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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.

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ABSTRACT

From the early cretaceous – Paleogene era to the current Cenozoic era, the earth has been slammed by Near-Earth asteroids throughout its history, but we are lucky that no large ones have slammed into the planet lately. Even though astronomers with modern computerized techniques are vigilantly watching the skies hoping to spot the potential impactors far enough in advance so that we can safeguard our earth by doing something to keep away the impactors bombarding our earth, but still, there are some innocuous asteroids with few meters in diameter that can only be detected a few hours in advance when they are passing very close to our planet. But the vast majority of the time, they are plainly imperceptible. One of the significant cases are the Chelyabinsk impact. Moving on its orbit around the Sun, it approached us in the daylight sky - totally hidden in the Sun's glare. So far, only four impact events have been successfully forecasted in advance. Inevitably, experiencing sudden impacts like these come out of the blue is indubitably the norm, rather than a misfit! So, analyzing the asteroid thoroughly from every aspect is a crucial need. This paper focuses on doing a case study of the asteroids that have impacted the earth and by using the simulation software, a complete research evaluation will be done on possible immediate and long-term effects of the future impactors on our planet. The motive of the paper is to develop an iterative simulation technique that would predict the possible effect of future impact by analyzing the collected data from the previous asteroids that have hit the earth. That is by changing the parameters like size, velocity, angle of impact, the density of asteroids we will be evaluating the post-impact effect loss over the global, land, or the water concerning the impact scenario.

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

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

Where m=impactor mass

v=impactor velocity

ρ=Asteroid Density

L=Asteroid diameter

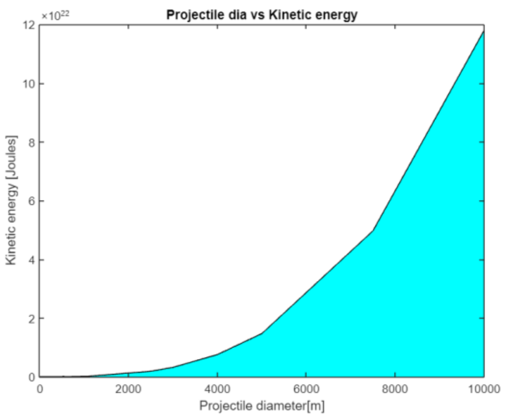

Figure 1: Kinetic energy vs Impactor size

It is clear 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.

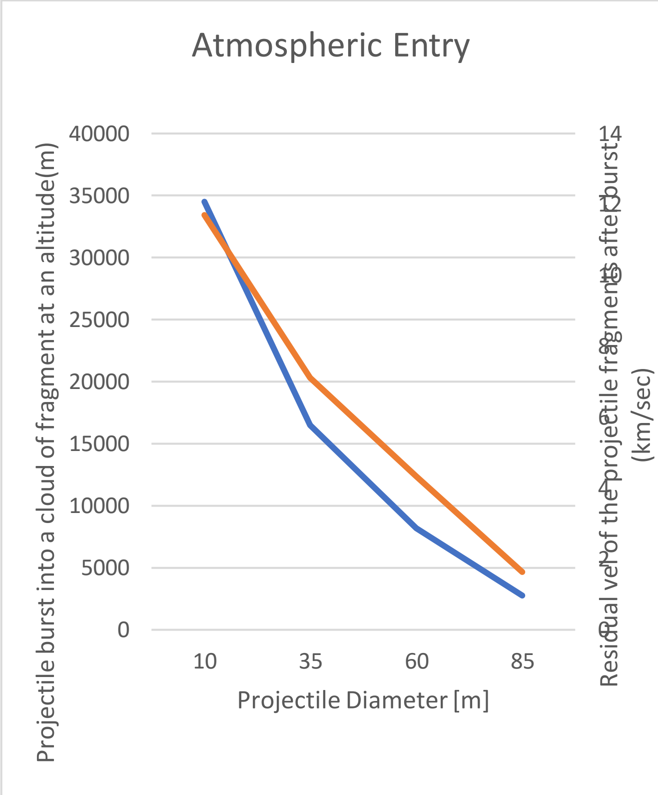

Figure 2: Projectile cloud burst and its residual velocity for smaller asteroids that enter the earth's atmosphere

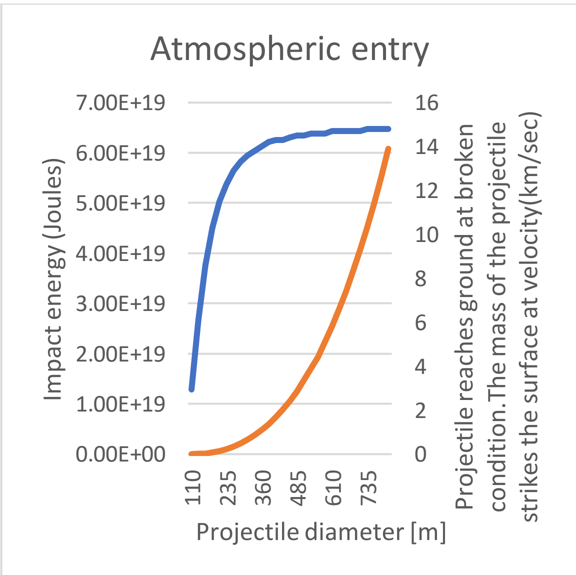

Figure 3: Impact energy and the velocity of the asteroid for larger asteroids that enter earth's atmosphere

