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Asteroids and Comets: U.S. and International Law and the Lowest-Probability, Highest Consequence Risk

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COLLOQUIUM ARTICLES

ASTEROIDS AND COMETS: U.S. AND INTERNATIONAL LAW AND THE LOWEST-PROBABILITY, HIGHEST CONSEQUENCE RISK

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Introduction

Asteroids[1] and comets[2] pose unique policy problems. They are the ultimate example of a low probability, high consequence event: no one in recorded human history is confirmed to have ever died from an asteroid or a comet, but the odds are that at some time in the next several centuries (and conceivably next year) an asteroid or a comet will cause mass localized destruction and that at some time in the coming half million years (and conceivably next year), an asteroid or a comet will kill several billion people. The sudden extinction of the dinosaurs, and most other species 65 million years ago, is now generally attributed to the impact of a 10-kilometer-wide comet or asteroid at Chicxulub in Mexico's Yucatan Peninsula that left a 110-mile-wide crater.[3]

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1 An asteroid is defined as "one of a multitude of objects ranging in size from sub-km to about 1000 km, most of which lie between the orbits of Mars and Jupiter." Hazards Due to Comets and Asteroids 1242 (Tom Gehrels ed., 1994).

2 A comet is defined as "a diffuse body of gas and solid particles . . . which orbits the sun." *Id.* at 1245.

3 Thomas Mallon, *The Asteroids are Coming! The Asteroids are Coming!*, N.Y. Times Mag., July 28, 1996, at 16, 19. *See also* Luis W. Alvarez et al.,

Even our own century has seen smaller-scale impacts. On June 30, 1908, hundreds of square miles of trees were burned and herds of reindeer may have been incinerated in the Tunguska region of Siberia by an explosion with the force of 1,000 Hiroshima bombs, apparently caused by a 60-meter asteroid.[4] Airborne blasts in the kiloton to megaton range were observed in 1930 at the Curuca River in Brazil; in 1947 at Sikhote-Alin, Siberia; in 1965 over Revelstoke, Canada; and over Ontario in 1966 and Alaska in 1969.[5] Most recently, on November 22, 1996, a meteorite crashed into a coffee field in Honduras, leaving a 165-foot-wide crater.[6]

On March 22, 1989, the asteroid 1989 FC came within about 690,000 kilometers of Earth—a near miss in astronomical terms—and crossed the Earth's orbit at a place where our planet had been only six hours before.[7] In July 1994, the large fragments of a broken comet, discovered sixteen months earlier by Gene and Carolyn Shoemaker and David Levy, smashed spectacularly into Jupiter, causing perturbances thousands of miles across.[8] After that incident, one National Aeronautics & Space Administration (NASA) astronomer reflected:

> The solar system no longer seems quite so far away as it did before July, 1994. Here we are, close to the edge, protected from the true immensity of the universe by a thin blue line. A

Extraterrestrial Cause for the Cretaceous-Tertiary Extinction, 208 SCIENCE 1095 (1980); Jan Smit, *Extinctions at the Cretaceous-Tertiary Boundary: The Link to the Chicxulub Impact*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 859. *See also*, *The Mass-Extinction Debates: How Science Works in a Crisis*, (William Glen ed., 1994). A recently-advanced theory that the comet or asteroid struck the Earth at an oblique angle, rather than directly, may answer some of the remaining questions surrounding the concept. *See* Steven D'Hondt & Peter H. Schultz, *Cretaceous-Tertiary (Chicxulub) Impact Angle and Its Consequences*, 24 GEOLOGY 963 (1996).

4 Vitaly V. Adushkin & Ivan V. Nemchinov, *Consequences of Impacts of Cosmic Bodies on the Surface of the Earth*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 721, 722; Richard Stone, *The Last Great Impact on Earth*, DISCOVER, Sept. 1996, at 60.

5 Leonard David, *Assessing the Threat from Comets and Asteroids*, AEROSPACE AM., Aug. 1996, at 24; Roy A. Gallant, *Sikhote-Alin Fifty Years Later*, SKY & TELESCOPE, Feb. 1997, at 50.

6 *November Meteorite Leaves Big Impression on Honduras*, ST. PETERSBURG TIMES, Dec. 17, 1996, at 15A.

7 Clark R. Chapman & David Morrison, *Impacts on the Earth by Asteroids and Comets: Assessing the Hazard*, 367 NATURE 33, 36 (1994).

8 THE GREAT COMET CRASH: THE IMPACT OF COMET SHOEMAKER-LEVY 9 ON JUPITER (John R. Spencer & Jacqueline Mitton eds., 1995).

> day will surely come when the sheltering sky is torn apart with a power that begs the imagination. It has happened before. Ask any dinosaur, if you can find one. This is a dangerous place.[9]

A number of astronomers around the world are now at work on detection, but the published literature contains little serious discussion of how our political and legal institutions are to deal with such a huge but remote threat of asteroids and comets reaching the Earth's surface. Scientific uncertainty, risk perception, intergenerational equity, arms control, and a host of other thorny problems come into play.

Part I of this Article briefly discusses the nature and magnitude of this danger, describes current efforts to detect asteroids and comets that could collide with the Earth, and summarizes the options if such an object were found. Part II compares this danger with other hazards to whose prevention our society has already decided to devote major resources, and describes both the risks of ignoring the problem and the risks of responding. Part III explores issues raised under U.S. domestic law in dealing with the threat, and Part IV discusses issues under international law. Concluding remarks give our thoughts on what should be done.

I
The Threat: Magnitude, Detection, and Responses

A. *Magnitude of the Comet and Asteroid Threat*

Astronomers have cataloged more than 180 asteroids[10] and 26 comets[11] in orbits that cross Earth's orbit. Only a small fraction of near-Earth objects have been found so far; it is believed that, very roughly, 2,000 such objects of at least one kilometer in size exist.[12] The largest, the asteroids (1627) Ivar and (1580) Be-

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[9] Timothy Ferris, *Annals of Space: Is This the End?*, NEW YORKER, Jan. 27, 1997, at 44, 49 (quoting Kevin Zahnle, NASA Ames Research Center, Mountain View, Cal.).

[10] David Rabinowitz et al., *The Population of Earth-Crossing Asteroids*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 285.

[11] Eugene M. Shoemaker et al., *The Flux of Periodic Comets Near Earth*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 313.

[12] Thomas J. Ahrens & Alan W. Harris, *Deflection and Fragmentation of Near-Earth Asteroids*, 360 NATURE 429 (1992). *See generally* Peter Hammerling & John L. Remo, *NEO Interaction with Nuclear Radiation*, 36 ACTA ASTRONAUTICA 337 (1995).

tulia, are of similar size to that which caused the mass extinction 65 million years ago.[13]

None of the approximately 200 known objects are expected to collide with Earth for at least two centuries, although one of them (the asteroid 2340 Hathor) warrants special attention.[14] Confident predictions cannot be made for the approximately 1,800 unknown-but-expected-near-Earth objects until they are found and their orbits are calculated. As will be discussed below, even less is known about long-period comets that quickly approach the inner planets from beyond the solar system.

Overall, current estimates are that objects about ten meters across strike the Earth almost annually with an explosive force of about 10,000 tons of TNT (roughly the yield of the Hiroshima bomb),[15] but break up harmlessly (though noisily) in the atmosphere; objects about 100 meters across, such as the one that burned Tunguska, arrive about once every 300 years and could destroy a large city; one about four times the size of Tunguska's, expected every few thousand years could, if it landed in an ocean, cause tsunamis with waves over 60 meters high that would wipe out coastal cities in all directions.[16] Objects about one kilometer across are estimated to hit approximately once in 500,000 years and can cause global catastrophic effects including the death of billions of people.[17]

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13 Rabinowitz et al., *supra* note 10, at 288.

14 Donald K. Yeomans & Paul W. Chodas, *Predicting Close Approaches of Asteroids and Comets to Earth*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 241, 256; *cf.* E-mail from Tom Gehrels to Michael B. Gerrard (Feb. 25, 1997) (on file with authors); *The Threat of Large Earth-Orbit Crossing Asteroids: Hearing Before the Subcomm. on Space of the Comm. on Science, Space, and Technology*, 103d Cong. 189, 190 (1993) [hereinafter *Asteroid Threat Hearing*] (statement of Dr. Wesley T. Huntress, Jr., Associate Administrator for the Office of Space Science, NASA Headquarters) ("NASA knows of *no* asteroid or comet that is currently on a collision course with the Earth. As best we can tell, no large object is likely to strike the Earth anytime in the next several hundred years.").

15 *See* RICHARD RHODES, THE MAKING OF THE ATOMIC BOMB 711 (1986) (noting that the Hiroshima bomb had a yield of 12,500 tons of TNT).

16 J.G. Hills et al., *Tsunami Generated by Small Asteroid Impacts*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 779.

17 *See* Thomas J. Ahrens & Alan W. Harris, *Deflection and Fragmentation of Near-Earth Asteroids*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1 at 897, 900; *cf.* David Morrison et al., *The Impact Hazard*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 59, 63 (noting most meteoroids—even ones as large as a few tens of meters in diameter—break up as they enter Earth's atmosphere and never reach the ground); Hammerling & Remo, *supra* note 12. *See also* Douglas O. ReVelle, Historical Detection of Atmos-

B. *Detection Efforts*

The location and tracking of near-Earth objects (NEOs), using a 36-inch telescope at Kitt Peak, has been one of the missions of the Spacewatch program directed by Tom Gehrels of the University of Arizona.[18] A new 1.8-meter telescope was installed at Kitt Peak in February 1997. Similar important work has long been conducted in the Palomar Mountain observatory in California, led by Eleanor Helin of the Jet Propulsion Laboratory, while newer efforts are beginning at Lowell Observatory in Arizona and in Italy and France.[19] In 1992, advisers to NASA proposed expansion of this effort into what they called the Spaceguard Survey, with half a dozen 2.5-meter telescopes around the world, at a cost of $50 million plus $10 million per year in operating costs. In 25 years, this survey would be able to detect 90% of all the Earth-crossing asteroids larger than a kilometer across.[20]

A tracking program of the Anglo-Australian Observatory in Siding Spring, Australia, the only program in the Southern Hemisphere, was shut down because of lack of money.[21] Such programs suffer because, relying primarily on decades-old technology, they lack the scientific prestige that tends to attract major funding. One leading NASA astronomer has said that the number of people working on these efforts worldwide is "smaller than the staff of one McDonald's restaurant."[22]

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pheric Impacts by Large Bolides Using Acoustic-Gravity Waves, Presentation at the International Conference on Near-Earth Objects, Sandia National Laboratory (Apr. 24-26, 1995) (examining global effects of large bolides (meteor-fireballs) entering Earth's atmosphere, 1960 to the early 1980s); Owen B. Toon et al., *Environmental Perturbations Caused by Asteroid Impacts*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 791 (discussing the catastrophic environmental impacts caused by large asteroid impacts).

18 The 15-year-old Spacewatch program aims to generate statistics on all comets and asteroids. The program locates some 33,000 such objects per year, of which approximately 35 are Near-Earth Objects (NEOs). E-mail from Tom Gehrels, *supra* note 14. *See* Mallon, *supra* note 3, at 16-19.

19 E-mail from Andrea Carusi to Michael B. Gerrard (Mar. 11, 1997) (on file with the authors).

20 Peter Tyson, *Comet Busters*, TECH. REV., Feb. 1995, at 28; *Spacewatch Telescope* <http://xlr8.lpl.arizona.edu/spacewatch/>.

21 *See* E-mail from Andrea Carusi, *supra* note 19 ("At this time there are only two continuous programs . . . . Nobody is observing in the Southern Hemisphere, something that causes the loss of all discovered objects which move into the south.").

