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Apollo Asteroids: Promise and Peril
(Part Two of Two Parts)

The Threat: Global Disaster

The Apollo asteroids represent a resource to enhance life on Earth, but they also represent a remote, but very real threat to that same life.

These asteroids cross the orbit of Earth as they follow their own paths around the sun. Fortunately, due to the vastness of space and the wide variety of the asteroids' orbital inclinations, the odds of having an Apollo asteroid enter that tiny volume of space that is occupied by the Earth is exceedingly small.

The odds can be calculated by taking into consideration the estimated number of objects which approach Earth (which include not only the Apollo asteroids, but other objects in eccentric orbits such as comets and fragments from collisions between asteroids in the Main Belt between Mars and Jupiter) and the remnants of ancient craters on the Earth's surface. There are a considerable number of these scars (called by geologists "astroblemes") in a wide variety of sizes. Most are not obvious except to experts, due to the great age of a majority of them and the natural erosive processes peculiar to Earth which tend to obliterate their forms.

The Barringer, or Meteor Crater in Arizona is the result of a recent strike, less than 50,000 years ago. It was created by a rather small nickel-iron asteroid (or large meteorite) between 100 and 200 feet in diameter. The odds of a Barringer-sized asteroid striking the Earth in a given year are about 1 in 1,000. Looked at another way, it is statistically likely that one such strike will occur every 1,000 years. One of the most recent known strikes of this type is the Tunguska object, which flattened almost 3,000 square miles of pine forest in Siberia in 1908. No single, large crater was left in Siberia, possibly because the strike consisted of either a dense cloud of small meteors or a single, frangible carbonaceous-type meteor which exploded in the atmosphere before reaching the ground. Strikes by larger objects are, of course, more rare.

The odds of a 1/2 mile-diameter asteroid (an average size for asteroids) hitting the Earth in a given year range between 1 in 170,000 and 1 in 500,000. The odds of a relatively large asteroid (a mile or more in diameter) hitting the Earth in a given year are anywhere from 1 in 5 million to 1 in 1 billion.

These look like pretty safe odds, and seem to indicate that being hit by an asteroid is not worth worrying about. For the average individual, this is, of course, true. Little thought is given to the threat posed by nature in the form of an asteroid collision. On the other hand, considerable publicity has been given to the destructive effects of a nuclear war. Films, and studies by well-known scientists dwell extensively on the effects on Earth and its life forms of the detonation of the estimated 10,000 megatons of nuclear warheads comprising the world's nuclear arsenal. At present, most of the attention has concentrated on the "nuclear winter" that might result from the smoke and dust hurled into the atmosphere by nuclear explosions and the fires caused by them. Admittedly, the odds of a nuclear war breaking out may be higher than the odds of even a small asteroid hitting the Earth, and certainly are higher than the odds of a large asteroid strike. What then is wrong with ignoring these rocks in space entirely as far as their threatening aspect is concerned?

A disaster that is extremely unlikely is still worth serious concern when that disaster has the potential to be extremely destructive.

The destructiveness of an asteroid strike can be illustrated by a few calculations, and compared with the damage potential of nuclear weapons. From the first part of this article, we can estimate the mass of an asteroid given its approximate size. Another factor is the velocity with which the asteroid hits the Earth. Generally, the relative velocity between Earth and Earth-approaching objects runs somewhere between 20 and 70 kilometers per second (about 65,600 and 230,000 feet per second). For these calculations, I'll be conservative and assume our asteroids lope in at "only" 20 km./sec. The kinetic energy of the asteroid which is released upon collision can be calculated by simply applying the equation $e = 1/2\ mv^2$. In order to compare the asteroid strike more easily with a nuclear detonation, we can convert e into millions of tons of TNT, or megatons (1 megaton = 4.2×10^{15} joules).

Using these equations, the Barringer strike works out to approximately 45 megatons (other sources disagree, some placing the figure higher, others lower). The crater it left is over 4,000 feet across and 570 feet deep. The largest hydrogen weapon ever tested topped out at about 60 megatons. Not bad for a rather tiny asteroid.

