Aliens, Asteroids, and Astronomical Odds

Plane Crash or Asteroid: Which One Do You Worry About the Most?

Many people have a fear of flying. For some it is merely an emotional stress, while others rearrange their lives repeatedly to avoid airplane travel. The fact that most of these individuals have heard that flying is safer than driving on a per mile basis does not seem to provide comfort.

Scientists have recently drawn attention to the potential threat to Earth from a collision with an extraterrestrial object. The movie *Armageddon* made the public aware of this possibility. Yet it is safe to say that very few people worry that their life may be cut short due to an asteroid, comet, or meteor striking the Earth.

It's clearly unlikely that the average person will die *either* in an airplane crash *or* because of an untimely meeting with an extraterrestrial object. Data from the airline industry show that for domestic jet travel the risk of dying on a given flight is about one in seven million.

Quantifying the risk of being killed by an object hitting the Earth is more difficult. Astronomers Clark Chapman and David Morrison have made detailed calculations regarding the risks that such impacts may pose [2]. Casualties would obviously be dependent on the size of the object hitting the Earth and the resulting effects (localized or widespread damage, large scale floods and fires, climatic changes). By far the most likely way for a person to be a victim is if a very large object caused the demise of a large portion of the Earth's population. You are probably aware that the dinosaurs are generally believed to have fallen victim to just such an event.

Chapman and Morrison focus on impacts severe enough to kill at least 25% of the Earth's population. They assume that these events occur randomly in both location and time, independently of each other (i.e., their probability model is a *Poisson process*) with a frequency of one such event per 300,000 years. There is substantial astronomical and geological data that help them estimate this rate of calamitous impacts. It follows (you can check this yourself) that the chance of a randomly chosen human being killed in a given two month period is ... around one in seven million. Thus for an individual who makes six domestic flights per year (not uncommon), the odds of dying from a plane crash and from an extraterrestrial object are, surprisingly, about the same. For most people who fly, the two risks appear to be at least of the same order of magnitude.

The one in seven million risk is about the same as the probability of purchasing two or three tickets in a typical state lottery and winning the grand prize. Informing those afraid of flying of this fact doesn't tend to relieve their worries, because many fully expect to win the lottery some day! Much better is to point out that a person could theoretically fly six times a year for 300,000 years and only expect to be involved in one fatal crash.

Many scientists think that we *should* be concerned with the threat of a future impact from a celestial object striking the Earth, and ought to be putting resources into dealing with this hazard. Justifying this on the basis of a once-every-300,000-years possibility will not be a very effective way to do this. Comparing the odds to those of lotteries just might.

How To Find Out Good News (Perhaps) Without Finding Out Bad

Suppose a DNA test could tell you with absolute reliability whether you were carrying a gene associated with a fatal illness. Would you want to take the test? If the results came out negative, indicating that you did not possess the gene, you would certainly be glad that you took the test. But you might be emotionally devastated if you took the test and found out that you had the gene. This dilemma appeared recently in Marilyn vos Savant's column in Parade Magazine, an insert in many Sunday newspapers. Marilyn (listed in the Guinness Book of World Records Hall of Fame for "Highest IQ") suggested that one could take the test with the following arrangement: a positive (bad) result would not be revealed, while a negative result would be reported only if a coin toss showed, say, heads. Additional tosses could be made if desired.

Suppose that prior to taking the test there is a 1 in 10 chance that you have the gene. Your chance of finding out that you do not have the gene after one toss is

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$.9 \times .5 = .45$, so there is a close to even chance that you can live out your life without worrying about contracting the fatal illness. With more tosses, your chance of hearing good news will be even higher. See if you can write the general formula assuming n tosses are made.

Conversely, what is your chance of having the gene after taking the test and not learning the result after one coin toss? After two? Three? At what point would you conclude that you probably have the gene?