22 David Morrison, *Target: Earth!*, 23 ASTRONOMY 34 (Oct. 1995). *See also* Leon Jaroff, *A Shot Across the Earth's Bow, Last Week's Heavenly Near Miss Has a Record. Are We Ready For the Next Incoming Asteroid?*, TIME, June 3,

Ground-based efforts attempt to locate new objects. Several space missions are trying to learn more about some of the largest asteroids that are already known. In 1991, NASA's *Galileo*, on its way to Jupiter, surveyed the asteroid "951 Gaspra" from a distance of 1,000 miles.[23] In February 1996, the first Near-Earth Asteroid Rendezvous (NEAR) spacecraft was launched from Cape Canaveral; in January 1999, it will approach "433 Eros," the largest near-Earth asteroid, and orbit for nearly a year (and possibly land) and make observations about its physical and geological properties.[24] (Italian and French mathematicians have calculated that there is a chance that in the next million years or so, gravitational forces could nudge 433 Eros onto a collision course with Earth.)[25] Other missions are scheduled for launches to various asteroids and comets in 1998, 1999, and 2003.[26]

C. *Possible Countermeasures*

If an NEO is found to be on a collision course with the Earth, some people's first reaction would be to attempt to blow it up with nuclear warheads. This could prove counterproductive, however, if several of the resulting fragments are still on a course to Earth and are large enough to penetrate its atmosphere; this situation could increase rather than decrease the destruction caused by impact with our planet.[27] The composition of the object is very important—nickel-iron asteroids will be far more difficult to break apart into multiple small pieces than chrondite

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1996, at 61; David L. Chandler, *Search for Earth-Bound Asteroids Looking Up*, BOSTON GLOBE, May 13, 1996, at 27; Guy Webster, *High-Tech System Aids Search for 'Disasteroids'; Saving Civilizaton Can Be a Lonely Job*, ARIZ. REPUBLIC, Aug. 28, 1995, at A1. At least one astronomer has questioned the McDonald's comparison, and the general notion that only a handful of people are working on the NEO effort, citing the equivalent of at least 20 full-time astronomers engaged in tracking NEOs worldwide. E-mail from Tom Gehrels, *supra* note 14.

23 *Asteroid Threat Hearing*, *supra* note 14.

24 Scott L. Murchie et al., *Encounter With Eros: The Near-Earth Asteroid Rendezvous Mission*, LUNAR & PLANETARY INFO. BULL. (1995) (visited Dec. 23, 1996) <http://newproducts.jpl.nasa.gov/calandar/nearl.html>.

25 Malcolm W. Browne, *Mathematicians Say Asteroid May Hit Earth in a Million Years*, N.Y. TIMES, Apr. 25, 1996, at B10.

26 David, *supra* note 5; Andrew F. Cheng et al., *Missions to Near-Earth Objects*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 651.

27 JOHN S. LEWIS, RAIN OF IRON AND ICE: THE VERY REAL THREAT OF COMET AND ASTEROID BOMBARDMENT 212-13 (1996); Clark R. Chapman et al., *Physical Properties of Near-Earth Asteroids: Implications for the Hazard Issue*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 537, 547.

asteroids or ice-and-dust comets.[28] Observation from a spacecraft located close to the object may be required to determine its particular composition.

Most astronomers seem to feel that it is usually better to deflect an object than to fragment it if there is enough warning time. The idea is simply to move the asteroid or comet enough so that it and the Earth will not be at the same place at the same time. In the words of John S. Lewis, co-director of the NASA/University of Arizona Space Engineering Research Center,

> we are not trying to banish the asteroid from the inner solar system; we are merely trying to avoid a single predicted impact with Earth. Suppose our asteroid-search team finds a 250-meter body that is due to hit Earth dead center a few hundred years from now. This same body has probably been crossing Earth's orbit for 10 million to 100 million years without an impact. If we can just ease it by Earth without an impact on this one occasion, we may well buy ourselves another 30 million years to figure out what to do the next time it threatens us.[29]

To accomplish this diversion, nuclear devices seem to be the only currently available technology that can deliver enough energy to move a large object far enough to avoid an Earth impact.[30] According to one analysis, the method that may transfer the momentum from the blast to the object most effectively involves burying the device below the surface of the asteroid.[31] Care must be taken not to inadvertently fragment the object.[32] Many of the technologies that would be necessary for such a mission-data processing, telemetry, power supply, sensors, propulsion, etc., have been under development for military purposes by

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[28] V.A. Simonenko et al., *Defending the Earth Against Impacts From Large Comets and Asteroids*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 929, 950; Joseph G. Gurley, *Vehicle Systems for Missions to Protect the Earth Against NEO Impacts*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 1035, 1049-51.

[29] LEWIS, *supra* note 27, at 213-14; *cf.* Gregory H. Canavan et al., *Near-Earth Object Interception Workshop*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 93, 94.

[30] Ahrens & Harris, *supra* note 17, at 923; Hammerling & Remo, *supra* note 12.

[31] Ahrens & Harris, *supra* note 17, at 917. A radically different mathematical analysis is presented in Pasquale M. Sforza & John L. Remo, *Subsurface Momentum Coupling Analysis for Near-Earth-Object Orbital Management*, 35 ACTA ASTRONAUTICA 27 (1995).

[32] Ahrens & Harris, *supra* note 17, at 913.

the U.S. Department of Defense's Ballistic Missile Defense Organization, formerly known as the Strategic Defense Initiative Organization (and popularly known as "Star Wars").[33]

For smaller NEOs, non-nuclear options may be available. Among the speculative techniques that have been imagined are pulsed lasers; kinetic energy deflection (i.e., simply striking the asteroid with a massive projectile); mass drivers (devices that would be installed on the surface of the asteroid, quarry the rock, place it in buckets, and fling it into space in the right direction over a period of years); very large solar sails that would be affixed to the asteroid and capture solar radiation to exert pressure; and solar collectors that would capture sunlight on a curved primary mirror, focus it onto the surface of the asteroid causing the surface layers to vaporize, and thereby generating thrust.[34]

All of the deflection options require abundant advance warning; an asteroid, unlike a sports car, cannot be turned on a dime. Fortunately, Earth-crossing asteroids that are large enough to pose a global threat are likely to be discovered decades, if not centuries or millennia, in advance of collision. Therefore, there would likely be ample time to decide on a strategy, develop the technology, launch a vanguard mission to learn more about the object's properties, launch the interception mission to execute the chosen strategy, and allow the deflection to take its course.[35]

A qualitatively different problem is posed by long-period comets, which are defined as comets with almost parabolic orbits and periods of revolution around the Sun exceeding 200 years; some have orbital periods of millions of years.[36] Thus, any long-period comet that comes into view is likely being seen by humanity for the first time. They move much faster than asteroids and

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33 S. Nozette et al., *DOD Technologies and Missions of Relevance to Asteroid and Comet Exploration*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 671.

34 H.J. Melosh et al., *Non-Nuclear Strategies for Deflecting Comets and Asteroids*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 1111. *See also* David K. Hill, *Gathering Airs Schemes for Averting Asteroid Doom*, 268 SCIENCE 1562 (1995).

35 Gurley, *supra* note 28, at 1038, 1041; LEWIS, *supra* note 27, at 211. *But see* B.G. Marsden & D.I. Steel, *Warning Times and Impact Probabilities for Long-Period Comets*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 241, 221 (arguing that some small but threatening objects, mostly resulting from the breakup of comets, may give only a few hours warning).

36 HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 1255.

their trajectories are difficult to precisely predict because their paths are influenced not only by gravity, but also by the solar forces that generate their tails, thus creating uncertainty about whether they will hit Earth. They are likely to be spotted 250 to 500 days before impact, although some sightings can occur later. On January 30, 1996, Yuji Hyakutake spotted a comet with a nucleus of one to two miles just two months before its closest approach to Earth (about 9.5 million miles away).[37] Comets that cannot be seen by optical telescopes because they come from the direction of the sun and are hidden by the glare may be found only a few days or hours in advance. These comets leave no time for deflection and very little time for deliberation and preparation; the only hope of defense would be to have nuclear-armed spacecraft ready for launch or in standby orbits.[38] In the understated words of one NASA official, "[f]or the worst case, a large object discovered to be on a collision course with Earth in a matter of days, there is at present no response that has a high probability of success."[39]

The good news is that long-period comets represent only a tiny fraction of the objects that may strike the Earth, so the odds that one will crash here in the next several centuries are exceedingly remote.[40]

II
The Risks in Context

A. *Quantifying Relative Risks*

One astronomer has calculated (in very round numbers, of course) that four times within every million years a large NEO will arrive that kills one billion people.[41] Other estimates are very similar.[42] The death of four billion people over one million

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[37] *Reflections on the "Comet of the Decade,"* Astronomy, July 1996, at 111; *Comet-Crash Warnings: Too Little, Too Late?*, Sky & Telescope, Feb. 1997, at 13.

[38] Marsden & Steel, *supra* note 35, at 221; Yeomans & Chodas, *supra* note 14, at 257.

[39] *Asteroid Threat Hearing*, *supra* note 14, at 29 (statement of John D.G. Rather, Assistant Director for Space Technology (Program Development) for the Office of Advanced Concepts & Technology, NASA Headquarters).

[40] Lewis, *supra* note 27, at 220-21.

[41] *Id.* at 209.

[42] *See generally* Chapman & Morrison, *supra* note 7. *See also*, Ahrens & Harris, *supra* note 17, at 900.

years works out to an average of 4,000 people per year. If there are four billion people on the planet, an average death rate of 4,000 people per year means that each year, every person statistically has a one in one million chance of being killed by a comet or asteroid. Of course, in actuality the results would be very lumpy, and not spread out like the averages suggest, but the averages do allow comparisons to more familiar risks.

An annual death rate of 4,000 people is very similar to the rate of annual drowning deaths in the United States (4,500 in 1995) or fires (4,100), and more than those who die from choking on food or objects (2,800) or from accidental discharge of firearms (1,400).[43] In an average year, about 700 people worldwide die in the crashes of commercial airlines.[44] All of these are causes of death that our society goes to great expense to try to prevent.

An individual's statistical risk of death also receives considerable regulatory attention. For example, the U.S. Environmental Protection Agency's regulations under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)[45] declare that a one in one million chance of contracting cancer is the threshold for considering the cleanup of sites contaminated with hazardous substances.[46] That is a *lifetime* risk that *any* person will contract a case of cancer, whether exposure to the chemicals is actual or hypothetical, without respect to the number of people actually exposed, and without respect to whether the cancers are fatal.[47] Thus, on a purely statistical basis, CERCLA addresses risks that are significantly lower than those posed by comets and asteroids. CERCLA risks are addressed by remedial programs that cost on average $30 million *per site*.[48] Thus the cost of cleaning up two to four average Superfund sites (there are a total of about 1,200 nationwide)

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[43] WORLD ALMANAC AND BOOK OF FACTS 1997, at 967 (Robert Famighetti ed., 1996).

[44] *Id.* at 968.

[45] 42 U.S.C. §§ 9601-9675 (1995).

[46] 40 C.F.R. § 300.430(e)(2)(A)(2) (1995).

[47] Katherine D. Walker et al., *Confronting Superfund Mythology: The Case of Risk Assessment and Management*, *in* ANALYZING SUPERFUND: ECONOMICS, SCIENCE, AND LAW 25, 26-27 (Richard L. Revesz & Richard B. Stewart eds., 1995).

[48] THOMAS W. CHURCH & ROBERT T. NAKAMURA, CLEANING UP THE MESS: IMPLEMENTATION STRATEGIES IN SUPERFUND 8 (1993).

is roughly the equivalent of carrying out NASA's recommendations for the worldwide Spaceguard program.

Of course, the temporal dimension must be central to any comparisons, and here too, CERCLA is instructive. Only a small fraction of the risks addressed in CERCLA pertain to current exposure of people to chemicals; most of these risks are for future hypothetical consumers of drinking water that is not now used for human consumption.[49] Thus CERCLA too is aimed primarily at future generations, though not nearly so far into the future as those most likely to be the victims of comets and asteroids.

Protection of generations in the far distant future is the focus of another group of environmental programs—those aimed at the disposal of radioactive waste. The U.S. government plans to build a repository for high-level radioactive waste (primarily spent fuel rods from nuclear power plants and certain wastes from nuclear weapons production) under Yucca Mountain, Nevada. The facility is being designed to protect people 10,000 years into the future. Its planning has required geologists to stretch the outer limits of their predictive capabilities. Another facility—the Waste Isolation Pilot Plant (WIPP)—has already been built, but not yet opened, in a deep salt deposit near Carlsbad, New Mexico, for the disposal of plutonium and other transuranic wastes.[50]

This begins to approach the time scale involved in guarding against comets and asteroids. It may be off by an order of magnitude, but these are time scales that the human mind is not equipped to grasp.

