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Book Review

Near-Earth Objects: The United Nations International Conference

Edited by John L. Remo, Annals of the New York Academy of Sciences, Vol. 822, New York, 1997, 632 pp., $140.00

Compared with the many other threats to humanity—global warming, ozone-layer depletion, pollution, and pandemics, for example—the threat to the world's ecosystem from an asteroid or comet impact has been recognized relatively recently. This threat from near-Earth objects (NEOs), the set of asteroids and comets whose orbits intersect the orbit of the Earth, is perhaps most distinctive in that it couples the lowest annual likelihood of occurrence with far more devastating consequences than any other in human history or even in the history of mammalian life on Earth. In less than two decades, interdisciplinary advances in astronomy, geology, paleontology, and atmospheric physics have collected overwhelming evidence that the great reign of the dinosaurs on Earth ended abruptly 65 million years ago due to the impact of a large NEO on the northern Yucatan peninsula. Because all of humanity is at risk, several international conferences were held regarding this threat, culminating with a United Nations conference in New York City on April 24–26, 1995, which was also supported by NASA, Sandia Laboratories, the Museum of Natural History, the Explorers Club, and the Planetary Society. This excellent book, published as Volume 822 of the Annals of the New York Academy of Sciences, represents the proceedings of this conference.

Unfortunately, the impression of most of the world's population, including people in management and government, is that the risk to humanity from the NEO threat is insignificant because of its very low probability and that the evidence is based on the science fiction school of catastrophism rather than hard technical data. Accordingly, it is appropriate that the first two thirds of this volume is devoted to recent scientific advances and data that further establish the technical database for the reality of the NEO threat. For this effort, John Remo invited most of the authors of Tom Gehrel's monumental book *Hazards Due to Comets and Asteroids* (University of Arizona Press, 1994) to provide updates of their earlier work. In this reviewer's opinion, Remo's book, although substantially smaller, is a worthy successor to Gehrel's landmark work. The many papers are extremely detailed and scholarly yet quite readable by a broad audience used to modern, peer-reviewed scientific and technical journals. Several of the papers are augmented by color plates, which even the Gehrel book does not enjoy.

Of course, the first issue relates to our knowledge of the population of NEOs, their sizes, and their orbits. Readers should rest easily because the astronomical community has not yet observed a large NEO on a collision course with Earth. But not too easily: Fewer than 10% of the estimated 2000 NEOs larger than 1 km in diameter have been detected, and if the detection rates stay at the rates typical of the 1980s, it would take a century to get the catalog up to the 90% level. The first section of the book provides updates on NEO search programs by the worldwide leaders in the field, including Marsden, Steel, Helin, Canavan, and Remo himself. Contrary to the "clockwork universe" paradigm, obtaining precise orbit determinations is far more difficult than previously thought, and the chaotic, unstable nature of NEO orbits is treated by Yeomans et al. in great detail. The NEO search area has its disappointments: NASA's failure to accelerate NEO searches, the crippling of Duncan Steel's budget for the only significant program in the southern hemisphere, and of course the tragic death of Gene Shoemaker. These are partially balanced by two areas of recent cooperation between NASA and the U.S. Department of Defense that the book covers: The paper by Tagliaferri et al. describes how space-based sensors developed for military intelligence gathering have substantially augmented the ground-based telescopic NEO searches, and the paper by Helin et al. discusses the establishment of the Near-Earth Asteroid Tracking (NEAT) program, which combines the U.S. Air Force's Ground-Based Electro-Optical Deep Space Surveillance System (GEODSS) with new computer-aided, focal-plane arrays for the most effective NEO search capability in the world today.

The next logical issue to be addressed is the effect on humanity in terms of casualties and damage that an Earth impact by a large NEO would cause. The paper by Toon et al. summarizes impact extinction mechanisms based on the geological and paleontological record as well as recent studies in atmospheric physics and tsunami formation. Whereas the Earth's atmosphere protects us from NEOs smaller than 30 m, it is also the mechanism for NEOs greater than 1 km to circulate high-altitude opaque particulates around the world that prevent sunlight from reaching the surface. Worldwide agriculture would be devastated, and the millions of casualties due to shock, earthquakes, volcanoes, acid rain, and fire could jump to billions of casualties due to mass starvation. This is the view of an increasingly large majority of the scientific community—but not everyone. The paper by Keller, with the inflammatory phrase "No cause for concern" in its title, presents a minority view: that the dinosaurs were in decline before the impact and the NEO just aggravated the extinctions. Her displayed data concentrate on marine microfossils, not large land animals. Perhaps

