# DEALING WITH THE THREAT OF AN ASTEROID STRIKING THE EARTH

**An AIAA Position Paper**

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## SUMMARY

Hundreds, perhaps thousands, of asteroids travel in orbits that intersect the Earth's orbit. Some have struck the Earth in the past, leaving large craters. Others have come very close, one as recently as March 23, 1989 (Apollo Asteroid 1989FC, estimated to be a fifth to a half mile in diameter). Such an object, if it struck the Earth today, could cause a disaster of unprecedented proportions.

Although the probability of such an occurrence is very small, its consequences (i.e., the casualty rate) could be enormous. The risk to Earth's inhabitants is therefore finite, warranting action to improve and expand our ability to detect Earth-orbit-crossing objects and to analyze and predict their orbits. It would also be useful to explore methods and technologies for deflecting or destroying any such objects that are predicted to impact the Earth and to alter their orbits sufficiently to preclude impact.

To begin the process of implementing such action, appropriate experts, both civil and military, should be tasked to formulate specific programs designed to address the issues involved.

## INTRODUCTION

On March 23, 1989, an asteroid bigger than an aircraft carrier, traveling at 46,000 miles per hour, passed through Earth's orbit less than 400,000 miles away. Our planet had been at that point only six hours earlier. The asteroid was not detected until after it had passed. Had it struck the Earth, the energy released would have been equivalent to that of 1000 to 2500 megatons of TNT (or 1000-2500 one-megaton hydrogen bombs). In an area of high population density such as the northeast corridor of the U.S., Los Angeles, or Tokyo, millions of people would have died instantly.

The passing of this asteroid, named Apollo Asteroid 1989FC by its discoverers (Henry E. Holt and Norman G. Thomas of the University of Arizona), was not an isolated event. 1989FC is one of a class of objects which periodically cross the orbit of the Earth. The first object of this type was discovered in 1932 by Karl Reinmuth of Heidelberg Observatory.[1] It was in an orbit around the Sun that crossed the Earth's orbit, and was named "Apollo," after the Greek Sun god, because of its close approach to the Sun. (Most asteroids orbit the Sun at much greater distances, generally between the orbits of Mars and Jupiter). Subsequent discoveries revealed that a whole class of such objects exists, and that an object the size of the one which just missed the Earth in March, 1989, probably comes by undetected once every two or three years.[2]

Despite the potential for the havoc such an object would cause if it were to impact the Earth, no systematic searches for them were initiated until 1973, when He[in and Shoemaker[3] began a program called PCAS (Planet Crossing Asteroid Search) using the 18-inch and 48-inch telescopes on Palomar Mountain in California. A second survey, called PACS (the Palomar Asteroid and Comet Survey), was initiated in 1982 by Shoemaker.[4] Combined, the two surveys are credited with finding about half the 96 known Earth crossers. (The remainder were found serendipitously in the course of other work). However, this is just the tip of the iceberg: Shoemaker estimates that there are still more than 1000 additional asteroids with Earth crossing orbits having diameters of 1/2-mile or more which have not yet been discovered.[5]

## IMPLICATIONS

Although the next close approach of 1989FC in its near-annual Earth-orbit crossings will not occur until 2012, according to Helin,[6] we *do* need to be concerned about the estimated thousand or so other objects out there with diameters of 1/2-mile or more. We don't even know where these objects are. Like 1989FC, any one of them could strike the Earth without warning. Further, an object can be significantly smaller titan 1989FC and still cause considerable damage. For example, Meteor Crater in Arizona (Barringer Crater) was created when an object about 140 ft. in diameter impacted the Earth approximately 49,000 years ago. Delivering more energy than 15 megatons of TNT, the asteroid left a crater 4000 ft. in diameter and 700 ft. deep.

Because there are so many more of these smaller objects, they impact the Earth more frequently than most people realize. In 1908, for example, an object estimated to be 1/4th the size of 1989FC entered the Earth's atmosphere near the Tunguska River in Siberia.

That object actually exploded before it hit the ground and so did not dig a crater, but the explosion was so devastating that it leveled hundreds of square miles of forest.

On August 10, 1972, an object estimated to be upwards of 80 ft. in diameter entered the Earth's atmosphere.[7] It was detected by a satellite. Hundreds of eyewitnesses reported watching the object, which appeared to them as a large ball of fire as it traversed the sky in a northerly direction from Utah to Alberta, Canada before leaving the atmosphere. Had its orbit been minutely different, it could have struck the ground, perhaps somewhere in the vicinity of Utah, where it would have created a crater about a third of a mile across.