Radioactive waste and comet/asteroid threats pose a threat to the present and also a (perhaps much greater) threat to the future. There is a key difference, however. What we do today in the realm of generating and managing radioactive waste will have great impact on the effect that waste will have on future generations. In contrast, what we do today about comets and asteroids will have no effect at all on the likelihood of a future collision, though today's observations could give our descendants a slightly

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[49] Walker et al., *supra* note 47, at 25; James T. Hamilton & W. Kip Viscusi, *The Magnitude and Policy Implications of Health Risks from Hazardous Waste Sites*, *in* ANALYZING SUPERFUND, *supra* note 47, at 66.

[50] *See generally* JAMES FLYNN ET AL., ONE HUNDRED CENTURIES OF SOLITUDE: REDIRECTING AMERICA'S HIGH-LEVEL NUCLEAR WASTE POLICY (1995).

greater head start. Thus, today's generation bears a far greater moral obligation to distantly future generations with respect to radioactive waste than with respect to asteroids and comets.

B. *The Psychology of Response*

If 4,000 lives each year are truly at stake due to NEOs, one would ordinarily expect very large public expenditures to follow. The figures vary widely depending on the program involved, but a rule of thumb in assessing the costs and benefits of life-saving programs is that one life is worth $4-$8 million.[51] At that rate, comet and asteroid detection would warrant $16-$32 billion per year. That exceeds what the astronomical establishment is seeking by a factor of more than one thousand.

One possible explanation for the discrepancy is the uncertainties involved. The estimates of likely deaths from extraterrestrial impacts depend on numerous assumptions based on necessarily sparse data. It is not clear, however, that CERCLA risk assessments, for example, are any less heroic in their strings of assumptions.[52] Another explanation for our unwillingness to spend heavily on comet and asteroid protection may be that we greatly discount the value of lives in remotely distant generations—those that will come millennia after our great-grandchildren's tombstones have been eroded into dust. Some regulatory agencies[53] and at least one court[54] have formally embraced the idea of discounting future lives in making present day spending decisions.

Nonetheless, preservation of the planet for future generations is a common theme in environmental law. It underlies numerous statutes, such as the Endangered Species Act,[55] the

[51] Carl F. Cranor, Regulating Toxic Substances: A Philosophy of Science and the Law 125 (1993), and sources cited therein. Wide variations in what is actually spent to save lives through various means are discussed in Tammy O. Tens et al., *Five-Hundred Life-Saving Interventions and Their Cost-Effectiveness*, 15 Risk Analysis 369 (1995).

[52] *See generally* Wendy E. Wagner, *The Science Charade in Toxic Risk Regulation*, 95 Colum. L. Rev. 1613 (1995). *See also* Howard Latin, *Good Science, Bad Regulation, and Toxic Risk Assessment*, 5 Yale J. on Reg. 89 (1988).

[53] *See generally* Daniel A. Farber & Paul A. Hemmersbaugh, *The Shadow of the Future: Discount Rates, Later Generations, and the Environment*, 46 Vand. L. Rev. 267 (1993).

[54] Corrosion Proof Fittings v. Environmental Protection Agency, 947 F.2d 1201, 1218 (5th Cir. 1991).

[55] 16 U.S.C. § 1531 (1994).

Wilderness Act,[56] the Wild and Scenic Rivers Act,[57] and the National Historic Preservation Act.[58] It has deep psychological, religious, and philosophical origins.[59] The U.S. Constitution was adopted to represent a fundamental value by "secur[ing] the Blessings of Liberty to ourselves and our Posterity."[60] One extensive poll found that people from every walk of life cite concern for future generations as a central reason to protect the environment.[61]

Just how far into the future this concern will extend is hard to say. The close attention paid to what will become of Yucca Mountain and WIPP in 10,000 years suggests that people do care about what happens beyond the horizon of fathomable time, even if the worst that could plausibly occur there is a local disaster—not something that could threaten the survival of the species. The sheer incomprehensibility of the time scales involved in both issues suggests that the great difference in public concern over radioactive waste versus asteroids is not a matter of quantified years. Rather, it may be partly due to the fact that since 1945 mankind has known for certain that nuclear material can cause mass death, whereas asteroids appear more hypothetical. It also may be attributable to the fact that radioactive waste implies evil (or at least negligent) human action, and therefore incites abhorrence in a way that a purely natural force does not.[62]

The reasons for the discrepancy between the statistical risk of death by comet and asteroid, and the amount of resources and attention devoted to the issue, are illuminated by studies in cognitive psychology. Some of these studies were performed in the context of individual decisions of whether to buy flood insurance. In this and similar contexts, willingness to spend money to guard against a low probability, high consequence risk correlated very poorly with what formal decision theory would suggest. Instead, people have been found to be heavily influenced by whether they know of similar disasters affecting others, especially people they

[56] 16 U.S.C. § 1131 (1994).

[57] 16 U.S.C. § 1271 (1994).

[58] 16 U.S.C. § 461 (1994).

[59] *See generally* John Passmore, Man's Responsibility for Nature: Ecological Problems and Western Traditions (1974).

[60] U.S. Const. preamble.

[61] Willett Kempton et al., Environmental Values in American Culture 95-102 (1995).

[62] *See generally* Paul Slovic, *Perception of Risk and the Future of Nuclear Power*, 9 Ariz. J. Int'l & Comp. L. 191 (1992).

know. Where the risk seems purely theoretical, there is little impulse to respond.[63] For a risk that seems never to have killed anyone so far, it is no surprise that few people take seriously the idea of taking precautions.

Before deep public concern can arise, the asteroid and comet threat must also overcome the "giggle factor" that now afflicts it.[64] Then-Vice President Dan Quayle received a good deal of ribbing for mentioning the issue in a speech in 1990.[65] This threat has been the stuff of Hollywood (at least six movies between 1951 and 1984, plus two more about to begin production), television (a 1997 NBC miniseries, *Asteroid*, a rash of documentaries in 1997, and episodes in the old *Superman* and *Star Trek* series),[66] and several science fiction novels (including Arthur C. Clarke's 1973 *Rendezvous with Rama*, Larry Niven and Jerry Pournelle's 1977 *Lucifer's Hammer*, and Pat Robertson's 1995 *The End of the Age*). In spite of this (or perhaps because of it), the general public does not take the danger seriously, even considering its statistical similarity to several common worries, because the similarity is purely statistical. In every meaningful way, the asteroid threat is wholly different from anything in human experience. Real crises (wars, depressions, explosions) spark major new laws, and there has never been an asteroid crisis, in the sense of a known imminent threat.[67]

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[63] Colin F. Camerer & Howard Kunreuther, *Decision Processes for Low Probability Events: Policy Implications*, 8 J. POL'Y ANALYSIS & MGMT. 565 (1989); Melvin Aron Eisenberg, *The Limits of Cognition and the Limits of Contract*, 47 STAN. L. REV. 211, 223-24 (1995); Roger G. Noll & James E. Krier, *Some Implications of Cognitive Psychology for Risk Regulation*, 19 J. LEGAL STUD. 747, 769-72 (1990); Amos Tversky & Daniel Kahneman, *Rational Choice and the Framing of Decisions*, *in* RATIONAL CHOICE: THE CONTRAST BETWEEN ECONOMICS AND PSYCHOLOGY 67 (Robin M. Hogarth & Melvin W. Reder eds., 1987).

[64] *See* Mallon, *supra* note 3, at 18.

[65] Mike Royko, *Astronomical Task Perfect for Quayle*, CHI. TRIB., June 6, 1990, at C3.

[66] Rick Schindler, *Comet Relief*, TV GUIDE, Feb. 15, 1997, at 22; *Stand By For Comet's Media Aftershocks*, 275 SCIENCE 761 (1997).

[67] However, the notion of NEO threats may be moving into the mainstream, as evidenced by TWA's statement in response to lawsuits filed against it that the crash of Flight 800 might have been caused by a meteor. *See* Gail Appleson, *TWA Seeks Dismissal of Flight 800 Suits*, REUTERS WORLD SERV., Jan. 15, 1997.

C. *The Risks of Counter-Measures*

Perhaps the biggest threat that asteroids pose to mankind today is the excuse they provide for continuing to deploy nuclear weapons. In 1996 there were two stark examples of this. In April, China refused to sign a treaty with Russia banning nuclear weapons testing, on the stated grounds that such weapons might be needed to combat the asteroid threat.[68] In September, a "Space Protection of Earth" conference was held at the Russian Federal Nuclear Center in Snezhinsk, and the sole American scientist to attend reported that the Russians are considering building a system of nuclear-armed missiles that could be readied for launch in ninety minutes if an incoming asteroid were spotted.[69] It seems obvious that the deployment of a nuclear weapons system in China, Russia, or anywhere else poses a threat of accidental or malevolent mass destruction that dwarfs the odds that such a system will be suddenly needed to beat back a long-period comet or another atypical threat that arises with too little warning for us to develop a defensive system from scratch.

Some U.S. scientists today advocate a testing program for nuclear explosions at remote asteroids to determine the parameters under which defensive measures would work best. The most visible proponent of this approach is the eighty-nine year old Dr. Edward Teller, who is better known as the "father" of the hydrogen bomb.[70] Representatives of the Ballistic Missile Defense Organization have also recently advocated an accelerated program of testing (not necessarily with nuclear warheads) utilizing some of the several hundred Russian intercontinental ballistic missiles (ICBMs) that must be destroyed by 2002 in accordance with the START II treaty.[71] One physicist who has studied the issue,

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[68] Patrick E. Tyler, *Chinese Seek Atom Option to Fend Off Asteroids*, N.Y. TIMES, Apr. 27, 1996, at 4.

[69] David Morrison, *Space Protection of the Earth (SPE-96) Conference* (visited Oct. 10, 1996) <http://ccf.arc.nasa.gov/sst/10-10-96.html>.

[70] *See* David Morrison & Edward Teller, *The Impact Hazard: Issues for the Future*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 1135. As a historical footnote, it might be pointed out that one of Teller's colleagues in the development of the atomic bomb, Luis W. Alvarez, who won the Nobel Prize for his work with subatomic particles, discovered (alongside his geologist son Walter Alvarez) compelling evidence that an asteroid caused the extinction of the dinosaurs. *See* Alvarez, *supra* note 3.

[71] David Morrison, Brief Report, PLANETARY DEFENSE WORKSHOP, (visited May 22-26, 1995) <http://ccf.arc.nasa.gov/sst/news_01.html>.

while not explicitly advocating the testing of nuclear devices, has written:

> Clearly, the NEO hazard threat cannot be used as a pretext for rearmament and appropriate safeguards must be taken to minimize the threat of misuse. If mitigation methods and devices are to be developed, safeguards and rigorous controls against their misuse must play a dominant role at every state of design, development, testing, and deployment. However, in the absence of specifically developed mitigation technology it would be prudent to have available that technology and hardware which can most effectively deal with an Earth threatening NEO. We must and can establish the appropriate custodial mechanisms that allow us to maintain those options which can best protect the Earth.[72]

The development, fabrication, and launch of a device to carry out the experiments proposed by Dr. Teller and others seems to be fraught with risk. A release of dangerous quantities of radioactive material (whether or not through detonation) could occur through manufacturing error, launch failure, terrorist action, or other plausible scenarios. The probability of a radioactive release with locally adverse effects, or even of a catastrophic detonation, seems to exceed the chances of a long-period comet sneaking up on us. The risk/benefit calculation would have to consider the scale of destruction to be caused by a nuclear accident versus the destruction that might be averted by an experiment in comet hazard mitigation. Both items are probably beyond useful quantification, but it is doubtful that this factor would close the gap between the risks of conducting the experiment now versus the risks of waiting until an actual threat appeared. Experience confirms the fear of accidents in the handling of nuclear weapons.[73]

The danger that a purportedly defensive system could malfunction or be intentionally aimed at an Earth-based target seems obvious. A less obvious danger was pointed out by the late Carl Sagan who argued that development of asteroid-deflection technology "is a double-edged sword. If we can perturb an asteroid out of impact trajectory, it follows that we can also

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[72] John L. Remo, *Policy Perspectives from the UN International Conference on Near-Earth Objects*, SPACE POL'Y 13, 15 (1996).
[73] *See infra* part III.

transform one on a benign trajectory into an Earth-impactor."[74] For that reason, "through negligence, fanaticism, or madness, the technology to deflect asteroids and comets might be used to generate a global catastrophe on a time scale much shorter than the waiting time for the natural catastrophe that this technology is designed to circumvent."[75]

The authors wrote to Dr. Teller to ask his views concerning the balancing of the benefits and the risks of creating a planetary defense system in advance of the discovery of an actual threat. He replied that:

> mutual benefits and confidence due to international cooperation concerning a common danger far outweighs in importance the danger of misuse. Indeed, successful international cooperation on any subject is apt to decrease the motivation for conflict. To my mind, this is the main problem that we have to solve.[76]

The advantages of international cooperation cannot be denied. However, in the absence of a known threat, we believe that the deployment of a defensive system (as opposed to a detection system) poses far greater dangers to mankind, through accident or criminal act, than the asteroid/comet threat itself.

