Lunar Meteorite Impact Risks

A December 4, 2006 CNN.Com news story, based on the research by Bill Cooke, head of NASA's Meteoroid Environment Office suggests that one of the largest dangers to lunar explorers will be meteorite impacts. Between November 2005 and November 2006, Dr. Cooke's observations of lunar flashes (see image) found 12 of these events in a single year. The flashes were caused primarily by Leonid Meteors about 3-inches across, impacting with the equivalent energy of 150-300 pounds of TNT.

The diameter of the moon is 3,476 kilometers.

Problem 1: From the formula for the surface of a sphere, what is the area, in square kilometers, of the side of the moon facing Earth?

Problem 2: Although an actual impact only affects the few square meters within its immediate vicinity, we can define an impact zone area as the total area of the surface being struck, by the number of objects striking it. What was the average impact zone area for a single event?

Problem 3: Assuming the area is a square with a side length 'S', A) what is the length of the side of the impact area? B) What is the average distance between the centers of each impact area?

Problem 4: If the impacts happen randomly and uniformly in time, about what would be the time interval between impacts?

Problem 5: From the vantage point of an astronaut standing on the Moon, the horizon is about 3 kilometers away. How long would the lunar colony have to wait before it was likely to see an impact within its horizon area?

Problem 6: The lunar image shows that the impacts are not really random, but seem clustered into three groups. Each group covers an area about 700 kilometers on a side. What is the average impact zone area for four strikes per zone?

Problem 7: If you were an colony located in one of these three zones, what would be your answer to Problem 5?

Answer Key:

Problem 1: From the formula for the surface of a sphere, A) what is the area, in square kilometers, of the side of the moon facing Earth?

Answer: $2 \times 3.141 \times (1738\text{ km})^2 = 1.89 \times 10^7\text{ km}^2$

Problem 2: Answer: $1.89 \times 10^7\text{ km}^2 / 12 = 1.58 \times 10^6\text{ km}^2$

Problem 3: Assuming the area is a square with a side length 'S', A) what is the length of the side of the impact area? B) What is the average distance between the centers of each impact area?

Answer: A) $S = (1.58 \times 10^6\text{ km}^2)^{1/2}$ about 1,257 kilometers B) 1,257 kilometers.

Problem 4: If the impacts happen randomly and uniformly in time, about what would be the time interval between impacts?

Answer: 1 year / 12 impacts = One month.

Problem 5: From the vantage point of an astronaut standing on the Moon, the horizon is about 3 kilometers away. How long would the lunar colony have to wait before it was likely to see an impact within its horizon area?

Answer: 1 impact per 1.58×10^6 square kilometers per month. The area of the horizon region around the colony is about $\pi \times (3\text{km})^2 =$ 27 square kilometers. This area is $1.58 \times 10^6\text{ km}^2 / 27\text{ km}^2$ or about 60,000 times smaller that the average, monthly impact area. That suggests you will have to wait about 60,000 times longer than the time it takes for one impact or 60,000 months, which equals 5,000 years, assuming that the distribution of impacts is completely random, unbiased and has a uniform geographic distribution across the Moon's surface.

Problem 6: Answer: (700 km) x (700 km) / 4 = 1 impact per 122,500 km^2 zone area. Horizon area = 27 km^2, so the impact zone area is 122,500 / 27 = 4,500 times larger. You would need to wait about 4,500 x 1 month or 375 years for an impact to happen within your horizon.

<u>Note to Teacher:</u> This calculation assumes that the clustering of impacts is a real effect that persists over a long time. In fact, this is very unlikely, and it is more statistically probable that when thousands of impacts are plotted, a more uniform strike distribution will result. This is similar to the result of flipping a coin 12 times and getting a different outcome than half-Heads and half-Tails.