Some scientists have estimated that asteroids 10 miles in diameter probably strike the Earth every 50 to 100 million years.[8] Such an impact, striking with the force of about 100 million megatons of TNT (10,000 times more energy than the nuclear arsenals of the U.S. and the Soviet Union combined), would probably destroy life on Earth as we know it. It is argued that just such an impact occurred 65 million years ago and caused the extinction of the dinosaurs, along with up to 90% of the species on Earth at the time. Impacts from "small" bodies such as the 1908 and the 1972 objects occur much more frequently and would be as devastating as the immediate effects of large nuclear weapons.

Despite the low probability that a life-destroying asteroid impact will occur (in all recorded history no human has yet been killed by one), the fact is that the probability of such an event *is* finite, and should it occur the resulting disaster is likely to be without precedent. The average risk to an individual human (that is, the product of an extremely low probability of occurrence and the extremely high casualty rate should such an event actually occur) is estimated[8] to be comparable to that of an airplane trip. Hence, any action we can take to mitigate the effects on humanity of a possible future impact would appear to be worthwhile. Interestingly enough, we *do* have the technology needed to detect, track, and, if necessary, change the orbit of such an asteroid. Indeed, some experts believe it may even be possible to perform the much more difficult and dangerous feat of capturing an asteroid in either Earth or Lunar orbit and mining it for its potentially valuable resources.

Moreover, since the risk of danger from the impact of an asteroid is global, it is clearly in the best interests of all the world's nations to meet those risks collectively. This is a particularly good time to consider an international effort led jointly by the U.S. and the Soviet Union. Relations between the U.S. and the USSR have not been this cordial since the 1920s, and this program provides an excellent opportunity for the two superpowers to demonstrate leadership in an area of global concern. Further, the costs of defining such a program would be nominal, giving both sides the opportunity to build trust without having to make a large financial commitment. Finally, any implementation of an operable system able to deflect an asteroid could not proceed without at least the tacit approval of the Soviets, and probably of other nations as well.

## FINDINGS AND RECOMMENDATIONS

Earth-orbit-crossing asteroids clearly present a danger to the Earth and its inhabitants. Although no fatalities have yet been recorded as a consequence of such events, the impact of even a rather small object would have a devastating effect on humanity. Perhaps we have been lucky: since 1908 there have been one direct hit, one atmospheric entry, and at least two near misses. Hence, in view of the fact that we have the technology needed to detect and track such an object, and possibly to divert it from an impending impact, we would be derelict if we did nothing.

Therefore AIAA recommends that a systematic and open program be established to detect and define the orbits of Earth-crossing asteroids with a precision which will permit the prediction of impacts with some confidence. Although there are searches (such as those discussed above) being performed today, the small number of telescopes, constraints on available viewing time, and the scarcity of people capable of analyzing the observations limit the detection rate to about 10 to 20 asteroids a year. That rate is clearly insufficient.

Shoemaker, for example, suggests that the judicious placement of a few wide-aperture (about l-m), fast (F/1.5) Schmidt telescopes would speed up the search considerably. Military systems such as GEODDS (the Ground Based Electro-Optical Deep Space Detection System), suitably modified, may also be applicable.

Helin suggests that three or four more conventional telescopes could also be added in locations around the globe to supplement those already in place. The requirements for these telescopes have been defined in detail elsewhere,[9] but basically they would consist of conventional Schmidt telescopes similar to the 18-inch and 48-inch telescopes presently in use on Palomar Mountain. At a price of $2-3 million each, this would not be a major investment. It is perhaps even more important to make support available for research teams to man the telescopes. Conceivably, such support could be international in scope and would involve scientists from several nations. As part of the process for obtaining such support the entire subject should be openly and thoroughly debated.

The first step in creating a "search" program would be to define a specific action plan, including goals, objectives, schedules, budgets, and assignment of responsibilities. Such action would require input from both civil and military experts working in ail pertinent fields.

The AIAA recommends that a study also be performed to define systems which can deflect or destroy, or significantly alter the orbits of, asteroids predicted to impact the Earth. Much applicable technology exists in the technology base developed for U.S., Soviet, and other space programs, particularly the Strategic Defense Initiative (SDI). It would be necessary, however, to focus that technology on the problem of asteroid interception rather than ballistic missile interception, with the added requirement of being able to make the interception far enough from the Earth to prevent damage to its inhabitants. Since the systems needed might require the use of nuclear warheads, there would have to be international agreement on when an interception is needed. Ideally, of course, the effort would be international in scope, with all advanced nations participating and providing resources. Here, too, input would be needed from experts in all pertinent fields, drawn from those nations having such expertise.

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