III
DOMESTIC LEGAL ISSUES

Having discussed the nature and magnitude of the risks posed by comets and asteroids, as well as the programs to detect and defend against them, we turn to the legal implications of these programs.

A. *Congressional Interest*

Congress has exhibited some interest in near-Earth asteroid detection. In conjunction with the passage of the 1990 NASA Multiyear Authorization Act,[77] the Committee on Science, Space, and Technology of the House of Representatives directed

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[74] Carl Sagan & Steven J. Ostro, *Dangers of Asteroid Deflection*, 368 NATURE 501 (1994).

[75] Allan W. Harris et al., *The Deflection Dilemma: Use Versus Misuse of Technologies for Avoiding Interplanetary Collision Hazards*, *in* HAZARDS DUE TO COMETS AND ASTEROIDS, *supra* note 1, at 1145, 1146.

[76] Letter from Dr. Edward Teller to Michael B. Gerrard (Jan. 30, 1997) (on file with authors).

[77] 42 U.S.C. §§ 2465, 2471a (1990).

NASA to design a comprehensive program for the detection of asteroids crossing the Earth's orbit and to define systems for destroying or altering the paths of asteroids headed for the Earth.[78] The Committee provided the following rationale for its recommendation:

> The Committee believes that it is imperative that the detection rate of Earth-orbit-crossing asteroids must be increased substantially, and that the means to destroy or to alter the orbits of asteroids when they threaten collision should be defined and agreed upon internationally.
>
> The chances of the Earth being struck by a large asteroid are extremely small, but since the consequences of such a collision are extremely large, the Committee believes it is only prudent to assess the nature of the threat and prepare to deal with it. We have the technology to detect such asteroids and to prevent their collision with the Earth.[79]

The results of the Congressional directive were presented at a 1993 meeting of the Committee by NASA officials, who recommended continued funding for both detection of NEOs and the design of a comprehensive response system.[80] In 1994, the House Committee on Science and Technology again indicated its support of NEO detection by directing NASA, in conjunction with the Department of Defense and the space agencies of other countries, to identify and catalogue within ten years the orbital characteristics of all asteroids and comets greater than one kilometer in diameter whose orbits cross that of the Earth.[81]

The Republican ascendance to control of the House in 1994 changed the composition of the Committee on Science, Space, and Technology. It is unclear whether the current Committee leadership shares the concern with NEO detection. Plagued with other budgetary problems since 1994, NASA has not pressed Congress for funding for Spaceguard or for other NEO detection programs.[82] Federal agency attention, however, has continued: from 1992 to 1996, the Department of Energy, NASA, and the

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[78] H.R. REP. No. 101-763, at 30 (1990).

[79] *Id.*

[80] *Asteroid Threat Hearing*, *supra* note 14, at 28 (statement of John D.G. Rather); *id.* at 189 (statement of Dr. Wesley T. Huntress, Jr.).

[81] HOUSE COMM. ON SCIENCE, SPACE & TECHNOLOGY H.R. REP. No. 103-19 (1994). Available on the Internet, <http://ccf.arc.nasa.gov/sst/c_statements.html>.

[82] Mallon, *supra* note 3, at 18.

U.S. Air Force Space Command held a series of gatherings to identify impact hazards and discuss potential defenses.[83]

B. *Environmental Review: NEPA*

Any U.S. sponsored NEO program must comply with the requirements of U.S. environmental laws, principally the National Environmental Policy Act (NEPA).[84] Each of the potential NEO program activities—land-based detection, space-based detection, interception, destruction, and deflection—may have environmental impacts that must be considered. The remote areas and high elevations that are most favorable for telescope construction are often ecologically fragile or unique areas. Rocket launches are associated with local environmental impacts at the launch site, and rocket fuel has been linked to ozone depletion.[85] The use of nuclear or other technology to destroy or deflect NEOs will potentially have environmental impacts on Earth; raising the additional issue of whether the effects of such activities, if solely confined to outer space, would be subject to regulation under U.S. law.

NEPA provides that every federal agency has "the obligation to consider every significant aspect of the environmental impact of a proposed action [and to] inform the public that it ha[d] indeed considered environmental concerns in its decision-making process."[86] As discussed below, the nature of the analysis required under NEPA will depend on the activities contemplated by the NEO project and how the project is defined.

In order to document its consideration of environmental impacts, each federal agency must prepare an Environmental Impact Statement (EIS) for "every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment."[87] Agencies may conduct a preliminary analysis, in the form of an

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[83] Hill, *supra* note 34, at 1562.

[84] 42 U.S.C. §§ 4321-4347 (1996).

[85] Lenny Siegel, *Muck: No Free Launch*, 15 MOTHER JONES 6, Sept./Oct. 1990, at 24; William J. Broad, *New Methods Sought to Dispose of Rockets With No Harm to Earth*, N.Y. TIMES, Sept. 17, 1991, at C4. *See also* David Swinbanks, *Japan Fishes for More Space Launches*, 385 NATURE 287 (1997) (reporting that Japanese space agency pays fishermen in vicinity of its space launch centers, due to concerns over damage to fishing grounds).

[86] Baltimore Gas & Elec. v. Natural Resources Defense Council, 462 U.S. 87, 97 (1983) (internal citations omitted).

[87] 42 U.S.C. § 4332(2)(c) (1996).

Environmental Assessment, and may at that point conclude that the proposed project will not have a significant environmental impact. Issuance of such a Finding of No Significant Impact (FONSI) enables an agency to proceed with the action without preparing an EIS (though this FONSI is subject to a challenge in court).[88]

A NASA-sponsored program for NEO detection and study that employs currently existing detection equipment and technology is unlikely to require the preparation of a full EIS. According to the NASA guidelines implementing NEPA, the only actions that categorically require the preparation of an EIS are the development and operation of new space vehicles or new launch vehicles.[89] There are many other actions that fall into a grey area. The rules would not automatically require an EIS, and the application of criteria to determine whether the "federal action" contemplated is "major" or whether it might involve "significant impact" on the environment is subjective. Current NASA efforts related to NEOs, including the upgrade of existing telescopes at the University of Arizona and the Arecibo Observatory in Puerto Rico,[90] do not require an EIS under the regulations. In addition, in 1996, NASA issued a FONSI with respect to its near-Earth asteroid rendezvous (NEAR) mission, scheduled to reach the asteroid 433 Eros in 1999, stating that "expected impacts to the human environment associated with the mission arise almost entirely from the normal launch of the Delta II 7925."[91]

Even a simple detection program might require an EIS if it involved the construction of new telescopes on new sites[92] or a substantial increase in the number of space launches. As is illustrated by the series of challenges to the siting of a telescope project in Arizona,[93] the sites that are ideal for telescopes—isolated, elevated locales—are often protected areas that have unique bio-

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88 For a general discussion of National Environmental Policy Act (NEPA) review, *see* Valerie M. Fogleman, *Ch. 1: Environmental Impact Statements, in* ENVIRONMENTAL LAW PRACTICE GUIDE (Michael B. Gerrard ed., 1992).

89 14 C.F.R § 1216.305(c) (1988).

90 *Asteroid Threat Hearing*, *supra* note 14, at 189 (statement of Dr. Wesley T. Huntress, Jr.).

91 Eros FONSI, 61 Fed. Reg. 1950, 1951 (1996).

92 It will be possible to complete the NEO survey without constructing new telescopes, according to one astronomer. E-mail from Tom Gehrels, *supra* note 14.

93 *See* Mount Graham Coalition v. Thomas, 89 F.3d 554 (9th Cir. 1996).

logical values. That series of cases pitted the defenders of the endangered red squirrel, an inhabitant of Mount Graham and its surroundings in the Coronado National Forest in southeastern Arizona, against an international consortium seeking to construct several telescopes on various peaks of Mount Graham. Aided by Congressional intervention, the telescopes were eventually sited in areas found less vital to the squirrels' survival.

Space launches are also associated with significant if local environmental effects, including noise pollution and the release of pollutants such as carbon monoxide, hydrochloric acid, and aluminum oxide.[94] The potential environmental effects are not confined to the local launch site; the burning of rocket fuel has been labelled a potential cause of stratospheric ozone pollution.[95] The risk of accidental release of toxic substances—possibly including radioactive materials—has also been considered in evaluating space launches under NEPA. In two cases titled *Florida Coalition for Peace and Justice v. Bush*,[96] the plaintiffs challenged NASA's decision to go forward with two space exploration projects: (1) the "Galileo Mission," which involved the launch of the space shuttle Atlantis to study Jupiter, and (2) the "Ulysses Project," the launch of a space probe to study the sun. In both cases, the plaintiffs' claims were brought on the ground that the EIS did not adequately assess the projects' risks. One of the risks considered was the possibility of an accident causing the release of plutonium dioxide (present as part of the probes' energy supply), which poses a risk to humans if ingested or inhaled. In both cases, the court concluded that NASA had adequately assessed the risks of the projects and denied a temporary restraining order to the plaintiffs.

Any launches in connection with asteroid/comet defense will be dwarfed in number (and hence in environmental impact) by launches for commercial purposes. Given the greatly expanding use of satellites for telecommunications, it has been estimated that 1,700 commercial satellites will be launched in the next dec-

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[94] Eros FONSI, 61 Fed. Reg. 1950, 1951 (1996).

[95] *See generally* Lynn Anne Shapiro, Note, *The Need for International Agreements Concerning the Ozone Depleting Effects of Chemical Rocket Propulsion*, 4 S. Cal. Interdisc. L.J. 739 (1995).

[96] 1990 U.S. Dist. LEXIS 13345 (D.C. Cir. Oct. 5, 1990); 1989 U.S. Dist. LEXIS 12003 (D.C. Cir. Oct. 10, 1989).

ade (compared to the 150 now in orbit).[97] Equipping space probes with nuclear warheads or nuclear propulsion systems, however, may pose much greater risks, since in recent years approximately one in ten unmanned satellite launches have failed.[98]

Even the worst case environmental effects of a detection system are relatively minor when compared to the environmental effects associated with a planetary defense program. A planetary defense program would likely involve, in addition to space launches, the detonation of nuclear weapons or the use or testing of other high-powered devices in outer space. These activities raise familiar concerns about nuclear weapons and, additionally, may trigger questions about the impacts of explosions in space on the human environment.

Many of the potential impacts of a planetary defense program would occur outside the United States—in fact, off the planet—raising in the extreme the question of NEPA's extraterritorial reach, an issue that has been the subject of extensive debate. In general, there is a presumption against the extraterritorial reach of federal statutes.[99] Neither Congress nor the courts have ultimately decided whether NEPA's requirements apply extraterritorially in all cases; courts that have addressed the issue have produced varied results.[100] In the case

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[97] Eric Schine & Peter Elstrom, *The Satellite Biz Blasts Off*, Bus. Wk., Jan. 27, 1997, at 62, 63.

[98] Andy Reinhardt, *What Goes Up . . . Has to Get There First*, Bus. Wk., Jan. 27, 1997, at 70. For a discussion of nuclear propulsion systems for this application, *see* Pasquale M. Sforza & John L. Remo, *Propulsion Options for Missions to Near Earth Objects*, Acta Astronautica (forthcoming 1997).

[99] *See, e.g.*, Natural Resources Defense Council v. Nuclear Regulatory Comm'n, 647 F.2d 1345, 1366 (D.C. Cir. 1981); Equal Employment Opportunity Comm'n v. Arabian American Oil Co., 111 S. Ct. 1227, 1230 (1991); Environmental Defense Fund v. Massey, 986 F.2d 528, 531 (D.C. Cir. 1993).