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. Throughout history, there were millions of crater formations but those were wiped out by other geological processes such as weathering, tectonics, volcanic eruption, erosion that happened throughout a long period of time. 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. Usually, there are three types of craters: Simple crater- are small, bowl-shaped craters with smooth walls; complex crater- common characteristics are central peaks, stepped sides, central peaks, and multiple rings; Impact basins- are formed by craters larger than 300 km, since there isn't any record of asteroid strike as big as this, these types of craters are not found on earth. The leap from simple to complex craters depends on the target's gravity so it's different for each celestial body.

When an asteroid strikes the earth's crust, a shock wave disseminates from the spot of the impact. The shock wave breaks and ruptures the rock and cuts out a large crater (which is usually much larger than the impactor). The impact sprays material known as ejecta out in all directions. The impactor that has struck the earth's crust is shattered into small pieces and those fragments may melt or vaporize. Sometimes the impact energy is great enough to melt some of the native rock. If an impactor is huge, some of the material press down toward the rim of the crater will slump back toward the center and the rock underneath the crater will bounce back, leading to a central peak in a crater. The rim of these larger craters also may slump, creating terraces that stand down into the crater.

The major part of a crater is

1.Floor- Known as the bottom of the crater which is either bowl-shaped or flat.
2.Walls-The interior side of the crater, they are usually quite steep. When the wall collapses due to gravity, step-like areas may be created.
3.Rim- Above the level of the surrounding terrain. Also known as the edge of the crater
4.Central Peaks-They are formed in the high central area of the large crater.
5.Ejecta- During impact, a rock material is thrown out of a crater area known as ejecta. Generally, the ejecta is thickest near the crater and thinnest further away.
6.Rays- Bright steaks of ejecta extending away from the crater, just like rays of the sun.

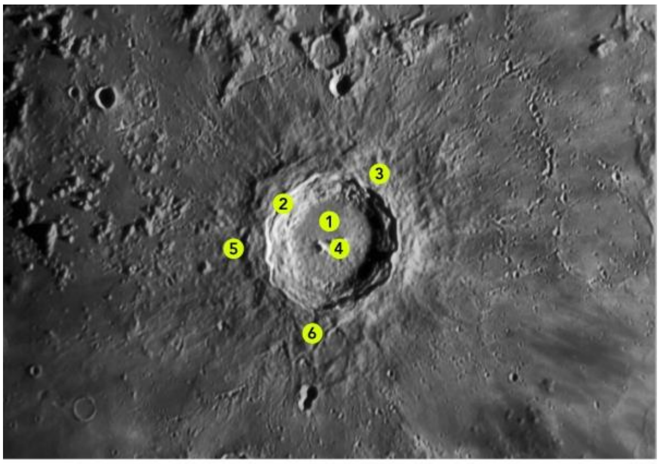

Figure4: Picture of a crater

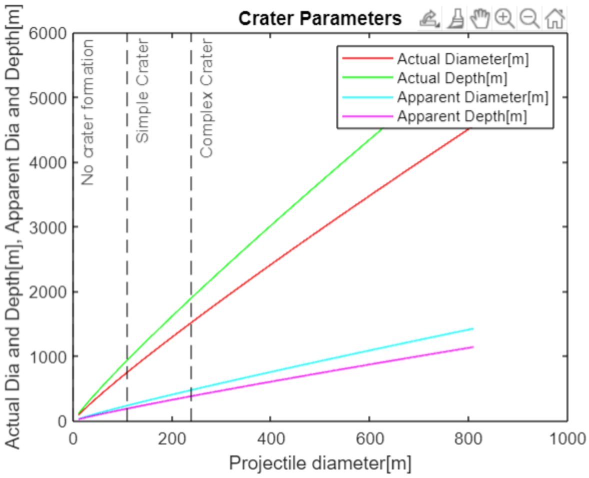

Figure 5: Crater Parameters

The above graph is generated by using the MATLAB software. Where the impact density is considered to be 2000kg/m^3, impact velocity is 15 km/sec, impact angle 45^o, and target density is 2200kg/m^3. 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**.**

