Eilene M. Galloway Symposium on Critical Issues in Space Law
The Near-Earth Object (NEO) Protocol

Russell L. Schweickart
Chairman, Association of Space Explorers Committee on Near-Earth Objects, 125 Red Hill Circle, Tiburon, CA 94920

Abstract: Near-Earth objects (NEOs) are being discovered at an accelerating rate in response to a Congressional directive in 1998 that NASA should discover 90% of all such object greater than 1 kilometer in diameter by 2008. The discovery rate is about to increase even more since Congress revised the goal in December 2005 calling for the discovery of 90% of all NEOs greater than 140 meters in diameter by 2020. This program is popularly known as the Spaceguard Survey. The discovery of over 4600 NEOs in the past eight years, 713 of which are greater than 1 km in diameter has been very impressive. Nonetheless these numbers will be dwarfed by the anticipated discovery of over 400,000 NEOs, of which approximately 40,000 will exceed the 140 meter diameter goal at the completion of the revised program.

Based on this very large anticipated database of NEOs and on the experience of the current program, it is certain that thousands of these NEOs will have at least a small probability of impacting Earth within the next 100 years. Of these thousands, perhaps dozens will have predicted impact probabilities high enough to warrant attention and potentially action. These specifics, in combination with the extant capability, with adequate advanced warning, to launch robotic space missions to deflect threatening NEOs will create a worldwide call for action to protect the public from the potential devastation of an unimpeded impact.

Given the inherent international nature of the NEO threat and the inevitable shifting of risk between nations in the process of deflection, the United Nations will have to be prepared to make, in a time constrained environment, a series of complex and vital decisions to assure that the world public is protected from a potentially devastating but preventable natural disaster.

Background:

The knowledge that the Earth has been subjected to impacts by asteroids and comets throughout its history has been known by astronomers and geologists for centuries. Public awareness of this reality became widespread during the last two decades of the 20th century due primarily to the claim by Alvarez, et al, in 1984 that the end-cretaceous mass extinction which eliminated the dinosaurs and approximately 75% of all species living at the time (65 million years ago) was caused by the impact of an asteroid or comet. Their claim was strongly reinforced with the discovery of the Chicxulub impact crater in the Yucatan Peninsula of Mexico in the mid 1980s.

In 1993, while conducting one of the first dedicated astronomical searches for Earth approaching asteroids, the team of Shoemaker, Shoemaker and Levy discovered a disrupted comet which subsequently, as predicted, crashed into Jupiter. This event, the impact of the Shoemaker-Levy 9 comet was watched in real time by dozens of major telescopes both on Earth and in space and made clear to the world that major impacts between asteroids and comets continue to occur.

Early Warning

In response to these and other developments the US Congress established what has come to be called the Spaceguard Survey, directing NASA to discover 90% of the NEO population greater than 1 kilometer in diameter by 2008. While this program has been making steady progress since its 1998 inception, the destructive power of the much larger population of objects down to diameters of 140 meters and below was called to the attention of Congress by many sources resulting in a revision of the Spaceguard Survey goal in December, 2005. In the FY2006 NASA Authorization Congress directed NASA to discover 90% of all NEOs with diameters of 140 meters and greater by 2020.

The challenge of meeting this far more ambitious goal is currently being addressed by NASA and the Congress and a plan to achieve it is under development. Regardless of the specific implementation details the NEO discovery rate will increase dramatically over the next decade effectively increasing the known population of NEOs from approximately 4,600 today to well over 400,000. This fact becomes a powerful driving force in the consideration of future public policy for protecting life and property from this cosmic natural hazard.

Whenever a NEO is discovered by the search telescopes it is intensively observed to determine its orbit as accurately as possible. Once an orbit is calculated it is projected forward in time for 100 years to determine whether or not, within the uncertainty of the observations, there exists an intersection (i.e. a collision possibility) with the Earth. Generally this is not the case; however of the 4600 NEOs discovered to date there are approximately 135 which do have some small probability of Earth impact. Of these one or two have been tracked over enough time that they bear watching.

When the revised search program reaches a comparable level of completion these numbers will rise dramatically with the "risk table" (i.e. those with some non-zero probability of impact) growing to the thousands of potential impactors. Of these there are likely to be as many as 100 which fall into the watchful category. Indeed some few may exhibit probabilities of impact that cause general concern.