Our "average" half-mile nickel-iron asteroid (the one we were mining in Part One of this article) should it strike the Earth, would do so with the power of nearly 104,000 megatons. This is over ten times the explosive power, in a single location, of every nuclear weapon on the face of the globe. The results would be about what you would expect. The impact would immediately produce an enormous, blinding fireball, blazing in the blue-violet range of the spectrum and beyond. A shock wave of heat and destructive force would radiate outward for miles at near sonic speeds, igniting forests and cities. The crust of the Earth would buckle, and gigantic earthquakes begin. If the strike is in the ocean (3 to 1 odds), waves as tall as buildings would inundate coastal areas thousands of miles from the strike zone. Finally, an all-encompassing cloud of dust and debris (and, in the case of a water strike, steam and water vapor) would spread outward, blotting out the sun. A "nuclear winter" would be trivial compared to the climatic effects of this "natural" phenomenon. The crater left behind would be over a dozen miles in diameter. And this is an average sized asteroid...there are larger ones in Earth-crossing orbits.

A strike from a medium-large Apollo asteroid, about 2 kilometers [1.24 miles] in diameter, would convert into destruction up to 1.6 million megatons of kinetic energy. Such an impact is hardly imaginable...on land or sea it would tear open the crust of the planet exposing the glowing magma beneath. The crater would be well over a hundred miles across. The planet Earth has taken such impacts in the past and survived--the Vredevoort Basin in South Africa was the result of such a collision ages ago. The same survival cannot be guaranteed for the life forms living on the Earth. Vast, and possibly permanent shocks to the ecology of the planet would be almost certain. Some have theorized that an "asteroid winter" created by a asteroid strike 65 million years ago may have contributed to the extinction of the dinosaurs. The phenomenon which led to this theory was an unusually large amount of iridium (a platinum-group metal more abundant in asteroids than in the Earth's crust) detected around the world in the geological strata corresponding to that period of time.

So, granting that these asteroid collisions are apocalyptic enough to merit some concern despite the odds against them, what can be done about it?

Problem One: spotting the danger. Only a small number of the larger Earth-crossing asteroids have been catalogued, and those have orbital paths that are none too certain. Perturbations from the planets can alter the orbit of any of these objects so that they don't show up where you expect them next time around. The asteroid Hermes, a chunk of iron and stone the size of Manhattan Island, sauntered past Earth in 1937 at a distance from Earth less than twice that of the moon--a very close shave as astronomical distances go. Hermes then promptly got lost. At this moment, no one knows exactly where it is. As far as the "smaller" chunks go, the Barringer-sized ones, the situation is even worse. They're by far the most common, and at present, the hardest to find. So, the first step is to find out where all the rocks are and where they're going...a sort of spacegoing "iceberg patrol" (there are people already working on this task--they will be discussed later in this article).

Problem Two: okay, we spot one, and it's headed straight for us. How do you stop three billion tons of rock? Systems envisioned to protect us from ballistic missiles would be useless. Trying to use a missile-defense laser or particle beam to break up an asteroid into chunks small enough to be harmless would be like trying to wear away an oncoming tank with a B-B gun.

Actually, the solution here is easier than it sounds. The objective is not to destroy the threatening asteroid, but merely to bump it enough off course to miss the Earth. The average half-mile asteroid could be deflected off a collision course by a strategically-placed 10-kiloton nuclear explosive...about half the power of the atomic bomb dropped on Hiroshima. The greatest course change could be accomplished with the least amount of energy while the asteroid is at perihelion--the point in its orbit where it is nearest to the sun. Obviously, this brings us back to step one: detecting the asteroid soon enough to prepare for it, and tracking it closely enough to be able to effectively deflect it.

It goes without saying that a mature asteroid mining technology would also be very useful in predicting and preventing asteroid strikes on Earth. Of major importance in solving Problem One would be the detailed surveys of the locations and orbits of near-Earth space objects which would, as a matter of course, be carried out as part of any mining endeavors. And, as far as Problem Two goes, any advanced propulsion technologies that would be useful in the exploitation of asteroid resources would also be useful in deflecting any Earth-threatening objects.