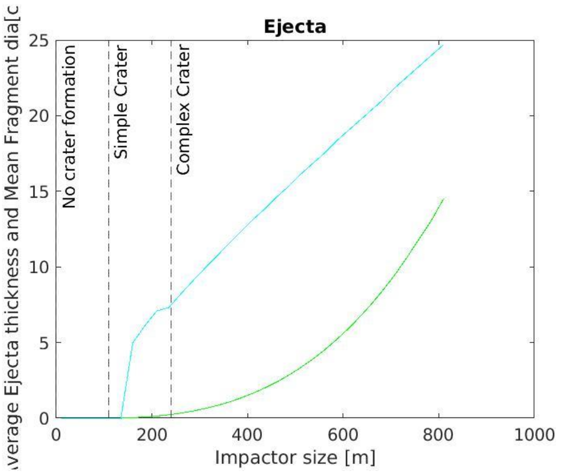

Figure 6: Ejecta thickness (cm) and mean fragment diameter (cm) vs Impactor size (m)

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.

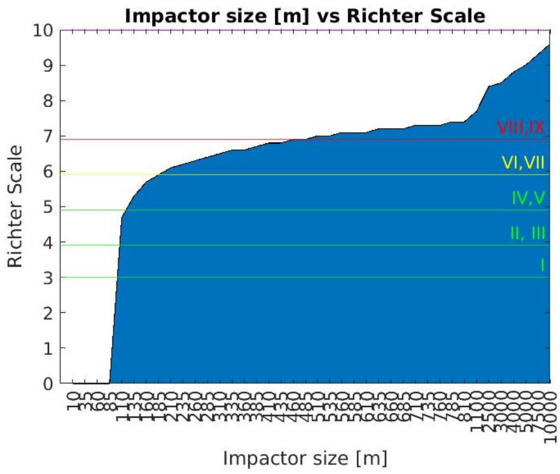

Figure 7: Richter Scale

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

Table 1: 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 into a sound wave.

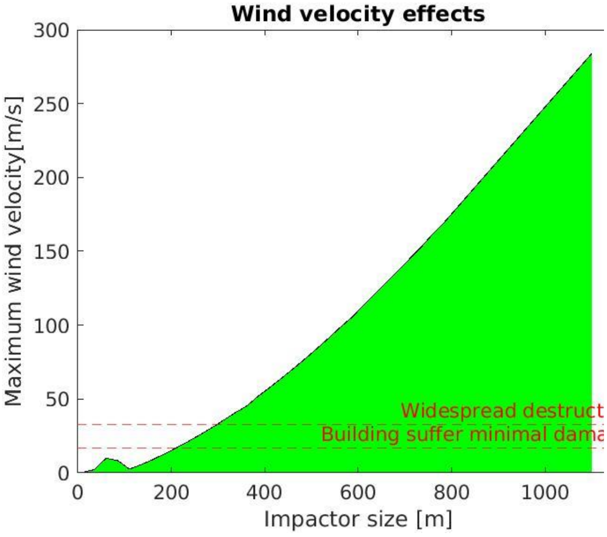

Figure 8: Wind velocity effects

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.

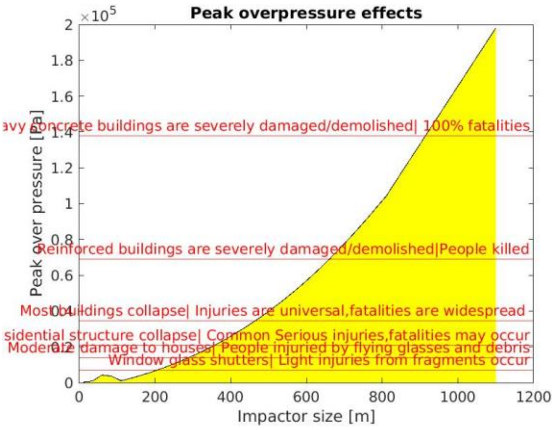

Figure 9: Peak overpressure effects

Sound Intensity:

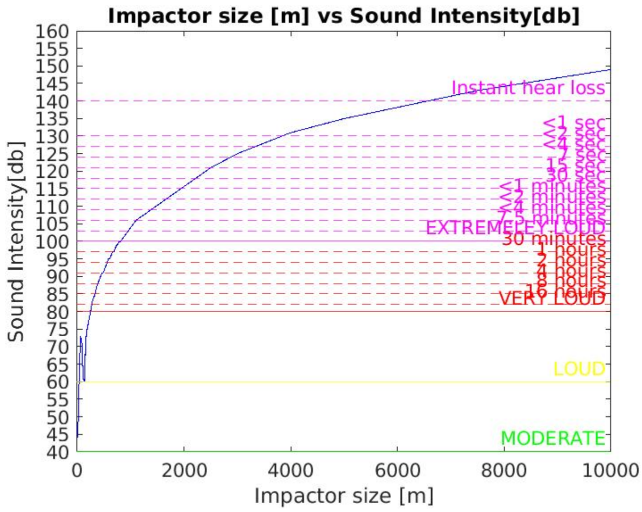

Figure 10: Sound pulse amplitude [db]

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.

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