

TRASHING THE FINAL FRONTIER: AN EXAMINATION OF SPACE DEBRIS FROM A LEGAL PERSPECTIVE

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I.	INTRODUCTION	369
II.	EXISTING LAW	376
A.	<i>International Law: The Outer Space Treaty</i>	376
B.	<i>The United States Law: NASA's Space NEPA</i>	379
1.	NASA's Implementation of Its NEPA Regulation	384
III.	SUGGESTIONS UNDER EXISTING LAW	388
A.	<i>Challenge NASA's Findings Using NEPA</i>	388
B.	<i>Combining NEPA and the Outer Space Treaty to Address the Proliferation of Space Debris</i>	392
IV.	CONCLUSION AND RECOMMENDATIONS	394

I. INTRODUCTION

The rapidly growing space junkyard evidences humans' ever increasing presence in space. Space debris emanates from various sources as a result of human activities in space. It poses a threat to manned and unmanned space missions and interferes with earth-based astronomical research.¹ A great deal of space junk was (and continues to be) deposited into space knowingly and intentionally (*i.e.*, when launched, it was known that the objects were or would ultimately become waste). Some debris, however,

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1. This paper will not address naturally occurring sources of space debris (such as meteor collisions) because they are a natural component of the extraterrestrial environment.

has been left in space either negligently or unintentionally.² Regardless of the reasons, with each space mission, the problem grows more severe.

As early as 1961, less than four years after the Soviets launched Sputnik 1, the United States Air Force had discovered and tracked approximately sixty foreign objects in orbit.³ Later that year, the number had risen to over 300 objects as the result of a space communications experiment, Project "West Ford," carried out by the United States.⁴ By 1966, the number had risen to over 1300 trackable objects of ten centimeters or larger.⁵

Today, in a 200 mile-deep sphere of space, the United States Space Command is tracking over 7500 objects of space debris, the combined weight of which is more than 6.5 million pounds.⁶ Even more alarming is the research discovery made in 1989 using the Arecibo radiotelescope in Puerto Rico and the Goldstone dish antenna in southern California. A mere sampling of portions of the sky revealed 150,000 Earth-orbiting objects measuring at least one centimeter across. The Goldstone data suggest that an additional one million two millimeter-sized objects are whizzing through outer space.⁷

2. During a flight of the Discovery space shuttle, a screwdriver was accidentally dropped and never recovered. This screwdriver is now a part of the space debris population. Diederiks-Verschoor, "Legal Aspects of Environmental Protection In Outer Space Regarding Debris," *The Thirtieth Colloquium on Law of Outer Space*, at 131 (1987).

3. Jonathan Eberhart, *Tallying Orbital Trash*, SCIENCE NEWS, July 14, 1990, at 29.

4. Project West Ford involved the ejection of a 35 kg canister containing 350 million hair-like copper dipoles. In theory, these dipoles were supposed to slowly disperse to form an orbital belt that would act as a passive reflector for relaying military communications. Unfortunately, most of the dipoles remained clumped together. Consequently, the clumps, which have a much longer lifetime than the dipoles (which decayed as planned within a few years) are still in orbit. In January 1987, 60 out of the 102 tracked clumps remained in orbit. Karl-Heinz Böckstiegel & Marietta Benkő, *Editor's note in SPACE LAW: BASIC DOCUMENTS A.VI.1*, at 1 (Karl-Heinz Böckstiegel & Marietta Benkő eds., 1991).

5. Eberhart, *supra* note 3, at 29.

6. Paul Hoversten, *Flying Defensively*, DISCOVER, Apr. 1990, at 28.

7. Eberhart, *supra* note 3, at 29.

Others estimate the number of microparticulate space objects at 3.5 million.⁸ Pieces of space junk less than four inches in diameter comprise ninety-nine percent of man-made space trash.⁹ While seemingly innocuous, these tiny bits of debris can disable or destroy a large spacecraft. Every piece of space junk is moving at amazingly high speeds and even the smallest fragments pose a serious threat to space exploration.¹⁰

The increasing magnitude of the menace and economic costs associated with space junk cannot be ignored. In 1989, space junk caused two dedicated display units in the Columbia/Astro mission to overheat and burn up, preventing several planned outer space observations.¹¹ Engineers believe that the failure was caused by overheating from trapped debris.¹² Although microscopic analysis has not yet been completed, a NASA data systems engineer stated that the debris "looked like it consisted of blue lint, human hair of several different colors, several colors of paint chips, a piece of food that looked like a piece of a peanut, and some clear bits, probably of glass and plastic."¹³ Also, during a Soviet space mission in 1987, a cosmonaut's life was endangered when he attempted to retrieve a plastic sandwich bag that was preventing the spacecraft from docking.¹⁴

In 1984, the Solar Max satellite was permanently disabled after it collided thousands of times with what may have been

8. Mark D. Uehling, *Tackling the Menace of Space Junk*, POPULAR SCIENCE, July 1990, at 82, 83.

9. *Id.*

10. Debris in space can reach speeds as high as Mach 20. Each particle of debris delivers four times its weight in TNT. For example, a two inch piece of space trash travelling at 15,000 miles per hour (an average speed) could strike with the force of a steel safe dropped from a ten story window. *Id.* at 82-83.