[100] *See, e.g.*, Enewetak v. Laird, 353 F. Supp. 811 (D. Haw. 1973) (holding that NEPA applies to Pacific Island Trust Territories, where federal law does not generally apply); Sierra Club v. Adams, 578 F.2d 389 (D.C. Cir. 1978) (assuming, without deciding, that NEPA applies to federally funded construction activities in Panama); Natural Resources Defense Council v. Nuclear Regulatory Comm'n, 647 F.2d at 1366 (holding that NEPA does not apply extraterritorially with respect to nuclear export decisions); Greenpeace USA v. Stone, 748 F. Supp. 749 (D. Haw. 1990) (holding that, based on foreign policy concerns and the application of Executive Order 12114 ("Environmental Effects Abroad of Major Federal Actions"), NEPA did not apply to the transport of chemical munitions abroad). For a general discussion of NEPA's extraterritorial application, see The *Forum: Should NEPA Apply Abroad?*, 8 Envtl. Forum, Nov./Dec. 1991, at 24; Daniel R. Mandelker, NEPA Law and Litigation § 5.04 (1996).

that is probably closest to the asteroid situation, *Environmental Defense Fund v. Massey*,[101] the D.C. Circuit found NEPA applicable to the National Science Foundation's incineration of food waste in Antarctica. NEPA was designed to ensure that federal agencies make decisions after full consideration of the environmental effects; the court held that the regulated conduct is the decision itself, rather than the execution. The *Massey* decision also hinged in part on the fact that the United States exercised a "real measure of legislative control over the region at issue"[102] and that Antarctica was not a sovereign nation with laws that might conflict with those of the United States.

The notion that NEPA regulates not the execution of a decision, but the federal decision-making process itself, which presumably occurs within the United States, might suggest that it should always apply extraterritorially. While the court restricted its decision to the particular facts of the case—notably, that the challenged activity took place in Antarctica—either of the *Massey* rationales suggests that a U.S. sponsored planetary defense program would be subject to NEPA. However, no court has had to confront the question of whether the "environment" protected by NEPA includes outer space. The notion of the environment encompasses our environs and our surroundings, and the idea of proximity and of potential impact (however indirect) upon ourselves is implicit. Though NEPA was enacted the same year that man first walked on the moon, it does not appear that NEPA's framers considered whether the new law would apply to activities in space.[103]

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[101] 986 F.2d 528 (D.C. Cir. 1993).

[102] *Id.* at 534.

[103] The only mention of outer space in NEPA's legislative history comes in a report by the person who is widely credited as the intellectual father of NEPA, Professor Lynton K. Caldwell of Indiana University. This report, which NEPA's sponsor, Senator Henry Jackson, inserted into the record, states:

> The United States, as the greatest user of natural resources and manipulator of nature in all history, has a large and obvious stake in the protection and wise management of man-environment relationships everywhere. Its international interests in the oceanic, polar, and outer space environments are clear. Effective international, environmental control would, under most foreseeable contingencies, be in the interest of the United States, and could hardly be prejudicial to the legitimate interests of any nation. American interests and American leadership would, however, be greatly strengthened if the Nation's commitment to a sound environmental policy *at home* were clear.

115 Cong. Rec. 29066, 29072 (1969) (emphasis added).

A planetary defense program—a concerted plan for detection and for the design and testing of a NEO response system—might trigger the preparation of a "programmatic EIS" for the development of new technology. Agencies may not avoid drafting an impact statement simply because doing so requires "some degree of forecasting."[104] If, hypothetically, the Department of Defense and NASA together devised three possible strategies for responding to the NEO impact hazard and decided to develop and test the three technologies simultaneously, without deciding which would be implemented, an EIS might still be required to consider the environmental effects of the potential technologies. If an NEO deflection program employed already existing technologies, the technology development (as opposed to its use) might not require the preparation of an EIS.[105]

A programmatic EIS requirement can also arise where a group of disparate activities that share the same goal may have a significant environmental impact, even if none of the individual component activities would require an EIS. The Council on Environmental Quality (CEQ) guidelines implementing NEPA define a "major federal action" requiring an EIS as one likely to have environmental effects that include the "[a]doption of programs, such as a group of concerted actions to implement a specific policy . . . ."[106] Where proposed actions are "related to each other closely enough to be . . . a single course of action"[107] then a programmatic EIS will be required, if cumulatively the activities have a significant environmental impact.[108]

Strategic Defense Initiative (SDI) has been the subject of several programmatic EISs and numerous Environmental Assessments related to particular aspects of the program. The No-

[104] Scientists Inst. for Pub. Info. v. Atomic Energy Comm'n, 481 F.2d 1079, 1089 (D.C. Cir. 1973) (holding programmatic Environmental Impact Statement (EIS) required for development of liquid metal fast breeder reactor).

[105] Concerned About Trident v. Rumsfeld, 555 F.2d 817, 826 (D.C. Cir. 1977) (holding Navy not required to look in detail at environmental impacts at all 89 sites under consideration for siting Trident missiles; distinguishing from *SIPI* on grounds that "Trident Program does not involve the implementation of any brand new technology with the possibility of unforeseen or unknown consequences").

[106] 40 C.F.R. § 1508.18(b)(3) (1997).

[107] 40 C.F.R. § 1502.4(a) (1997).

[108] *See, e.g.*, Foundation on Econ. Trends v. Lyng, 817 F.2d 882 (D.C. Cir. 1987) (programmatic EIS not required for Department of Agriculture's animal productivity research on grounds that activities are too diverse and discrete).

tice of Intent to prepare the "umbrella" EIS for the Ballistic Missile Defense System stated that the EIS would examine the potential environmental consequences associated with the life-cycle activities for the proposed action, including "development, testing, production, basing and siting, operations and maintenance support, and eventual decommissioning activities."[109] Although this was the "umbrella" EIS, it did not propose to consider the effects of actually employing any of the weapons systems alternatives.

The risk of "uncontrolled reentry" into Earth's atmosphere is one disturbing aspect of any program that involves space launches of nuclear materials. On November 17, 1996, a Russian space probe bound for Mars malfunctioned and crashed back to Earth, landing in the Pacific Ocean near Chile.[110] It is not known whether the half-pound of plutonium on board was dispersed in the atmosphere, where it may do harm as an airborne toxin, or remained with the spacecraft, where it may persist under water for 2,000 years.[111] As of 1992, six Russian nuclear missions had failed.[112] As of 1991, the United States had launched a total of twenty-five nuclear power sources; of these launches, four failed.[113] In one of those incidents, on April 21, 1964, the "launch vehicle was destroyed after failing to achieve orbit;" the plutonium metal fuel was ejected over the West Indian Ocean and dispersed over the upper atmosphere.[114] In two incidents the nuclear fuel sank into the ocean, and in the fourth "[t]he satellite was subsequently boosted into a higher orbit to ensure sufficient radioactive decay prior to reentry."[115] In October 1997, NASA is planning the launch of a mission to Saturn that will

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109 57 Fed. Reg. 4191 (1992).

110 Michael R. Gordon, *Mystery of Russian Spacecraft: How Did it Fall Back to Earth?*, N.Y. Times, Nov. 19, 1996, at A13.

111 Karl Grossman & Judith Long, *Nuclear Roulette*, Nation, Dec. 16, 1996, at 6.

112 *Id.* Among the failed Russian nuclear missions was the 1978 re-entry into Earth's atmosphere of the radar surveillance satellite Cosmos-954. Carrying a nuclear reactor fueled with enriched uranium, the satellite vaporized in Canadian airspace, leaving a trail of radioactive debris scattered across northern Canada. Karl-Heinz Bocksteiger, *Case Law on Space Activities, in* Space Law: Development and Scope 206 (Nandasiri Jasentuliyana ed., 1992).

113 John W. Lawrence, *Nuclear Power Source in Space: A Historical Review*, Nuclear News, Nov. 1991; at 85.

114 *Id.*

115 *Id. See also* Chris Bryson, *How Safe Are Nuclear-Powered Space Missions?*, Christian Sci. Monitor, Dec. 17, 1996; David L. Chandler, *Mars 96*

involve over seventy-two pounds of plutonium. The EIS for that project reported that an inadvertent reentry to Earth's atmosphere could mean in a worst case scenario that approximately five billion of the estimated seven to eight billion world population could receive radiation exposure, with 2,300 resulting injuries.[116]

All of these incidents involved nuclear power systems for spacecraft. There have also been several dozen accidents with nuclear weapons, known as "broken arrows." These have included the crash (and one midair collision) of planes carrying nuclear bombs; the accidental dropping of nuclear bombs (some of which have still not been found); the crash of an airplane into a nuclear bomb storage facility; and explosions in missile silos and on board nuclear-armed ships. In several of these "broken arrows," the conventional explosives that formed part of the bombs' detonation devices blew up, killing people nearby (mostly servicemen) and causing localized radioactive contamination. In none of these incidents did a nuclear detonation occur.[117]

The EIS for a full NEO program should give at least some consideration to various worst-case scenarios. Such scenarios—a six kilometer wide asteroid crashing undetected into the Earth, the misfire of a nuclear deflection system, causing pieces of an exploded asteroid to impact, or the use of such a system by terrorists, to catalogue some of the more gruesome examples—are all remote possibilities and are difficult to predict. The CEQ's regulations on the consideration of the worst case in an EIS require only that the EIS address "reasonably foreseeable" environmental risks.[118] "Reasonably foreseeable," as defined in the regulations, "includes impacts which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis of the impacts is supported by credible scientific

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Failure Renews Concern About Plutonium-Carrying Spacecraft, BOSTON GLOBE, Dec. 9, 1996, at C1.

116 *See generally* SOLAR SYSTEM EXPLORATION DIVISION, NATIONAL AERONAUTICS & SPACE ADMINISTRATION, FINAL ENVIRONMENTAL IMPACT STATEMENT FOR THE CASSINI MISSION (1995).

117 ANN MARIE CUNNINGHAM & MARIANA FITZPATRICK, FUTURE FIRE: WEAPONS FOR THE APOCALYPSE 205 (1983); CHARLES PERROW, NORMAL ACCIDENTS: LIVING WITH HIGH-RISK TECHNOLOGIES 283-84 (1984). *See generally* SCOTT D. SAGAN, THE LIMITS OF SAFETY: ORGANIZATIONS, ACCIDENTS AND NUCLEAR WEAPONS (1993).

118 40 C.F.R. § 1502.22 (1996).

evidence, is not based on pure conjecture, and is within the rule of reason."[119] Events that have an extremely low probability of occurrence do not require lengthy consideration in an EIS; however, they should be acknowledged.

Exemption from NEPA is available if the government would be required to quickly respond to an emergency. The exemptions will most likely apply to long-period comets. As discussed in Part I, asteroids and short-period comets are generally slower and more predictable, and can therefore be detected earlier.[120] CEQ regulations exempt agencies from NEPA review in emergency circumstances,[121] but the exemption applies only to the activities necessary to respond to the emergency, and requires consultation with the CEQ.[122]

Another potential exemption from the NEPA public review process springs from national security concerns. Documentation of the environmental review process related to new weapons systems is often kept secret. As illustrated by the U.S. Supreme Court's decision in *Weinberger v. Catholic Action of Hawaii*,[123] NEPA's decision-making and public disclosure requirements are distinct. The plaintiffs in *Weinberger* claimed the Navy was required to prepare an EIS with respect to the proposed use of facilities to store nuclear weapons.[124] The Court held that, while the Navy might be required to prepare an EIS for internal purposes, the Navy was not required to make the EIS public.[125] Public disclosure is required under NEPA by specific reference to the Freedom of Information Act (FOIA),[126] which provides that matters critical to the national defense can be protected from disclosure by Executive Order.[127] Much information related to nuclear weapons has been classified as secret pursuant to Executive Order.[128]

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119 *Id.* § 1502.22(b).

120 However, planning a response to any type of large extraterrestrial object on its way towards Earth could take several months or more, which may alter the time frame of what we would normally consider an "emergency."

121 40 C.F.R. § 1506.11 (1996).

122 *Id.*

123 454 U.S. 139, 143 (1981).

124 *Id.* at 142.

125 *Id.* at 146.

126 42 U.S.C. § 4432(2)(c) (1994).

127 5 U.S.C. § 552(b)(1) (1994).

128 MANDELKER, *supra* note 100, § 5.03(7).

The national security exemption from NEPA disclosure is grounded in concerns about secrecy. Maintaining the secrecy of nuclear technology is certainly justified with respect to the technology's technical details, even in relation to a planetary defense program, because there is a legitimate concern that the publication of too much information may enable the wrong people to build nuclear weapons. However, since the "enemy" in this scenario is flying pieces of rock, rather than a sentient being with the ability to formulate a counterstrategy, secrecy with respect to the existence of a planetary defense program and its basic contours may be difficult to justify.