While I don't know if anyone has actually employed this procedure, a similar external probabilistic mechanism is sometimes used in surveys that contain questions of a personal and/or sensitive nature. For example: "Have you taken illegal drugs during the past twelve months? Toss a coin and answer truthfully if the coin comes up heads, answer 'No' if the coin turns up tails." It is then easy to estimate the percentage of the population surveyed who have taken illegal drugs during the past twelve months, without violating the confidentiality of the survey respondents.

Are We Alone?

Certainly one of the most intriguing and important still-unanswered questions is whether we are alone in the Universe. Author Amir Aczel contends [1] that the probability that intelligent life is present somewhere else in the Universe is virtually 1. His argument is based on the simple binomial probability model below:

Suppose that for each star in the Universe other than our own there is a certain probability p that intelligent life has originated and currently exists in a planetary system encircling that star. (We ignore the ambiguity regarding the concept of "currently" that arises from Einstein's Theory of Relativity for stars at great distances from Earth.) It seems reasonable to assume that the origination of intelligent life around one star is independent of whether it has originated near any other star. Thus if n is the number of stars in the Universe then the chance that intelligent life exists nowhere else than on Earth is $(1-p)^n$. Now n is known to be approximately of the order 10^{22}. Even if p is extremely small, the above expression will be close to 0.

Aczel claims a value for p of around 10^{-14}, in which case the probability that alien intelligent life does exist is $1-(1-10^{-14})^{10^{22}} = .9999\ldots$, a number beginning with approximately forty-three million 9's. Aczel's rationale for his choice of p is not convincing, and in actuality it is not within our current scientific capabilities to come up with a good estimate of p. Nevertheless the argument above implies that the odds in favor of intelligent life outside of our own planet are overwhelming unless the chances of such life around a randomly selected star are exceedingly small, specifically, less than 10^{-22} or so (do you see why?).

Several recent discoveries favor a "large" p rather than a small one, however. Specifically, the lifelike structures contained in the Martian meteorite found in Antarctica and the increasing number of probable nearby planetary systems that have been detected by astronomers both support a larger value of p than might previously have been conjectured.

As a fun exercise, you may wish to estimate the probability that we are not alone for the following values of p: 10^{-21}, 10^{-22}, 10^{-23}. You will probably not be able to do this directly on a hand calculator due to rounding error, so you will have to be a bit clever.

Pick 3—But Not Nines ...

The Arizona Lottery started a new game called "Pick 3" on May 3, 1998. In Pick 3, you choose three numbers from 0 to 9. Prizes are awarded according to how your numbers match the winning numbers. By June ninth, after 32 games, there were still no 9's in any of the 96 winning digits. A woman whose son was born on September 7 and who therefore always chose 9 0 7 called to complain that something must be wrong. She was assured that all was well, but then it was discovered that the company that supplied the random number generator had provided a program that omitted 9's!

About 1.2 million tickets with 9's had been sold during this period. Lottery officials agreed to refund the money of anyone who sent in their tickets. Since few people keep losing lottery tickets, this did not quell the storm. Therefore, from July 15 to July 31 lottery officials ran the same game but with all the prizes doubled. They also went back to the old-fashioned method of using numbered balls to determine the winning numbers.

Suppose you were a statistical consultant hired to oversee the Arizona lottery. What is the probability that, in $32 \times 3 = 96$ rolls of a ten-sided die, no 9 turns up? At what point would the absence of 9's make *you* suspicious? ■

Endnote

The source material for the stories above, as well as for parts of several previous Chance Encounters articles, was obtained from the Chance News website at Dartmouth College (`http://www.dartmouth.edu/~chance`). Many thanks to Professor J. Laurie Snell and his assistants and contributors for the use of these excellent features.

References

1. Amir Aczel, *Probability 1 — Why There Must Be Intelligent Life In The Universe,* Harcourt and Brace, 1998.
2. Clark R. Chapman and David Morrison, Impacts on the Earth by Asteroids and Comets: Assessing the Hazard, *Nature*, vol. 367, 1994, pp. 33–39.