11. The pointing and control problems forced reliance on ground command for telescope positioning during much of the flight. *Trapped Debris Called Culpit for Overheated Pointing Units Aboard Columbia/Astro Mission*, AVIATION WK. & SPACE TECH., Jan. 7, 1991, at 40.

12. *Id.*

13. *Id.*

14. *Risks From Rubbish In Space*, NEW SCIENTIST, Aug. 11, 1988, at 25.

nearly invisible pieces of rocket fuel or satellite fragments.¹⁵ Scientists who examined the aforementioned debris also discovered microscopic shards of human urine.¹⁶

The most widely publicized accident involving space debris occurred in 1983, when the space shuttle Challenger was struck by a paint chip measuring 0.2 millimeters across. The small fleck of paint struck Challenger's window, requiring that NASA replace the glass at a cost of \$50,000.¹⁷

Inactive payloads, which consist primarily of consumed Earth-orbiting satellites and space probes, account for approximately twenty percent of the total trackable space debris population.¹⁸ Presently, more than 1000 of these inactive payloads are careening through space and their numbers will continually multiply as more and more satellites are launched into space.¹⁹

Operational debris constitutes twenty-six percent of the trackable space debris.²⁰ This type of debris includes rocket bodies and apogee kick motors, payload shrouds, separation hardware and packing devices, empty fuel tanks and insulation, window and lens covers, raw propellant, and frozen sewage.²¹

15. Uehling, *supra* note 8, at 83.

16. *Id.*

17. Joel D. Scheraga, *Curbing Pollution In Outer Space*, TECH. REV., January 1986, at 8, 8. A hit from a denser fragment measuring a tenth of an inch could do more damage than a bowling ball flying at 60 miles per hour. Hoversten, *supra* note 6, at 28.

18. Inactive payloads, such as spent satellites and space probes, are former active payloads that can no longer be controlled from earth by their operators. *Orbital Space Debris Threatens Future of Scientific Missions*, SATELLITE NEWS, July 18, 1988, at 2, 3 [hereinafter *Debris Threatens Missions*].

19. *Id.*

20. Howard Baker, *Liability for Damage Caused in Outer Space by Space Refuse*, in 13 ANNALS OF AIR & SPACE L. 183, 184 (Nicholas Mateesco Matte ed., 1988). Operational debris consists of various objects associated with space activities that remain in outer space following the completion of the mission. Over 7500 of these objects have been deposited in outer space, either accidentally or intentionally, since Sputnik I was launched over thirty years ago. *Id.* at 185.

21. *Id.*

Of the several thousands of these objects placed into space either accidentally or intentionally during manned space flights, many have re-entered the Earth's atmosphere and disintegrated, while many remain in space.²²

Fragmentation debris composes the largest segment of the space debris population (forty-nine percent).²³ This type of debris is produced when space objects break apart, usually as a result of collisions and explosions. Satellite breakups account for forty-six percent of the trackable space objects.²⁴

Microparticulate debris results from solid-propellant rocket motors, from coatings that chip and degrade from surfaces of orbiting objects, and from manned space missions.²⁵ Microparticulate space debris cannot be tracked in space. Existing technology can track objects only if they are larger than one centimeter and microparticulate space debris generally ranges from one to one-hundred microns in diameter.²⁶ Current estimates of microparticulate space debris are in the trillions.²⁷

Together, the United States and the Soviet Union are responsible for approximately ninety-seven percent of the total space debris.²⁸ Most debris, once in space, will remain there

22. *Id.* On January 24, 1978, Kosmos 954, a 4.5 ton Soviet ocean surveillance satellite with an onboard atomic power plant, burned up in the atmosphere and landed in northern Canada. All but two pieces of the refuse found were highly radioactive. Jason Reiskind, *Towards A Responsible Use of Nuclear Power in Outer Space - The Canadian Initiative in the United Nations*, in 6 ANNALS AIR & SPACE L. 461, 463 (Nicholas Mateesco Matte ed., 1981).

23. *Debris Threatens Missions*, *supra* note 18, at 3.

24. *Id.*

25. Chipping of spacecraft coatings results from exposure to ultraviolet radiation and atomic oxygen and from expansion and contraction stresses due to severe temperature changes. Donald J. Fredrick, *Litter in Space Increasing: Orbiting Trash Can Proposed*, SPACE WORLD, Mar. 1985, at 17.