Many aspects of a planetary defense program would deserve consideration under NEPA. Because NEPA establishes procedures rather than benchmark standards of environmental performance, however, even a project with some environmental impacts would be allowed to proceed if the impacts were fully disclosed in the EIS and the sponsoring agency had considered the potential environmental impacts adequately in its decision-making process.

C. *Peripheral Issues*

The actual occurrence of a catastrophic NEO event—i.e., one causing substantial or total destruction of a particular geographic area or of the planet's ability to sustain life—raises a host of interesting, though not entirely legal, issues.

1. *Insurance Coverage*

Well-insured readers will be happy to know that local damage caused by an asteroid or comet is likely to be covered by a general umbrella policy. While general property insurance policies tend to cover only such pedestrian natural disasters as fire, hail, or wind damage,[129] broader umbrella policies often cover both imaginable and unimaginable sources of damage.[130] Of course, the ability of the world's insurance companies to pay all of the claims resulting from a global catastrophe is another matter.

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129 10A Mark S. Rhodes, Couch on Insurance 2d § 42.1 (rev. ed. 1982).

130 16 *id.* § 62:69; 8A John A. Appleman & Jean Appleman, Insurance Law and Practice § 4909.85 (1981).

2. *Selection for Survival*

Assuming that detection of an approaching NEO allowed time to evacuate a small number of people from the planet, how would we decide who was to survive? Or, to turn the tables, if destruction of a NEO required a one-way "kamikaze" mission, who would be on that spacecraft? The supply of volunteers would likely be greater for the former mission than the latter, but both are at bottom not legal questions.

3. *Detection Difficulties*

One practical reason for stepping up the current rate of NEO detection is that detection from the Earth may in the future become more difficult, in spite of technological advances. Some astronomical observatories, once isolated from the impacts of city lights and radio signals, are now finding that light and noise pollution are reducing telescope visibility.[131] The largest telescopes have increasingly had to move away from populated areas to remote locations such as Hawaii and mountainous inland areas. As sources of optical and radio interference—street and house lights, garage door openers, cellular phones, small appliances—increase, some astronomers postulate (presumably in jest) that telescopes will have to be operated from the dark side of the moon.[132]

IV
INTERNATIONAL LEGAL ISSUES

A planetary defense program, whether unilateral or multilateral, would implicate international treaties related to outer space, environmental protection, and arms control. Part IV discusses the most relevant treaties—the Outer Space Treaty, the Partial Test Ban Treaty, the Anti-Ballistic Missile Treaty, and the Space Objects Liability Convention—and addresses other factors affecting international cooperation in this area.

As discussed in Part I, there are many technologies that might be used to deflect or destroy asteroids and comets, including nuclear weapons, pulsed lasers, kinetic energy, mass drivers, and solar sails. Because several of these technologies involve nu-

[131] Malcolm W. Browne, *City Lights and Space Ads May Blind Stargazers*, N.Y. TIMES, May 4, 1993, at C2.
[132] *Id.*

clear power and because nuclear warheads are the only item on the list believed to be powerful enough to move the larger objects,[133] this discussion focuses on the legal implications of the use of nuclear technology in responding to NEOs.

The international community has begun to endorse the idea that a NEO detection and response system should be conducted on an international basis. For example, citing the Tunguska incident, the comet Shoemaker-Levy 9, and the possibility that a NEO impact could be mistaken for a nuclear explosion resulting in international havoc, the Council of Europe passed a resolution in March 1996, encouraging member states to fund international efforts to detect NEOs.[134] Furthermore, in 1995, a three day U.N. conference was devoted to NEO detection and the policy issues related to NEO response systems.[135]

A. *Applicable Treaty Law*

1. *Outer Space Treaty*

The basic principles governing international activities in outer space were established by the 1967 Outer Space Treaty.[136] Adopted by over 100 nations, the Outer Space Treaty provides that, like the high seas and the Antarctic, outer space is not subject to the sovereign jurisdiction of any nation, but rather may be exploited by all nations. This principle departs from the *terra nullus* concept historically applied to terrestrial land masses, per-

133 Ahrens & Harris, *supra* note 17, at 923; Hammerling & Remo, *supra* note 12.

134 Council of Europe, *Resolution on the Detection of Asteroids and Comets Potentially Dangerous to Mankind* (visited Mar. 20, 1996) <http://cfa-www.harvard.edu/~marsden/SGF/resol.html>.

135 *See generally* John L. Remo, *United Nations Conference on Near-Earth Objects*, 5 EARTH SPACE REV. 16 (1996).

136 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *opened for signature* Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 (*entered into force* Oct. 10, 1967) [hereinafter Outer Space Treaty]. A separate agreement relating to the Moon entered into force in 1984. This agreement, however, has only eight signatories, none of whom possess major space capabilities. Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, *opened for signature* Dec. 18, 1979, G.A. Res. 68, U.N. GAOR, 34th Sess., Supp. No. 46, U.N. Doc. A/68 (1979), 18 I.L.M. 1434 (*entered into force* July 11, 1984) [hereinafter Moon Agreement]. The Moon Agreement provides that the moon and other celestial bodies (as to which there are no separate agreements) shall be used only for peaceful purposes and that lunar resources shall be shared equally.

mitting one state to obtain jurisdiction over an area by occupying it.[137] Related to this treatment of outer space as the "province of all mankind" is the idea that outer space should be used only for peaceful purposes.[138] As discussed below, these principles, and the accompanying restrictions on activities in space, make international cooperation critical to the success of a NEO response program.

Article IV of the Outer Space Treaty provides that state parties shall not place into orbit around the Earth nuclear weapons or other weapons of mass destruction, and will not install such weapons on celestial bodies or station such weapons in outer space in any other manner. While chemical and biological weapons were considered by the Outer Space Treaty's negotiators to be weapons of mass destruction,[139] there is some debate as to whether nuclear-powered lasers are in that category.[140] The ban on placing such weapons in orbit, installing them on celestial bodies, or stationing them in outer space was intended to protect nations from space-based threats by other nations, and did not anticipate threats originating in outer space.

Article IV provides further that no State party may test *any* type of weapon on any celestial body.[141] This categorical ban would prevent any signatory from testing any NEO destruction system even on the smallest, most remote asteroid. Also banned are the establishment of military bases and installations and the

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[137] *See* Grier C. Raclin, *From Ice to Ether: The Adoption of a Regime to Govern Resource Exploitation in Outer Space*, 7 Nw. J. Int'l L. & Bus. 727, 733 (1986). The Outer Space Treaty seeks to capture the benefits of outer space for all mankind. While space colonization remains relegated to science fiction, the idea still sparks interest. If space exploration and permanent space installations become more common, the principle of cooperation may become more difficult to implement. In the future, it may be necessary to develop more specific rules governing space activities, perhaps modelled on the U.N. Convention on the Law of the Sea. *See generally id.* at 739-42 (analogizing the Moon Treaty to the Law of the Sea); Fred Kosmo, *The Commercialization of Space: A Regulatory Scheme that Promotes Commercial Ventures and International Responsibility*, 61 S. Cal. L. Rev. 1055 (1988) (preparing a model system to promote American commercialization of space); Heidi Keefe, *Making the Final Frontier Feasible: A Critical Look at the Current Body of Outer Space Law*, 11 Santa Clara Computer & High Tech. L.J. 345 (1995) (assessing flaws in current outer space legal regime).

[138] *See* Outer Space Treaty, *supra* note 136, preambles.

[139] Jozef Goldblat, Arms Control: A Guide to Negotiations and Agreements 119 (1994).

[140] Bocksteiger, *supra* note 112, at 147.

[141] Outer Space Treaty, *supra* note 136, art. IV.

"conduct of military maneuvers" on any celestial body.[142] The only type of military activity in outer space that is not clearly prohibited by the Outer Space Treaty is activity that: (1) does not come into contact with any celestial bodies and (2) does not involve the installation of weapons of mass destruction in outer space. The passage through space of weapons of mass destruction on their way back to Earth, without making a full orbit, would be permitted. The launch of a ballistic missile from one country to another via outer space is therefore not prohibited. Presumably, also, the installation in outer space of weapons that are not characterized as "weapons of mass destruction" would also be permitted. While, as described above, there is no universal agreement about what is included in the definition of "weapons of mass destruction," most weapons powerful enough to move a large asteroid are likely to qualify (though solar sails or reflectors, for instance, might not).

2. *Partial Test Ban Treaty*

Any testing of a nuclear planetary defense system would also violate the multilateral 1963 Partial Test Ban Treaty,[143] which prohibits nuclear weapon test explosions and any other type of nuclear explosion anywhere in outer space that is under the "jurisdiction or control" of the party conducting the explosion. The "other type of nuclear explosion" provision was included to prevent circumvention of the treaty and to avoid the need to differentiate between military and civilian uses.[144] The phrase "under its jurisdiction or control" was intended to extend the ban to non-self-governing territories, but not to territories under hostile control.[145] In other words, the Treaty does not on its face prevent explosions in enemy territory during armed hostilities. A good argument could be made that an asteroid or comet threatening the Earth is not under the "jurisdiction or control" of any nation, and therefore that the detonation of nuclear weapons would not be prohibited by the letter of the Treaty.[146]

142 *Id.*

143 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, Aug. 5, 1963, 480 U.N.T.S. 43 [hereinafter Partial Test Ban Treaty].

144 GOLDBLAT, *supra* note 139, at 41.

145 *Id.*

146 This conclusion does not reach the threshold question of whether the use of nuclear weapons violates a basic principle of international law, or whether

Barring an imminent threat (one that would be analogous to a hostile attack), testing of a nuclear planetary defense system on such an object would clearly violate the Partial Test Ban Treaty.

3. *Anti-Ballistic Missile Treaty*

The bilateral 1972 Anti-Ballistic Missile (ABM) Treaty limits the testing and deployment of "systems to counter strategic ballistic missiles or their elements in flight trajectory."[147] The ABM Treaty grew out of the notion that effective deterrence required mutual vulnerability to a second-strike attack.[148] The United States or the Soviet Union would only be deterred from attacking if it did not have the ability to repel a counterattack. The ABM Treaty prohibits the development, testing, and deployment of ABM systems which are sea-based, air-based, space-based, or mobile-land based. Each party was allowed only two fixed ABM sites, one to defend the nation's capital, the other to defend an ICBM complex.[149] The Treaty also prohibited the transfer of ABM technology to other states.

Compliance with the Treaty was relatively good until the establishment of the Strategic Defense Initiative (SDI) under President Reagan in 1983.[150] SDI was a space-based anti-ballistic missile program intended to provide full protection for the United States against a Soviet nuclear attack. U.S. officials now agree that SDI, if implemented, would have violated the ABM Treaty.[151] The Soviet Union never challenged SDI in its design and testing stages, and it was never deployed. The program has since been renounced by the Clinton administration in favor of a strategy that protects the United States from an unexpected nu-

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such use would be viewed as justified in a particular circumstance. *See* International Court of Justice, Advisory Opinion on the Legality of the Threat of Use of Nuclear Weapons, July 8, 1996, 35 I.L.M. 809 (holding that there is no *per se* prohibition of the use of nuclear weapons in international law).

147 United States-Soviet Treaty on the Limitation of Anti-Ballistic Missile Systems, May 26, 1972, art. II, 11 I.L.M. 784 [hereinafter ABM Treaty].

148 *See, e.g.*, PAUL ROGERS & MALCOLM DANDO, A VIOLENT PEACE: GLOBAL SECURITY AFTER THE COLD WAR 163 (1992).

149 GOLDBLAT, *supra* note 139, at 55.

150 *Id.* at 55-57. *See also* Major John E. Parkerson, Jr., *International Legal Implications of the Strategic Defense Initiative*, 116 MIL. L. REV. 67 (1987).

151 GOLDBLAT, *supra* note 139, at 57-58. At the time, representatives of the U.S. Government argued that the Treaty was ambiguous and that systems based on new technologies were not covered. *See* United States: Statements on ABM Interpretation, Oct. 22, 1985-Dec. 1, 1986, 26 I.L.M. 282 (1987).

clear attack by a renegade terrorist state.[152] While a planetary defense system would not be a "system to counter strategic ballistic missiles" and therefore its deployment would not be prohibited, the legal challenge would be distinguishing between a system designed to protect against asteroids and a system directed at missiles. It might therefore be difficult for either the United States or Russia[153] to develop a planetary defense system unilaterally without risking apparent violation of the ABM Treaty.