Without such widespread space-based technology, protecting the Earth from global disaster might be much more difficult. It would depend on spotting the threatening object from Earth observatories located at the bottom of the atmosphere, or from orbital scientific observatories which would (due to funding limitations) probably be fewer and more restricted in operation than profit-making mining survey observatories would be. Without advanced propulsion technologies, which are not likely to be developed except in response to the demand generated by exploitation of space resources (by no means restricted to asteroid mining), the response to any detected potential threat would also be limited. With no mature propulsion systems for moving large objects in space, some form of jury-rigged system would have to be rapidly developed to precisely deliver (and detonate) a nuclear device to deflect the asteroid. If the development process takes too long, civilization on Earth would be out of luck. Time and gravity wait on no schedule overruns.

There are some who might feel uncomfortable placing the safety of Earth in the hands of mining concerns, particularly if they are privately operated. After all, they say, such private concerns have no real Social Concience. These are the same people who are convinced that businessmen spend most of their time rubbing their hands together and chortling with glee as hazardous wastes and unsafe products destroy their customers. Even if space mining companies were the bastions of greed than these people visualize, it seems obvious that no rational business would stand by and watch an asteroid wipe out civilization if there was anything that could be done about it. Cavemen are not much of a market for platinum and cobalt.

Others point out that even granting that the mining companies behave rationally, that is no guarantee that everyone will. Terrorists might think nothing of deliberately guiding an asteroid into the Earth for their own reasons. However, this is not likely to be a major problem in the future. For one thing, terrorists aren't going to get hold of asteroid-moving technologies unless they are already widely available for mining or other purposes. This means, if they can start something, someone else is likely to be able to stop it--most likely the mining concerns who would have as much to lose as anyone else. In any case, it would normally take hundreds of times more energy to guide an asteroid onto a collision course with Earth than it would to deflect it away. The tiniest change in velocity can change a hit to a miss, but unless the asteroid is almost on course already, changing a miss to a hit requires a very large amount of delta-V.

It seems self-evident that exploiting the Earth-crossing asteroids and protecting us from them can go hand-in-hand. It may be possible to mount a space program specifically intended to guard Earth against potential collisions, but this would require vast expenditures on new technologies with no obvious return. Remember, the odds are very high against a major strike in any given year. How long could such an expenditure be credibly maintained if the threat does not materialize for years, or even decades? On the other hand, a profitable space mining operation would pay for its own technology development. Keeping one eye peeled for potential collision problems could be handled by such an operation at little or no extra expense. Meanwhile, the miners would be delivering vast resources to humanity. Which sounds like the better deal to you?

Present-Day Efforts To Locate Near-Earth Asteroids:

Currently, a few astronomers in scattered observatories are working on detecting and tracking Earth-approaching objects. Two major efforts stand out:

The Palomar Planet-Crossing Asteroid Survey (PCAS) is sponsored by NASA, The Planetary Society, and the World Space Foundation. This survey has to date located at least half of all the known near-Earth asteroids.

Eleanor F. Helin, a Planetary Scientist of the California Institute of Technology, along with a number of colleagues, uses telescopic cameras to record a given area of the night sky on film at different times. Later, the developed photos are carefully searched and compared for evidence that one of the tiny pinpoints of light in the sky has moved across the field of fixed stars, indicating the possible presence of an asteroid.

The cameras used are the 18-inch and 48-inch Schmidt telescopes at the Hale Observatory on Mount Palomar. They are capable of scanning wide areas of sky, and can locate asteroids with diameters in the half-mile range and larger.

Project Spacewatch is an effort sponsored by NASA, the University of Arizona at Tucson, and private donations. Spacewatch uses a different approach from the PCAS method of asteroid location.

Prof. Tom Gehrels of the University of Arizona, is working with his colleagues on perfecting an electronic asteroid locating system. Instead of Schmidt cameras and film, Spacewatch uses reflecting telescopes and solid-state light detectors called charge-coupled devices (CCDs). These CCDs detect faint light images and transfer them as electronic data to a computer, which handles the task of comparing different images to locate the movement that may indicate an asteroid. The present Spacewatch detector, which has been operating since early 1983, is installed in a 36-inch telescope at the Kitt Peak observatory. A newer system is under development, using better CCDs and a larger (72-inch) telescope.