It is this rapid increase in the anticipated discovery rate which recommends preparation today for the potential of finding one on which action may need to be taken. The essence of the search program is to make such a discovery decades prior to the projected date of impact.

Deflection/Mitigation

At the same time that NASA has been discovering, tracking and cataloging NEOs others have been concerned with and addressing the question of what can be done when one is discovered posing an unacceptable level of impact threat. While NASA and the University of Pisa (Italy) have regularly analyzed and reported the probability of impact (if any) for each discovered NEO over the next 100 years, they have not gone beyond this early warning analysis to address mitigation options should a potential impact rise to a significant level of concern. In large measure NASA's inaction in this regard is due to the lack of assigned responsibility for NEO impact mitigation and the consequent absence of budgetary authority.

In light of this deficiency in public policy several non-governmental organizations have addressed both the technical and policy aspects of NEO impact mitigation. Suffice to say here that the current assessment of the deflection challenge is that, using existing technology all but the most improbable fraction of the total threat (much less than 1%) can be diverted from impact.

The deflection technologies break several ways; impulsive vs. slow and nuclear vs. non-nuclear, being the primary descriptors.

Impulsive methodologies are those which provide a sudden, virtually instantaneous shove to the asteroid. The most obvious scheme is to simply run a spacecraft into the NEO, albeit in the correct direction. This capability was conceptually demonstrated in the July 4, 2005 Deep Impact mission where a US spacecraft impacted comet Tempel 1. While most NEOs of concern are considerably smaller than comet Tempel 1 the mission nevertheless demonstrated the intercept and impact capability.

Another impulsive technique employs a nuclear weapon or explosion on or nearby the asteroid to be deflected. The "favored" technique according to most proponents is a so-called stand-off blast wherein a neutron enhanced nuclear device explodes in the immediate proximity and proper direction from the NEO causing an instantaneous vaporization and explosion of the exposed surface off the asteroid. This departing high velocity surface material shoves the asteroid in the opposite direction as it flys off the asteroid surface.

A fascinating slow deflection technique employs the mutual gravitational attraction between an asteroid and a nearby spacecraft as a towrope. In this application a robotic spacecraft rendezvous with and positions itself immediately in front of (or behind) the asteroid and "hovers" there using very low thrust ion engines. Since the gravity tractor maintains its position in front of the asteroid the weak gravitational attraction between them effectively pulls the asteroid toward the spacecraft. While this technique is relatively weak it has the advantages of not having to touch the asteroid (which is presumably rotating or tumbling) and the spacecraft, with its radio transponder, provides to the Earth a continuous and precise current orbit for both itself and the asteroid.

This last characteristic points to a critical distinction between the impulsive and slow push techniques. While the impulsive methods have greater power (i.e. total impulse) than the gravity tractor (or slow techniques in general) both the kinetic impact and nuclear explosion produce highly uncertain results due to their unknown interaction with the asteroid and the variability of individual asteroids. Conversely the gravity tractor is relatively weak (although some deflections fall within its capability) but the deflection is precise and fully controlled. What appears to be of growing interest is the combination of a kinetic impact for the main push followed by the gravity tractor to precisely determine the result and "trim" the maneuver if required.

International Decision Making

While we can know that a NEO is probably headed for an impact and we have existing technology that can be used to deflect it from an impact, nothing will in fact happen unless a decision to act is made. Who will or should make such a decision?

One of the challenging characteristics of a NEO impact threat is that its probability of occurrence evolves over time and is never known perfectly. The orbit determination for a NEO is dependent (primarily) on optical tracking and as anyone with a technical background knows there is no such thing as a perfect measurement. Since all measurements have some small degree of error there is always an uncertainty in the precise position and velocity of an asteroid. This inherent uncertainty decreases as more measurements are made over time. Conversely even small uncertainties in our current knowledge of the position and velocity of the NEO propagate into much larger uncertainties as the position of the asteroid is projected forward to the time of potential impact.

