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The Probability and Potential Consequences of Different Sized Asteroid Impacts.

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Introduction:

Asteroids pose a threat to Earth by potentially inflicting regional to global-scale destruction via impacts. Smaller asteroids can cause significant regional damage, whereas larger asteroids, particularly those above 1 kilometer in diameter, might trigger global climate changes and perhaps lead to mass extinction events. The threat posed by asteroids is a concern for the global populace. Any location on Earth is vulnerable to an impact event. Furthermore, asteroid impacts can produce enough energy to affect extensive regions around the impact site, potentially leading to global consequences and making all locations vulnerable. The asteroid threat is distinct among natural disasters as humanity has the capacity to prevent a forthcoming catastrophe through asteroid deflection. This capability was only realized during the space age. The notion was previously validated by the Deep Impact mission, which impacted with a comet in 2005. Given that asteroid deflection is a viable technology, humanity has an ethical obligation to advance and execute the requisite technologies and protocols for a deflection mission. International space organizations have recognized this commitment and are cooperating to achieve it. In 2013, the United Nations formally endorsed the establishment of the Space Mission Planning Advisory Group (SMPAG) to lead the global effort in formulating unified response protocols and capabilities for the future. Asteroid impacts present a danger to human populations. This study developed a method to assess the impact risk of hazardous asteroids, employing the overarching concept of risk, resulting in the Asteroid Risk Mitigation Optimization and Research (ARMOR) tool. This application facilitates the computation of the global spatial risk distribution of a hazardous asteroid, quantified in terms of projected fatalities. Understanding risk distribution enables disaster managers to prepare for a potential asteroid impact by pinpointing high-risk zones and measuring overall risk as a scalar value. Expressing the risk in terms of projected fatalities would facilitate the classification of the asteroid threat alongside other human dangers. This unit provides a definitive approach for determining thresholds for asteroid threat response protocols, articulating the threat using an innovative hazard scale, and allocating adequate resources to alleviate the hazard in comparison to other natural disasters. Risk estimation necessitated the development of vulnerability models that correlate the severity of impact effects (wind blast, overpressure shock, thermal radiation, cratering, seismic shaking, ejecta outthrow, and tsunami) on the human population, resulting in the creation and presentation of a novel comprehensive suite of these models. The need for high-fidelity impact effect and vulnerability modeling, as opposed to a simplified, impact location-based approach, for the risk assessment of a specific asteroid hazard was analyzed and confirmed. Subsequently, the ARMOR approach was used to asteroid 2015 RN35 to obtain a sample risk distribution output. Subsequent study reveals that the distribution of asteroid impact sites is approximately uniform, so corroborating a previously established hypothesis in planetary defense for the first time. Extensive global simulations were performed with an artificial sample of 50,000 impactors, each measuring up to 400 meters, to determine which impact effects present the most significant risk to human populations. Aerothermal effects present considerable dangers, although tsunamis contribute only moderately to the overall risk. The standard terrestrial impactor poses significantly greater danger than an equivalent ocean impactor, and asteroids measuring less than 50-60 meters (density = 3100 kg/m3) are expected to airburst rather than make contact with the surface. Furthermore, the average loss estimation for asteroid impactors enables swift threat evaluation of freshly detected asteroids and aids in determining the asteroid size that substantially contributes to the residual impact risk. These findings provide new insights to enhance readiness for a potential asteroid threat. In the future, ARMOR may enable the design of terrestrial, risk-based asteroid deflection missions, so gradually alleviating the threat posed by an approaching asteroid, a capability unattainable with current methods. During the formation of the Solar System, primordial gas and dust aggregated to form the planets and several smaller bodies referred to as asteroids. Daily, Earth encounters around 100 tons of these objects, suggesting that asteroid impacts occur more frequently than one might intuitively expect (Plane, 2012). The majority of these objects, measuring less than one meter in diameter, constitute the lesser end of the size range and produce just a captivating meteor during their passage through the atmosphere. In contrast, asteroids can reach sizes of several kilometers, and a collision with such an object would result in disastrous consequences for the Earth. While it is highly unlikely that a kilometer-sized impact event would transpire during the next century (Boslough, 2013a), Earth frequently encounters asteroids several meters in diameter (NASA, 2014b). These minor repercussions occur usually once or twice each year (Brown et al., 2002). Objects several meters in size can cause localized devastation when striking a populated region. The events at Tunguska (Boslough, 2013a) in 1908 and Chelyabinsk (Brown et al., 2013) in 2013 exemplify this type of impact. Asteroids can impact any region on Earth (Rumpf et al., 2016b), hence presenting a threat to the worldwide populace. Asteroid impacts are categorized as natural disasters; however, in contrast to other natural disasters, they can be accurately predicted and minimized through asteroid deflection, so rendering them non-events.