4. *Space Objects Liability Convention*

The 1972 Convention on International Liability for Damage Caused by Space Objects (Liability Convention)[154] establishes the principle that a launching State is absolutely liable for damage to the surface of the Earth or to aircraft in flight caused by objects launched into space.[155] For this purpose, a "launching State" includes not only the state from whose territory a space object is launched, but also any state that launches or "procures the launching" of a space object.[156] If a launch conducted as part of a widely ratified planetary defense program failed and caused damage in a state that had not ratified the program, all participating states might be deemed to be launching States and might therefore be liable to the non-participating state jointly and severally.[157] The Liability Convention establishes a dispute resolution system that mandates non-binding arbitration via a Claims Commission[158] in the event that the parties cannot come to an agreement about compensation through diplomatic channels.

The Liability Convention also provides that damages are to be determined "in accordance with international law and the principles of justice and equity."[159] It is possible that the Claims Commission might take the view that a planetary defense program benefits all nations and might therefore allocate liability for

152 GOLDBLAT, *supra* note 139, at 58.
153 Russia succeeded the Soviet Union as a signatory to the ABM Treaty. Recent Actions Regarding Treaties To Which The United States Is Not A Party, Apr. 30, 1993, 32 I.L.M. 929 (1993).
154 24 U.S.T. 2389 (1972).
155 *Id.*, art. II.
156 *Id.*, art. I.
157 *Id.*, art. V.
158 The arbitration is binding if the parties so elect in advance. *Id.* art. XIV.
159 *Id.*, art. XII.

related accidents equally. The idea that nations supporting a planetary defense program are essentially good samaritans coming to the aid of the entire planet might also (absent any gross negligence) support a more equal sharing of liability.

The one real test of the Liability Convention's procedures came in 1979. Canada invoked the Liability Convention after spending six million dollars to conduct clean-up activities in the wake of the 1978 crash of the Soviet satellite Cosmos-954 in Canadian territory. The parties eventually signed a protocol settling the matter, within which the Soviet Union agreed to pay Canada approximately three million dollars (Canadian).[160]

Damages from failed launches have thus far been limited. Debris from exploded comets or asteroids entering the Earth's atmosphere can cause massive damage. Under the Liability Convention, nations might be responsible for any damage caused in other parts of the world as a result of either the testing or deployment of a planetary defense system. A good argument, however, can be made that incidental (even if massive) damage is an excusable collateral effect of a mission that is necessary to protect against even greater destruction.

B. *Testing Versus Deployment Under International Treaty Law*

The Outer Space Treaty was clearly concerned with protecting the Earth from threats of an Earthly origin and did not contemplate the need to use weapons to protect the Earth from potential impacts by asteroids or comets. Similarly, neither the Partial Test Ban Treaty nor the ABM Treaty were meant to address threats other than those originating from other nations. While a program to test the planetary defense system by, for example, exploding distant asteroids would violate the letter of the Outer Space Treaty and the Partial Test Ban Treaty, the issue of whether this violation would result in international legal sanctions (such as the imposition of a trade embargo or other multilateral action), or even the disapproval of other nations, is a separate question.

The reaction of the international community would depend in part on its view of the genuineness of the testing effort. It is doubtful, in the face of an imminent hazard, that any nation would object to the testing of a program designed for the sole

[160] For a discussion of this incident, see Bocksteiger, *supra* note 112, at 206.

purpose of protecting the planet. On the other hand, objections would likely arise if other nations felt that a planetary defense program was a pretext for otherwise prohibited weapons testing or if the test was seen to pose unacceptable Earth-based risks such as those associated with launch failure. It is also likely that, absent an imminent threat, some preservationists might be concerned about destroying or damaging celestial objects or generally causing outer space pollution.

The reaction of other nations would also be influenced by which nation was conducting the testing. If a small state with a developing nuclear program were to start conducting unilateral tests on asteroids, the international community might view the activity as an attempt to improve the state's nuclear program for defense or aggression. If, on the other hand, the United States and Russia were to commence joint testing of a planetary defense program, the international community might be less suspicious of the motive. In any event, the fact that no less than two international treaties prohibit the meaningful testing of a planetary defense program underscores the importance of obtaining international consensus on the issue before the commencement of any such program, particularly in the absence of an emergency.

Neither the Partial Test Ban Treaty nor the Outer Space Treaty expressly prohibit the launch of ballistic missiles carrying nuclear weapons heading towards a hostile nation. But either could be interpreted to prohibit any nuclear explosion in space; this is not because the drafters of these treaties would have intended such an interpretation, but rather because they did not envision the need to respond to a NEO threat. However, it is persuasive to argue that if a rapidly approaching NEO were sighted, the United States should be able to invoke the justification of self-defense, the right to which is codified in the U.N. Charter,[161] in support of a decision to launch a nuclear missile. Many view self-defense as an inherent and autonomous right existing independently of any positive law[162] and therefore superseding obligations under positive law.

161 U.N. CHARTER art. 51.

162 *See, e.g.*, Military and Paramilitary Activities in and Against Nicaragua (Nicaragua v. U.S.), 1986 I.C.J. 14, 94 (June 27) ("It is hard to see how [self-defense] can be other than of a customary nature, even if its present content has been confirmed and influenced by the Charter."). *See generally* Oscar Schachter, *Self-Defense and the Rule of Law*, 83 AM. J. INT'L L. 259 (1989);

The justification of self-defense is stronger in the NEO context than the more typical scenario, where self-defense is used to justify aggression against another nation. Successful planetary defense is, assuming the mission is successful, a victimless activity, harming no one and causing no violation of another nation's sovereignty. This is quite different from the situation where a nation invades another nation, kills people, and claims self-defense.[163] Similarly, "humanitarian intervention" to save others from a NEO impact requires less justification (again, assuming that the mission is successful and does not otherwise risk human life) than a humanitarian mission that involves the invasion of another country.[164] These rationales for a planetary defense mission should, therefore, be readily available to counter arguments about arms control treaty violations in an emergency situation.

In the absence of testing, great physical uncertainties would surround a defense mission. Would calculations about the flight paths of the missiles and the comet prove correct? Would the blast be of a magnitude and nature sufficient to destroy the comet or move it out of our way? What is the best place (for example, above, below, or on the object) to detonate the weapon? Would the explosion send comet fragments hurtling towards the Earth? Of course, many of these questions would be unanswerable even with extensive outer space testing of response systems—the precise path of a comet is often unpredictable, the composition of any particular object may be different from what was anticipated, and we may not be able to model accurately all the forces at work on objects in space.

The Outer Space Treaty's goal of fostering cooperation among nations in the exploration of outer space may provide a

David R. Penna, *The Right to Self-Defense in the Post-Cold War Era: The Role of the United Nations*, 20 DENV. J. INT'L L. & POL'Y 41 (1993).

163 Self-defense was claimed in the following instances, among others: Kuwait's response to Iraqi invasion; U.S. military actions in Nicaragua and Grenada; the USSR's invasion of Afghanistan; Israeli attacks on Palestinian camps in Jordan; and Argentina's intervention in the Falkland Islands. *See* Schachter, *supra* note 162, at 265.

164 Unilateral missions characterized as humanitarian rescue missions (with varying degrees of agreement by the international community) have included the following: Israel's 1976 rescue mission at a Ugandan airport; France's 1979 intervention in the Central African Republic; and India's 1971 intervention in Pakistan. Steve G. Simon, *The Contemporary Legality of Unilateral Humanitarian Intervention*, 24 CAL. W. INTL. L.J. 117, 145-49 (1993). Many other such missions have, of course, been conducted on a multilateral basis under the auspices of the United Nations.

rationale for a global effort to address NEO threats. The Outer Space Treaty provides that

> States Parties to the Treaty shall regard astronauts as envoys of mankind in outer space and shall render them all possible assistance in the event of accident. . . . States Parties . . . shall immediately inform the other States Parties . . . of any phenomena they discover in outer space, including the moon and other celestial bodies, which could constitute a danger to . . . astronauts.[165]

The parties either did not envision a situation in which a celestial body might constitute a danger to the Earth itself or thought the possibility too remote to include in the Outer Space Treaty. The parties, however, did see the Outer Space Treaty as the framework for global cooperation in space efforts, including protection against space-based threats to humans. In the face of a threat to survival, the fact that the right to national self-defense is codified in the U.N. Charter,[166] and is accepted as part of customary international law, provides a legal rationale—as if any were needed—for the international community not to see the Outer Space Treaty and the Partial Test Ban Treaty as impediments to a planetary defense program.

To the extent that a planetary defense program includes the expansion or continuation of nuclear weapons development, it might also violate both the letter and the spirit of the Partial Test Ban Treaty, one of the stated objectives of which is to "put an end to the contamination of man's environment by radioactive substances."[167] It is also possible that other arms control treaties—such as the bilateral Treaty on Reduction and Limitation of Strategic Offensive Arms (START I)[168] and the Non-Proliferation Treaty[169]—could be implicated if new or additional nuclear weapons technology were necessary, or if nations without nuclear weapons capability wished to participate in the planetary defense program. START I limited the number and types of nuclear weapons that the United States and the former Soviet

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165 Outer Space Treaty, *supra* note 136, art. V. International obligations to protect astronauts were expanded by the 1968 Agreement on the Rescue of Astronauts. Return of Astronauts and the Return of Objects Launched into Outer Space, Dec. 3, 1968, 19 U.S.T. 7570.

166 U.N. CHARTER art. 51.

167 Partial Test Ban Treaty, *supra* note 144, preamble.

168 Treaty on Reduction and Limitations of Strategic Offensive Arms, July 31, 1991, 31 I.L.M. 246 (1992).

169 Non-Proliferation Treaty, July 1, 1968 7 I.L.M. 809.

Union were permitted to maintain and test. It is possible that the development of new weapons might either be prohibited under START I or might displace weapons in a certain START I category.

The 1968 Non-Proliferation Treaty[170] prevents the transfer to or the development by non-nuclear states of a nuclear weapons program. The nuclear powers agreed in exchange to pursue disarmament talks "in good faith."[171] The bargain struck between the nuclear and the non-nuclear states also included positive assurances that the nuclear states would come to the aid of the non-nuclear states in the event of a nuclear attack.[172] Presumably, non-nuclear states would want some similar assurances in the event of the development of a nuclear planetary defense system, to the effect that such a system would not be used for Earth-based attacks and would be used in the unlikely event of a NEO threat headed only toward a non-nuclear state.

C. *Environmental Issues*

Space launches are accompanied by certain environmental impacts that may, in the aggregate, be significant enough to implicate international treaty obligations. The greatest atmospheric damage connected with rocket exhaust probably occurs in the upper atmosphere, where the very thin air prevents released gases from mixing or dispersing easily. As noted above, while rocket fuel has been connected to ozone layer depletion, further study is needed to determine the effect of rocket launches and space activity in general on atmospheric pollution.[173] Launches associated with anti-NEO defense, however, would only be a small fraction of all space launches, and therefore would not be likely to contribute significantly to any atmospheric degradation.

The Outer Space Treaty provides that parties shall "conduct exploration of [celestial bodies] so as to avoid their harmful contamination."[174] While "harmful contamination" is not defined, this provision contemplates the preservation of celestial bodies in their natural state and is certainly inconsistent with blowing up or

170 *Id.*

171 *Id.*, art. VI.

172 U.N. Security Council Resolution 255 on Security Assurances to Non-Nuclear Weapons States, June 19, 1968, S/RES/255.

173 *See supra* text accompanying notes 95 to 98.

174 Outer Space Treaty, *supra* note 136, art. IX.

irradiating asteroids or comets.[175] Existing international environmental law[176] and the Liability Convention[177] also support the principle that nations have an obligation not to pollute outer space.

Debris left in orbit from space activities currently poses some risks to space launches and to satellites and this will likely continue to increase.[178] Eventually, specific guidelines should be created by the international community.[179] In the meantime, the architects of any planetary defense program should keep in mind the goal of minimizing space debris. This is a further reason to minimize testing or, if necessary, to carry it out if possible in locations that are so remote that any resulting debris (except, of course, that from a failed launch) would not threaten human activities.