The Spacewatch CCD system is capable of detecting fainter, faster-moving objects than the PCAS film system. A CCD-equipped Spacewatch telescope should be able to spot asteroids only about 100 feet in diameter. A CCD system is also faster, requiring less time to take a single shot of the sky than a photographic system.

However, the price of this increased speed and sensitivity is that the field of view that can be covered by the CCD camera in that single shot is much less than can be covered by the PCAS Schmidt cameras. The Schmidt cameras, using large film plates, can cover over 8,000 times as much sky area per exposure than the presently operating Spacewatch CCD camera.

<u>Under these circumstances, film based and electronic observational methods complement each other</u>, and both together are more useful than either alone. This has been recognized by the scientists involved, and there is a good deal of cooperation between PCAS and Spacewatch.

Although there is some government and institutional support for these projects, private donations (tax deductible) are welcomed.

The Palomar Survey can be directly supported by subscribing to the World Space Foundation's Asteroid Project. Write: Asteroid Project, D-118, World Space Foundation, P.O. Box Y, South Pasadena, CA, 91030. Subscriptions range from $25.00/year and up.

Project Spacewatch donations can be sent to: University of Arizona, Project Spacewatch, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, 85721.

<u>References and Recommended Reading</u>:

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Update: Man Vs. Black Box

<u>Space Shuttle astronauts attempted an unplanned satellite rescue during mission 51-D in April</u>. An $85 million Hughes Syncom satellite, the Navy's Leasat 3, <u>failed to follow</u> its flight program after being successfully ejected from the Shuttle

Discovery's cargo bay. Rather than unfolding its antenna, spinning up, and firing the rocket that would take it into geosynchronous transfer orbit, the satellite sat inert, slowly rotating, some distance from the Shuttle.

An unrehearsed and ingenious repair scheme was worked out and executed by personnel both aboard the Shuttle and back on Earth. The objective: trip an arming lever mounted on the satellite's exterior, suspected of having failed to move far enough upon ejection to switch on the power to the satellite.

The scheme involved a "flyswatter," built from wire, plastic report covers, and duct tape (that universal fixit material beloved of all engineers). Astronauts S. David Griggs and Jeffrey A. Hoffman suited up and entered the cargo bay to attach the flyswatter (along with two other handmade devices in case the flyswatter didn't work) to the end of Discovery's remote manipulator arm.

Astronaut Rhea Seddon would use the arm to brush these tools against the stuck switch as it rotated past on the slowly spinning satellite, hopefully actuating it and bringing the satellite to life. This method was deemed safer than simply having spacesuited astronauts go right out and flip the switch by hand. Unlike the satellites that were rescued on Shuttle mission 51-A (C.S.R., Dec. 1984, pp. 3-4), the Leasat still contained six tons of solid and liquid propellants, and no one was exactly sure what was wrong. Therefore, the satellite was approached in much the same way as one approaches a cherry bomb whose fuse has just gone out--very carefully.

Timing was critical. The satellite, if restarted, would fire its motor only 45 minutes later. The Shuttle would have to be far away by this time. In addition, the motor must fire only at a certain point in the satellite's orbit in order to place it on the correct trajectory. This meant there was a "window" only six minutes long during which the lever must be tripped.

Nevertheless, Seddon successfully struck the lever on the satellite several times with the flyswatter during the short time window, and succeeded in moving it.

Unfortunately, the satellite remained inert, indicating a problem more severe than the stuck lever. Still, despite the loss of the satellite (barring any future recovery mission), the rescue attempt succeeded in demonstrating, once again, the enormous flexibility in problem-solving provided by the presence of humans on the scene in space.

Whatever the problems with NASA, the Space Shuttle, and Shuttle marketing, the value of manned spaceflight itself is beyond question.

Until next time,

Tom Brosz

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