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The History of AIAA's Interest in Planetary Defense

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by
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Abstract

On March 23, 1989, an asteroid passed within less than 400,000 miles of the earth, moving at over 46,000 miles per hour. Had it struck the earth, it would have detonated with an energy equivalent to over 1000 megatons of TNT, causing a disaster unprecedented in recorded history. The asteroid, Apollo Asteroid 1989FC, is one of a class of objects orbiting the sun with orbits that periodically cross the earth's orbit. Although the orbits of many of these objects are known, the orbit of 1989FC was not, and in fact, no one saw it coming. Had it struck, it would have hit without warning, a literal bolt out of the b e! The facts surrounding this event were so astounding that AIAA headquarters asked the Space Systems Technical Committee to look into the issue of Near Earth Objects, and determine if they really presented a threat to earth. The result was an AIAA position paper that set about to bring the reality of NEO's to the attention of the public and Congress. In this paper, we present the history of how the paper was developed, the fight to get it published, and the seemingly unending battle of the "giggle factor".

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 6 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."

This was the opening paragraph of the AIAA position paper entitled: "DEALING WITH THE THREAT OF AN ASTEROID STRIKING THE EARTH". The asteroid was one of a class of objects called Apollo Asteroids, so named because their orbits brought them closer to the sun than most asteroids, which orbit the sun in orbits confined between Mars and Jupiter. And, in fact, it had come at us from out of the sun, and had not been detected (by Henry E. Holt and Norman G. Thomas of the University of Arizona) until three weeks after it had passed. Had it hit us, we would have had virtually no warning. It most likely would have hit in the oceans of the earth, causing tsunamis of such proportions as to wipe out population centers with millions of inhabitants. Military surveillance systems in place and operated by the US Department of Defense at the time would have permitted us to piece together what happened after the fact, but that would have been of little comfort to the survivors. Johan Benson, Administrator of Public Policy at AIAA Headquarters at the time, asked the Space Systems Technical Committee (SSTC) to look into the matter, and, if appropriate, develop a position for the AIAA. As Vice Chair of the Space Systems Technical Committee (SSTC) at the time, it fell to me to examine the issue, and prepare what was to become a very controversial AIAA position paper.

The Search for "Truth"

I started with a literature search to seek out the status of Near-Earth-Asteroid research and find out who the key players were. I quickly discovered that there were only about a dozen serious searchers for such asteroids, and that really only about half that number were responsible for almost all of the discoveries to date. The key players were Caroline and Gene Shoemaker, then of the US Geological Survey; and Alan Harris, Elinor Helin, Steve Ostro, and Don Yeomans of JPL. Over half of all discoveries of NEO's to that time had been made by Helin and the Shoemakers, initially as a team and later, as separate investigators. David Morrison of NASA Ames and Clark Chapman, then of the Planetary Science Institute, had written a book intended for general audiences called ***Cosmic Catastrophes*** [1] assessing the potential hazards posed by NEO's. Tom Gehrels at the University of Arizona was still struggling to get his "SpaceWatch" telescope, with its revolutionary CCD array in the focal plane and its computerized asteroid detection software, operational at Kitt peak.

All of these people were contacted, and all helped me make sure that the paper was based on sound, scientific, fact. Gene Shoemaker not only carefully reviewed the paper, making numerous suggestions, but even made special computer runs for me so that the paper would have the latest number of Earth Crossers. Elinor Helin reviewed the paper, made numerous suggestions, and showed me "hands-on" in her laboratory at JPL how asteroid searches were conducted. Alan Harris taught me about the structure of these objects, or at least, what was thought at the time. In fact, the details of the structure for any specific object were and still are unknown; all that was known at the time was known from spectra taken from ground based telescopes. Don Yeomans taught me about details of how NEO orbits were determined from optical observations, how difficult it was to get precise orbits from optical measurements alone, and the importance of follow-up observations. I was amazed at how many NEO's had been found and then lost; Hermes, which, until 1989FC came along, had made the closest recorded approach to the Earth in 1937 (when it came within 0.005 AU of the Earth, the same as 1989FC) was promptly lost, and is now listed as "Very Lost" [2]. Steve Ostro showed me the value of radar, both for precisely determining the orbits of NEO's and for extricating details of the rotation rate, surface roughness and object shape. He was soon to get his first radar "images" of an NEO[3].