To the extent that any planetary defense program employs nuclear power in its propulsion (as opposed to nuclear weapons), the U.N. General Assembly Resolution and Principles Relevant to the Use of Nuclear Power Sources in Outer Space ("Nuclear

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175 For purposes of this analysis, we could assume that "harmful contamination" means anything that damages the surface, integrity, or atmosphere (if any) of the celestial body or, in the alternative, anything that humans would find harmful.

176 Principle 21 of the Stockholm Declaration on the Human Environment provides that "[s]tates have, in accordance with the Charter of the United Nations and the principles of international law . . . the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment . . . of areas beyond the limits of national jurisdiction." Declaration of the United Nations Conference on the Human Environment, June 16, 1972, 11 I.L.M. 1416. The use of the phrase "jurisdiction and control" from the Outer Space Treaty suggests that Principle 21 may apply to outer space as well as to Earth. Lawrence D. Roberts, *Addressing the Problem of Orbital Space Debris: Combining International Regulatory and Liability Regimes*, 15 B.C. INT'L & COMP. L. REV. 51, 66 (1992). The extent of the "environment," however, remains an open question.

177 *See supra* note 155.

178 A United Nations status report on space debris reported that as of 1988 there were approximately 7,000 man-made objects larger than 20 centimeters in size in near-Earth orbit, most of which are fragments of launched objects. Bocksteiger, *supra* note 112, at 163 (citing *Space Debris: A Status Report*, Committee on Space Research Annex, U.N. Doc. A/AC.105/403 (Jan. 6, 1988).

179 *See generally* Glenn H. Reynolds, *Space Law in the 1990s: An Agenda for Research*, 31 JURIMETICS J. 1 (1991); Roberts, *supra* note 176; Major Bernard K. Schafer, U.S.A.F., *Solid, Hazardous, and Radioactive Wastes in Outer Space: Present Controls and Suggested Changes*, 19 CAL. W. INT'L L.J. 1 (1988).

Power Principles")[180] will be implicated. While resolutions of the General Assembly are non-binding,[181] the Nuclear Power Principles were the result of twenty years of negotiations by the U.N. Committee on the Peaceful Uses of Outer Space (COPUOS) and represent an important step in the evolving outer space legal regime.[182] The Nuclear Power Principles provide that "nuclear power sources in outer space shall be restricted to those space missions which cannot be operated by non-nuclear energy sources in a reasonable way."[183] While not an absolute prohibition, the Nuclear Power Principles require serious consideration of alternative energy sources. With respect to the risk of radiation exposure, the Nuclear Power Principles provide that "the design and use of space objects with nuclear power sources on board shall ensure, with a high degree of confidence, that the hazards, in foreseeable operational or accidental circumstances, are kept below acceptable levels . . . ."[184] The record of past nuclear-powered space launches suggests that such assurances are difficult to provide.

D. *Multilateral Action*

The potential for some type of accident or misuse of a testing program suggests that the least risky option at present (both physically and legally) is to create only a global detection system. Such a system would cost very little, compared to other similar programs, and poses no apparent risks. If the international community decides to proceed with the design and testing of a planetary defense system, in spite of evidence demonstrating that it may be safer to concentrate on detecting NEOs and worry about deflecting them later if a threatening object is found, the effort should be multilateral and should be accompanied by an agreement to exculpate the launching country, if the launching country is acting with reasonable care and with the consent of all parties.

With regard to the deployment of a planetary defense system against an imminent threat, the potentially catastrophic re-

180 General Assembly Resolution and Principles Relevant to the Use of Nuclear Power Sources in Outer Space, Dec. 14, 1992, 32 I.L.M. 917 [hereinafter Nuclear Power Principles].

181 U.N. CHARTER art. 10, &1.

182 *See* Carl Q. Christol, Introduction to Nuclear Power Principles, *supra* note 180, 32 I.L.M. at 917.

183 Nuclear Power Principles, *supra* note 180, 32 I.L.M. at 922.

184 *Id.*

sults of a NEO impact would render any concerns about international liability trivial in comparison and therefore irrelevant. Each nation would be motivated to respond to a potential NEO impact in order to protect itself and, one hopes, the rest of mankind. The international legal regime, however, should encourage nations to act on behalf of the planet as a whole, with international consent where time allows.

A further rationale for a multilateral response system is that the risks of direct NEO impacts are distributed equally around the globe which respect to surface area.[185] It may be difficult or impossible even to predict where a comet or asteroid would land more than a few hours or days in advance of its impact.[186] This is an attribute particular to threats from outer space.[187]

Practical reasons also support a multilateral detection effort. International cooperation will be necessary not only to address potential treaty violations, but also because it is impossible to track all approaching NEOs from one continent. To achieve a comprehensive tracking system, wide geographical coverage of optical observatory sites is essential; both the northern and southern hemispheres must be covered.[188] The Spaceguard Survey proposal for six detection sites worldwide, for example, involves five countries. International cooperation among asteroid-spotters is not a new idea; for years astronomers have communicated their sightings to one another through the Central Bureau for Astronomical Telegrams in Cambridge, Massachusetts.[189] Similarly, nations have historically cooperated in the placement and tracking of satellites and the division of the frequency band

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185 This is not true with respect to the risks of flooding by tsunamis if a large asteroid hit the ocean. Coastal nations are at much greater risk than wholly inland nations. For example, the UK's risk is greater than Germany's; and, given the relative size of the bodies of water (and therefore the impact risk), countries on the Pacific are at greater risk of tsunamis than are countries on the Mediterranean. All nations, however, are probably at equal risk of a direct NEO impact, proportionate to their land mass.

186 *See supra* notes 35-37 and accompanying text.

187 Even climate change presents greater risks to some countries than others. Island nations, for example, are at greater risk with respect to climate change because melting polar ice caps might place them below sea level.

188 THE SPACEGUARD SURVEY: REPORT OF THE NASA INTERNATIONAL NEAR-EARTH-OBJECT DETECTION WORKSHOP 8.1 (1994) <http://ccf.arc.nasa.gov/sst/spaceguard.html>.

189 Sightings are reported to Central Bureau for Astronomical Telegrams and from there are disseminated to subscribers, usually via e-mail. *See, e.g.*, Ferris, *supra* note 9, at 44.

spectrum through the International Telecommunications Union, a U.N. body established in 1982.[190]

Decision-making will of course be more difficult as more nations are involved, particularly because matters of national security are implicated. The decision to establish an international NEO detection and tracking system should be simple, given that the costs are relatively low and current technology could be employed. The three critical decision points are the commencement of a planetary defense program, the decision that a particular threat warrants its use, and the selection of how and when to use it. While nations will certainly differ on the structure of a planetary defense program, acting by consensus with full transparency will be less likely to create international concern and possible instability in response to a program that involves weapons development and testing. If there are vehement disagreements about proceeding with such a program, however, commencing a NEO response testing program may cause greater detriment—in the form of international political instability—than benefit.

The second and third critical decision points arise when an Earth-bound NEO is discovered. Again, if time allows, international consensus is preferable to unilateral action. The U.N. Security Council, given the mandate of settling disputes between nations in the case of "dispute[s] . . . likely to endanger the maintenance of international peace and security,"[191] should be involved if the use of weapons of mass destruction is contemplated. If there is very little advance warning, a nation may have to respond without more than perfunctory consultation with other nations, perhaps through the Security Council. The "hot line" system for communicating in the event of an accidental launch or other emergency could be used for this purpose. After the Cuban missile crisis, Moscow and Washington established the hot line to guard against miscommunication in stressful circumstances and reduce the risk of a nuclear attack premised on misinformation. The original telegraph and radio links provided 24-hour communication ports between the two capitals. The agreement was revised in 1971 to provide for more reliable satellite links instead. Other safeguards such as the Nuclear Accidents

[190] *See* Francis Lyall, *Law of Satellite Communications*, *in* SPACE LAW, *supra* note 112, at 113.

[191] U.N. CHARTER art. 34, &1.

Agreement of 1971[192] and the Prevention of Nuclear War Agreement of 1973[193] clarified procedures in case of emergencies or misunderstandings.

The hot line has been used several times, mainly during military crises such as the Arab-Israeli wars of 1967 and 1971, the 1971 Pakistan-India war, and the 1979 Soviet intervention in Afghanistan.[194] In 1987, the two superpowers took the step of establishing Nuclear Risk Reduction Centers in each country, which would serve to notify the other in the case of accidental missile deployment. A system structured like the former U.S.-Soviet system, especially if it were expanded to include the other members of the U.N. Security Council, which would facilitate contact with any other nation in the event a NEO were headed in its direction, would be sufficient to handle the exceedingly unlikely planetary defense emergency.

E. *Paying For the NEO Program*

Funding an international NEO program may face some of the roadblocks that afflict many other international efforts. Developing nations focused on building infrastructure and feeding the population may not want to allocate resources to a remote threat. This issue was encountered in the implementation of the U.N. Framework Convention on Climate Change ("Climate Change Convention"),[195] which has the goal of stabilizing or reducing worldwide greenhouse gas emissions. Many developing nations said that they would implement technologies as required by the Climate Change Convention only if implementation were funded largely by the wealthier, developed nations.[196] In this case, just as in the Climate Change Convention, certain nations may have to decide if the benefits of the NEO defense program justify paying a disproportionate share of the costs.

[192] Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War Between the United States and the Union of Soviet Socialist Republics, Sept. 30, 1971, 10 I.L.M. 1172.

[193] Agreement Between the United States of America and the Union of Soviet Socialist Republics in the Prevention of Nuclear War, June 22, 1973, 12 I.L.M. 896.

[194] GOLDBLAT, *supra* note 139, at 202.

[195] United Nations Conference on Environment and Development: Framework Convention on Climate Change, May 9, 1992, 31 I.L.M. 849.

[196] *See generally* Daniel Bodansky, *The United Nations Framework Convention on Climate Change: A Commentary, in* GREENING INTERNATIONAL LAW (Philippe Sands ed., 1994).

Because the costs of a detection program are so low, a few nations may not object to funding such a program largely on their own. If one or more nations decide to proceed with the development of a planetary defense program, the benefits of having control of the technology, and therefore preventing its misuse, may outweigh the desire to share the costs with others.

The tasks of coordinating the funding, administration, and planning of NEO detection and countermeasure programs could be carried out by an existing organization, COPUOS, which includes delegations from all the space-faring nations and several others. COPUOS drafted most of the existing treaties concerning outer space, and seems to be well suited to forge new international agreements dealing with NEOs.[197]

Conclusion

As knowledge about near-Earth objects improves, we are learning that the risks posed to Earth by NEOs are of the same numerical magnitude as many other risks to whose prevention society has devoted significant money and attention. Yet the amount of money currently devoted to NEO detection is tiny when compared to the resources devoted to risks of similar magnitude—in some cases, thousands of times lower.[198]

A comprehensive program for NEO detection is relatively inexpensive and is by far the most effective way to improve the chances that a NEO could be prevented from doing significant damage to the Earth. Nations with astronomical capabilities should make a commitment to provide continued funding for a multi-year NEO detection project. The contributions required are low in comparison to the potential benefits.

On the other hand, implementation of a planetary defense program is much more expensive and much less likely to provide overall global benefits. In addition to its implications under U.S. and international law, the development of a weapons-based NEO response program raises significant concerns regarding accidents or misuse. Any advantages of testing or deploying a nuclear-based NEO defense system, in the absence of a known threat, are greatly outweighed by the dangers of creating such a defense system.

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197 *See* Gary L. Bennett, *Reaching the Outer Planets-With or Without the U.N.*, AEROSPACE AM., July 1996, at 26. *See also* Remo, *supra* note 135, at 16.

198 *See supra* notes 42-43 and accompanying text.

It is possible that international activity related to NEOs might eventually reach a point where a treaty addressing the subject would be a useful way to delineate rules and respective national responsibilities. Some elements of an eventual international agreement on detection of and response to NEOs might be full transparency of national NEO response efforts; exculpation of nations launching spacecraft as agreed and authorized by the international NEO program; establishment of a NEO detection and response agency to manage the international effort (perhaps COPUOS); formalization of information and technology sharing processes; institution of emergency response procedures to address potential NEO collisions and accidents; and prohibition of any unilateral planetary defense program except in the case of emergencies. Some or all of these provisions could be included in a revision of the Outer Space Treaty.

However, the time for a treaty is a long way off. The current priority—both in the United States and internationally—should be establishing consistent funding for NEO detection and tracking.