NASA's Asteroid Watch estimates the next five close passes (within ~4.6 million miles ~7.5 million km) include:

Name	**Size**	**Date**	**Distance from Earth**
2025 MC92	~29 ft	July 8	944,000 mi
2019 NW5	~200 ft	July 9	3.62 M mi
2019 JM	~44 ft	July 9	3.96 M mi
2025 MH90	~170 ft	July 10	4.61 M mi
2025 MD89	~120 ft	July 11	3.49 M mi

Additional noteworthy approaches this year included asteroids passing within ~0.05–0.3 lunar distances, such as **2025 FY6**, **2025 FV12**, **2025 MA**, and **2025 MB**, all safely distant but closely monitored

Why Asteroids Are Dangerous

1. High Impact Energy

What Does "High Impact Energy" Mean?

Asteroids, though often small in size, can travel through space at extremely high speeds — up to 72,000 km/h (45,000 mph). When one enters Earth's atmosphere and strikes the surface, its kinetic energy is converted into heat, shockwaves, and light, creating a powerful explosion. Even a 20-meter-wide asteroid can release the energy of several nuclear bombs without carrying any explosives — purely due to its speed and mass.

The Chelyabinsk Meteor – A Real-Life Example

On February 15, 2013, a 19-meter-wide meteor entered Earth's atmosphere over Chelyabinsk, Russia. It exploded in the sky at an altitude of about 30 km, creating a super bolide (a very bright fireball).

Key Facts:

- **Speed**: 18.6 km/s (67,000 km/h)
- **Energy Released**: ~470–500 kilotons of TNT (About 30 times the energy of the Hiroshima atomic bomb)
- **Injuries**: Over 1,500 people injured
- **Damage**: Thousands of buildings had windows shattered by the shockwave

Why It Was So Dangerous

1. Unexpected Shockwave

The meteor didn't strike the ground it exploded mid-air, creating a pressure wave that damaged windows and buildings across 6 cities. Flying glass from the shattered windows caused the majority of injuries.

2. No Prior Warning

The asteroid came from a direction near the Sun, making it invisible to telescopes. This shows how small asteroids can go undetected until impact.

3. Urban Proximity

Had it exploded closer to the ground, or over a densely populated city, the damage could have been far worse, potentially with many fatalities.

Mass Extinction Events

What Is a Mass Extinction Event?

A mass extinction event occurs when a large percentage of Earth's life forms disappear in a geologically short period of time. These events drastically change ecosystems and can wipe out dominant species.

How Are Asteroids Involved?

When a large asteroid (10+ km wide) strikes Earth, the consequences go far beyond the impact site. The explosion releases millions of times more energy than a nuclear bomb, triggering global-scale disasters:

- **Massive fires** across continents
- **Global dust clouds** blocking sunlight

- **Drastic climate change** ("impact winter")
- **Disruption of food chains**

Such an event leads to the collapse of ecosystems, both on land and in oceans, affecting nearly all life on Earth.

When Did an Asteroid Cause Major Destruction?

1. 66 million Years Ago – Dinosaur Extinction

- A 10–15 km wide asteroid hit Earth in what is now Chicxulub, Mexico.
- It caused:
    - A giant explosion (100 million megatons of TNT)
    - Global wildfires
    - Dust and ash that blocked sunlight
    - A drastic drop in temperature (impact winter)
- This led to the extinction of dinosaurs and 75% of all life on Earth.

2. 2013 – Chelyabinsk, Russia

- A 19-meter-wide meteor exploded in the sky.
- Released energy equal to 30+ atomic bombs.
- Over 1,500 people were injured by broken glass from the shockwave.
- No one died, but it was a warning sign.

Conclusion

Asteroids, though often ignored, pose a serious threat to life on Earth. Their high-speed impacts can release devastating amounts of energy enough to destroy cities, trigger tsunamis, or even cause mass extinctions. History has shown us, through events like the Chicxulub impact and the Chelyabinsk explosion, that even small or distant space objects can have global consequences. While major impacts are rare, the danger is real. That's why early detection, space research, and planetary defence missions are essential for protecting our future. Understanding asteroid risks helps us prepare better and possibly, one day, prevent a catastrophe.

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