During this process I discovered that Shoemaker[4] had made careful estimates of the predicted impact rates of asteroids of various sizes. For asteroids with diameters of 1 kilometer or more (a size that could cause disaster on a global scale upon impact with the Earth), his estimates at the time (which have not changed much since), were that there were approximately 1500 to 2000 with orbits that cross the Earth's orbit, and that eventually a significant fraction of these would hit the earth. Of those, the orbits of less than 100 were known. This meant that what could be a deterministic problem was, because of our ignorance, reduced to a stochastic process. In other words, since we do not know the orbits of the preponderance of the really threatening objects, we have no idea of when they are going to impact.

Clark Chapman and I had many conversations about what all this meant. The problem, simply put, is that all of the estimates put the rate of really dangerous impacts at maybe once in a million years. If we knew the orbits of all of the threat objects, we could predict when the million years was up. Since we do not know the orbits, the million years could be up tomorrow, and we would never know it! Yet, every time I talked to people, even people supposedly knowledgeable in statistical processes, the statement would be made that "we would have plenty of time to prepare for an impact; after all, the really dangerous ones only happen once in a million years". (This discussion centers on asteroids and short period comets; long period comets are another matter altogether!).

The immediate problem was the rate of discovery. At the time, NEO's were being found at the rate of about 3 to 5 per year. At that rate, it was going to take about 300 to 500 years to find them all. During that time anything could happen. We were almost certain to experience 3 to 5 Tunguska like events. We could also experience the "one with our name on it", the 1 to 10 kilometer diameter object, the impact of which would almost certainly end the human race as we know it.

The longer range problem was, what do we do about it if we did somehow discover one with our name on it. Helin[5] related how she had discovered an NEO with an orbital error ellipsoid that included the Earth. In other words, until its orbit could be refined, there was a finite chance that it could hit the Earth. The warning time was short. She reported the find to Brian Marsden at the Minor Planet Center, and then everyone held their breath until the refinements showed that the object was, indeed, going to miss the Earth. In fact, it would have done little good to give notice to the Government of the possibility of an impending impact; there were then and still are no means in place to mitigate an impact if one is predicted to occur.

The Paper Takes Shape

From the foregoing, three things were clear.

First, the threat was real. These things are out there; they have orbits that cross ours, and that means that, ultimately, a significant fraction of them will hit the Earth. A large number of the objects are of such a size that they could trigger a "mass extinction" should they impact the Earth, with the human race being among the species annihilated.

Second, we were almost totally ignorant of where these things were. The rate of detection and the subsequent orbit determination of the potentially threatening objects was occurring at a glacial pace. Somehow, the rate of detection had to be dramatically increased.

Finally, no one had really done a systematic study of how we would cope with the threat of an impending impact. There were some studies, such as the senior engineering class project at MIT (which led to the movie "Meteor"). That study, motivated by the approach of Icarus in 1968, actually did a good job at defining the dynamics of such a situation. NASA had held a workshop at Snowmass, Colorado in 1981, pulling togeth" a first rate team of scientists to look at the situation, but apparently lost courage at the last minute and never published the final report.

So, the structure of the paper took shape.

Even though the probability of impact of a very large object is small, it is finite, and the consequences are so horrendous that the threat must be taken seriously.

To address the low rate of discovery of potential threats, we recommended that "a systematic and open program be established to detect and define the orbits of Earth-crossing asteroids with a precision that will permit the prediction of impacts with some confidence". The first step towards creating this program would be a workshop pulling together an international team of knowledgeable scientists and engineers to develop a specific action plan to define what would be needed to be done and estimates of the cost of carrying out the program in a reasonable time period. Applicable military technology, such as embodied in the Ground Based Electro-Optical Deep Space Detection and Tracking System (GEODDS) operated by the US Air Force, was to be included in the study.

What was to become the most controversial recommendation was that a study be performed to define systems that could be used to deflect or destroy an asteroid predicted to impact the Earth. Here, one not only needed an international team of knowledgeable scientists and engineers, but participation from the military community as well, since most of the technology needed to cope with such a threat would have been developed during the US Strategic Defense Initiative and it's Soviet counterpart.

Getting the Paper Approved

After the groundwork had been laid, the actual writing of the paper was relatively straight forward. Getting it approved was another matter!

The first obstacle was time; it was taking the SSTC up to two years to get a position paper approved. I felt that this was too long; by the time we would have the paper out, the event that motivated it would have been long forgotten. Because this paper had scientific as well as policy implications, after approval by the SSTC, it would have to be approved by both the Technical Activities Committee (TAC) and the Public Policy Committee before it could be submitted to the AIAA Board for final approval. Traditionally, after TC approval, papers were first sent through TAC, then to Public Policy, then back to TAC to make sure that changes by Public Policy were acceptable to TAC, then back to Public Policy to make sure no changes were made that were unacceptable to them, etc.. I elected to send the paper to both committees simultaneously. I then herded it through both, answering questions from one committee, making the changes they recommended, inserting those changes in the version submitted to the second committee when making changes they requested, etc. A concerted effort was needed to get SSTC approval, and then to get TAC and Public Policy approval of the paper in time for submission to the Board at the January 1990 Reno Board meeting.