the NEO impact was not the only cause of the extinction of the dinosaurs and two thirds of all species then living, but as a citizen of the Earth I feel that I have justifiable cause for concern if an object only a hundredth as massive as the one that struck the Yucatan can deliver the equivalent energy of 100,000 1-Mton nuclear bombs, destroy all agriculture for years, cause millions of casualties through shock and drowning and hundreds of millions more casualties through starvation, the slaughter of all animals—including whales and dolphins—for food, the institutionalization of cannibalism, the collapse of all of the world's infrastructures, and most assuredly the setting back of our fragile, highly interdependent civilization for a thousand years. Keller might not be concerned because humanity may not actually perish, but the spirited discussion following the paper presentation proved that the community of scientists in the audience were quite concerned indeed.

Given that a reasonable case has been made regarding the NEO threat's likelihood and consequence, the remaining one third of the book addresses issues associated with the threat's mitigation, such as the engineering, management, and policy aspects of beginning a planetary defense capability.

The AIAA has taken a high-priority interest in the engineering and management aspects of the NEO threat and has published two position papers on the subject approved by its Board of Directors. The first paper, in 1990, written by Ed Tagliaferri, then the Space Systems Technical Committee Chairman, was stimulated by the near miss of asteroid 1989FC with a *negative* warning time and strongly urged the establishment of two NEO workshops: one for the detection of the objects and the other for their interception. Stimulated by this paper, the U.S. Congress directed NASA to conduct these workshops, and the results were reported back in 1993, but no additional funding ensued. The second paper, in 1995, written by this reviewer, then AIAA's Chairman of Planetary Defense, was stimulated by the lack of a systems engineering focus and the continued lack of governmental priority and funding, as well as the additional "wake-up call" of the impact on Jupiter of Comet Shoemaker–Levy 9. This paper was also endorsed by the Institute of Electrical and Electronics Engineers, the International Council on Systems Engineering, and the Space Studies Institute in Princeton.

Two papers by Gertsch, Gertsch, and Remo address the material resources in near space as well as the practical aspects of mining and exploiting these resources. This work is crucially important because of the great expense of lifting mass from the Earth's surface into orbit. Because the many optimistic projections of dramatically decreasing these costs have not materialized, any space operation—including planetary defense—would be enormously aided if the materials required could be obtained in space itself, not at the bottom of a gravity well.

Sforza and Remo's paper on NEO mission dynamics provides a family of engineering trade studies on the propulsion and payload alternatives to achieve a spectrum of mission kinematics and timelines. Powell et al. make a strong case for the use of nuclear propulsion for NEO interaction missions, taking advantage of the millionfold advantage in energy density that the nuclear approach has over chemical propulsion. They urge increasing research and development budgets for this goal; regrettably, recent budgets have been severely diminished. A wide variety of methods to obtain momentum coupling to NEOs in support of interception missions is considered by Shafer et al., including lasers, kinetic energy impactors, and nuclear or conventional explosives. In all of these papers discussing engineering alternatives, the analyses were presented very clearly and professionally but only minor attention was given to a top-down systems approach that addressed questions such as the following: What is the range of NEO sizes to be addressed, and what is the required precision of orbit determination to allow the intercept missions to be deployed?

This last question also applies directly to Binzel's well-intentioned paper suggesting a "hazard index" for NEOs. His Fig. 1 is an excellent attempt to map a two-dimensional "risk space" as a function of collision probability and impact energy. However, this graph appears to indulge in the "double fantasy" that there will be sufficient time to develop a capable intercept system *after* a NEO is confirmed to be heading our way and that we will be able to generate high-confidence projections of probability of hit on Earth decades in advance. Not only are these fantasies far from our present capability, but we have not even defined the *path* to bring them to reality.

The final section is devoted to four papers by Gehrels, Carusi, Lala, and Haubold describing the increasing activity of the United Nations in astronomy in general and with specific issues of planetary defense. A. Carusi describes the working group on NEOs established within the International Astronomical Union, and Tom Gehrels, the primary developer of the advanced technology methods to accelerate NEO detection rates, argues that a substantial increase in the U.N.'s support of planetary defense would be an excellent investment for the safety of all humanity.

In summary, this book is a worthy addition to the planetary defense literature and should be in the libraries of scientists, engineers, managers, government executives, educators, and the general informed public concerned with the future of humanity. John Remo is to be commended not only for organizing the conference and editing the book but also for his energetic efforts to bring an increased awareness about NEOs to the United Nations, including briefing the U.N. General Assembly and establishing NEOs on the agenda of the U.N. Committee on Peaceful Uses of Outer Space. It is hoped that there will be more U.N. conferences and books of this type in the future.

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