It is therefore not unusual for an asteroid to require tracking for several years before the uncertainty in precisely where it will be at the time of anticipated impact is smaller than the dimensions of the Earth. In many cases what this will translate into is that a decision of whether or not to deflect a specific threatening NEO will have to be made while the uncertainty is still larger than the Earth. In other words, at the latest time a specific asteroid can be successfully deflected it may not be known whether or not it will actually impact Earth. Waiting for such certainty is not an option and a deflection mission may have to be mounted while the probability of impact is (for example) only 1 in 10, or less.

In such cases it will be unknown where on Earth the NEO will impact, or indeed if it will impact. In general the path of risk, the narrow corridor within which the asteroid will hit, if it is going to hit, extends fully across the entire planet. Therefore, at the latest time a decision to deflect must be made, there will be many nations across whose territory this path of risk traverses. For this, and many additional technical reasons, a NEO deflection decision is an international challenge and not that of any one nation.

Furthermore liability considerations will play a major role in any decision to divert an asteroid. The deflection of a threatening asteroid must either cause it to pass in front of the Earth at the time of impact or behind it rather than hitting it. As a consequence of this any deflection, if only partially successful, may have a new impact point on Earth somewhere along the path of risk in the direction toward which the deflection was targeted. Since by touching (i.e. changing the orbit of) the asteroid an act of God has been converted into an act of humankind the deflecting agent may be very seriously exposed to legal action by the impacted state. It is therefore highly unlikely that a nation state would assume such responsibility absent indemnification having been prearranged.

Since every nation on Earth is at risk of a NEO impact it is clear that international agreements with broad national inputs will have to be developed. However it is also clear in considering the timing requirements which may prevail at the time a threat matures that there is no time available for debate if a deflection is to be successfully executed.

In considering this very challenging international decision process the Association of Space Explorers (ASE) concluded that the international community would need to have in place a boilerplate agreement with specific decision thresholds and criteria such that when a threat materializes the specifics of the situation can be applied and an immediate (or timely) decision emerge.

An analog to the decision process the UN will confront in considering the NEO threat exists in the form of "Mission Rules" which have been developed prior to every human mission in the US space program. Mission rules are a set of codified procedures developed in the months and years before every mission which emerge from a process of considering each possible failure that can occur during that mission. The best response to many such failures is complex and highly debatable. Discussion and debate on these rules may go on for many months and require considerable research and simulation. However, once agreed to and documented they are available for immediate action if and when such failures occur during the mission. Many failures in a space mission demand rapid if not immediate response and month-long debates cannot be tolerated in real-time without jeopardizing the safety of the crew and success of the mission.

The development of an agreed set of thresholds, criteria, and obligations, as well as an agreement on indemnification and other legal instruments will be challenging to develop. Yet if a generalized decision-system is not developed prior to a specific threat arising, it is highly likely that a debate between the subset of nations threatened in a specific instance will be prolonged and acrimonious and perhaps not resolved at all.

The ASE has therefore assumed the challenge of bringing this issue to the attention of the United Nations, specifically COPUOS, with the intention of developing an agreed international NEO deflection decision process prior to any specific threat arising. Such an agreement (or set of instruments) would contain within it the criteria by which equitable and timely decisions can be made when an actual threat develops. Such criteria and guidelines would be developed and agreed upon independent of national borders and boundaries but rather on general principles of common human interest. Should such a decision system not exist at the time a specific threat arises the debate will then revert to power politics and competing national self interest. While the inputs of nations will be essential in the development of a pre-determined decision process, the time for those inputs is nevertheless prior to the emergence of a specific threat.

In order to facilitate the development of such a decision system the ASE is bringing together, in a set of workshops, a pre-eminent group of international experts in diplomacy, international law, space policy and technology, disaster management , etc. Over a period of two years this group of Principals will develop and confront the multitude of challenging decisions facing the international community and generate, as a work product, a draft UN instrument (treaty, guidelines, convention, TBD) codifying a coordinated process for reaching a timely decision on NEO deflection. The output of this series of workshops will be submitted to the Scientific and Technical Subcommittee (STSC) of COPUOS in February 2009 for consideration and deliberation.

ASE has worked with COPUOS (where it enjoys formal observer status) for the past several years making formal technical presentations in STSC on the NEO challenge in 2006 and 2007. ASE also has formal membership on Action Team 14 (NEO) of STSC and will enter the draft NEO agreement into the UN process via the AT-14 adopted workplan.