressure of 105 Pa (1 bar). A huge deal of damage is caused for high peak overpressure.

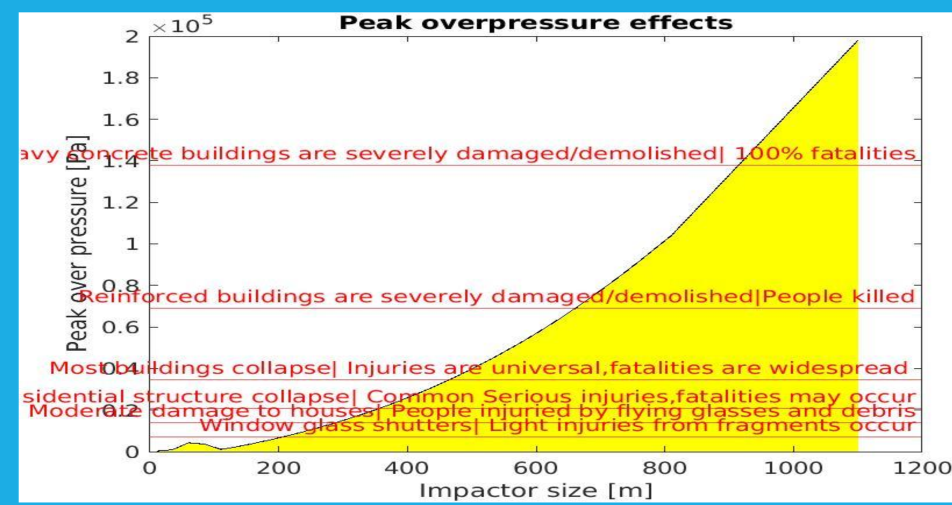

Figure 8: Peak overpressure effects

Sound intensity: From the above graph, we know that the sound pulse amplitude is directly proportional to that of the projectile size. The time mentioned here is the maximum time that is allowed for an average person to listen at the particular sound intensity, without any ear protection before the hear- drum gets permanently damaged.

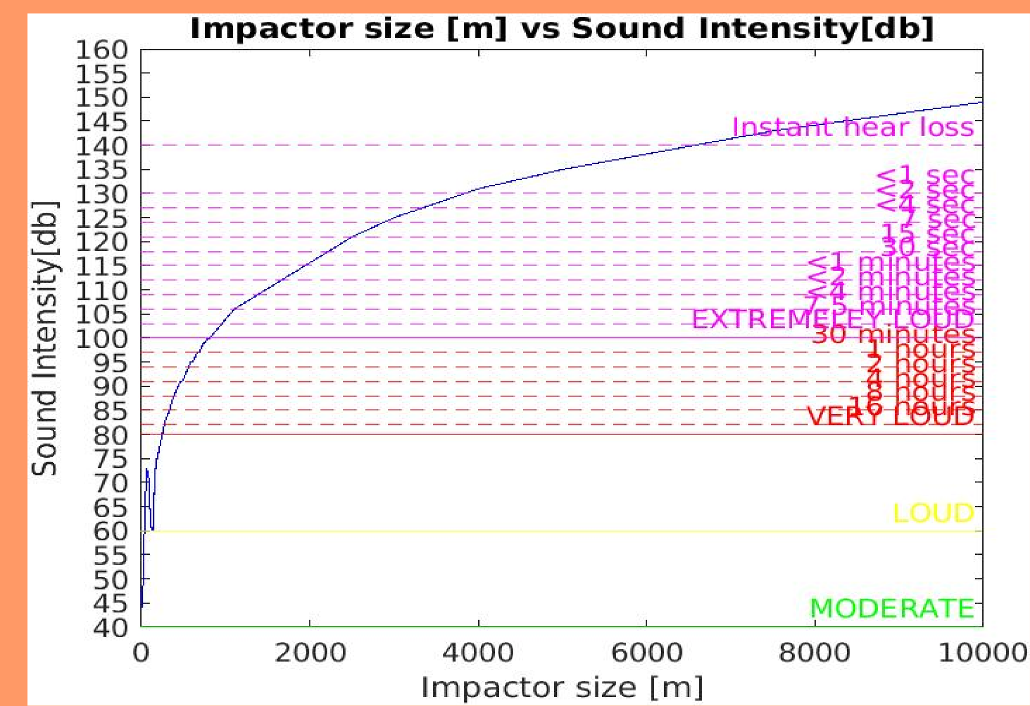

Figure 9: Sound pulse amplitude [db]