At the board meeting, I am told that the "giggle factor" again raised its head. Several board members felt that it was not in the best interests of the AIAA to be involved in such a controversial, and to some, sensational, subject. To the credit of the Board, the final vote was 11 to 10 for approval. The paper set a new record for the shortest length of time to get a position paper approved: less than 6 months from the time of submission to the time of Board approval.

The paper was published in April 1990. It was to become the most often cited AIAA position paper ever. By early 1993, when the counting stopped, the paper had been cited over 2000 times! The previous record for citations was 200.

The Follow-Up

A major contributor to the success of the paper was the follow-up after publication.

Johan Benson sent copies of the paper to every US Congressman and Senator. He was instrumental in getting us appointments with several high-level government decision makers, to whom we presented the paper and the background detail surrounding its development.

One of these appointments was with Colonel (then Lt.Col.) S.P.Worden of the National Space Council. Col. Worden was an astronomer by training and immediately understood the implications of what we were presenting. He got the paper into the hands of the Vice President of the US, who endorsed the concept. (Worden was to become the Director of Technology for the Strategic Defense Initiative Office, in which position he was instrumental in helping me get previously classified Department of Defense data on detections of meteoroid impacts by space-based sensors released for publication. He also initiated and funded Clementine.)

Several briefings to top-level NASA people evinced interest but no action. Although NASA was providing some very small funding for NEO searches, they felt that there were other demands for their limited funds that more appropriately fit their charter.

Over the next year Benson gave several briefings to members of the US Congress, including one given to Congressman George Brown, who subsequently (in 1991) became Chairman of the Committee on Science, Space and Technology, a post from which he provided consistent support for the recommendations contained in the AIAA position paper.

The key briefing was to Dr. Terry Dawson, then a senior staffer on the Space Subcommittee of the House Committee on Science, Space and Technology. This subcommittee was responsible for authorizing NASA's annual budget, and Dawson got wording into the Committee Report that accompanied the 1991 NASA Authorization Bill that the Agency should sponsor the two workshops recommended in the AIAA position paper. NASA took the direction and assigned the task of organizing and chairing the detection workshop to David Morrison. The second workshop was chaired by John Rather of NASA Headquarters. The final reports[6,7] were published and presented to Congress in Hearings before the Space Subcommittee of the House Committee on Science, Space and Technology on March 24, 1993, just 4 years and one day after the near-miss of 1989FC.

Epilogue

The work continues. George Friedman of the SSTC has produced a follow-on to the 1990 position paper entitled *Responding to the Potential Threat of a Near-Earth-Object Impact.* This paper reinforces the conclusions of the earlier paper, and of great significance, it was not only published by the AIAA, but was endorsed by the IEEE's Aerospace and Electronics Systems Society, the National Council on Systems Engineering, and the Space Studies Institute. Quoting Dr. Friedman: **"If some day an asteroid does strike the Earth, killing not only the human race but millions of other species as well, and we could have prevented it but did not...., *then it will be the greatest abdication in all of human history* not to [have used] our gift of rational intellect and conscience to shepherd our own survival, and that of all life on Earth."** (Italics added.)

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2. Marsden, B. G. and Williams, G. V. (1994) Earth Crossing Asteroids. In *Hazards Due to Comets and Asteroids* (T. Gehrels, Ed), PP 1233-1238, University of Arizona Press, Tucson.

3. Hudson, R. S., and Ostro, S. J. (1994) Shape of Asteroid 4769 Castalia (1989PB) from Inversion of Radar Images. *Science* 263:940-943.

4. Shoemaker, E. M. 1983. Asteroid and Comet Bombardment of the Earth. *Annual Review of Earth and Planetary Sciences.* 11:461-494.

5. Helin, E. F. (1993) Jet Propulsion Laboratory, Private Communication.

6. Morrison, D. ed. 1992. *The Spaceguard Survey: Report of the NASA International Near-Earth-Object Detection Workshop* (Pasadena: Jet Propulsion Laboratory).

7. Rather, J. D. G., Rahe, J. H., and Canavan, G., eds 1992. *Summary Report of the Near-Earth-Object Interception Workshop* (Washington, D. C.: NASA)