26. Eberhart, *supra* note 3, at 29.

27. Donald J. Kessler, *Space Debris: More Than Meets the Eye*, SKY & TELESCOPE, June 1987, at 587.

28. Approximately fifty-seven percent of space debris has been generated by the United States, forty percent by the Soviet Union, and three percent by a combination of the United Kingdom, the European Space Agency, France, West Germany, India, Japan, and the People's Republic of China. These percentages exclude inactive payloads. Eliot Marshall, *Space*

forever unless technological advancements enable scientists to eliminate junk from the extraterrestrial environment. Such technology does not currently exist.²⁹

Because science and engineering have not yet devised offensive technology capable of eliminating space debris, they are taking a defensive technological approach. At the Johnson Space Center in Houston, engineers are designing armor that can absorb hits from space shrapnel and prevent damage to the spacecraft and its inhabitants.³⁰

Despite the growing space debris problem and the dearth of solutions, manned space activities are on the rise. The United States and other space-faring nations have plans to increase their space presence in all sectors: civil, commercial, and military.³¹ Dollars spent on space related expenditures illustrate this increase. Space related expenditures include complete space vehicles, systems, parts and components, services, engines and propulsion units, and research and development.³² In 1985, the United States spent approximately \$6 billion on space related items.³³ By 1989, these expenditures had increased to \$30 billion and are predicted to be over \$36 billion in 1993.³⁴

Currently, the United States has plans to construct a manned, fully operational space station and place it in orbit by

Junk Grows With Weapons Tests, SCIENCE, Oct. 25, 1985, at 424.

29. An engineering professor at the University of Arizona is working on a robotics space vacuum to eliminate some of the space debris. However, this robotics device could not remove radioactive debris or satellites containing unspent fuel. Larger pieces of space junk may also be outside the capabilities of this device. Finally, the robotics device is not capable of collecting tiny flakes that compose ninety-nine percent of the existing space debris. Mark Holman Turner, *Garbage Truck of the Future?*, POPULAR SCI., July 1990, at 83.

30. NASA uses a hypervelocity gun that fires simulated space debris at simulated space ship skins to study what happens on impact. Hoversten, *supra* note 6, at 28.

31. *Growth Trends: U.S. Space Sales 1980-1993*, AVIATION WK. & SPACE TECH., Mar. 18, 1991, at 145.

32. *Id.*

33. *Id.*

34. *Id.*

1998.³⁵ Augmented use of the outer space environment will increase the risk of collisions and exacerbate the already serious space debris problem.

Recognizing that space junk constitutes a real threat to continued space exploration, NASA has invested substantial resources into developing technology that will protect its spacecraft (of particular concern is the space station Freedom, which will provide a very large, expensive target) from collisions with space junk.³⁶ Existing technology only protects spacecraft from collisions with small, particulate debris measuring one inch or less in diameter; the protective mechanisms triggered on impact actually create additional space debris.³⁷

The National Security Council issued a report that recognized the severity of the space debris problem.³⁸ The report stated: "[L]eft unchecked, the growth of debris could substantially threaten the safe and reliable operation of manned and unmanned spacecraft in the next century."³⁹ Unfortunately, in light of collisions that have already occurred, this assessment seems unrealistic. Already, the debris population at its present level precludes safe and reliable operation of spacecraft.⁴⁰

NASA has declined to acknowledge the full import of the space junk problem. In April 1990, the General Accounting Office (GAO) accused NASA of underestimating the potential damage that space debris could cause to the space station Freedom.⁴¹ Contractors hired by NASA to design the space station originally

35. On January 5, 1984, the President of the United States directed NASA to develop a permanently manned space station within a decade. NASA plans to launch the first element of the station in 1996 and complete assembly by 1998. 52 Fed. Reg. 15,789 (1987); 55 Fed. Reg. 8622 (1990).

36. Hoversten, *supra* note 6, at 28.

37. Fred Whipple, a Smithsonian astronomer, has developed an aluminum shield that protects space vehicles from impacts with relatively small debris. However, with each violent impact, the shield sends a burst of aluminum fragments into space, resulting in an increase of fragmentation space debris. Uehling, *supra* note 8, at 83-84.

38. *Id.* at 85.

39. *Id.* at 82.

40. See *supra* notes 11-17 and accompanying text.

41. Uehling, *supra* note 8, at 82-83.

were given 1984 space debris data.⁴² The GAO directed NASA to re-assess the problem before proceeding.⁴³

In addition to its efforts to devise protective technology, NASA has adopted an "avoidance policy."⁴⁴ NASA's actions do not always comport with such a policy, however, because NASA continues to augment the space debris problem (seemingly) unnecessarily by launching satellites and transmitters whose purposes could be accomplished via land-based technology.⁴⁵ Moreover, NASA often discounts the severity of the space debris problem when planning missions.⁴⁶

II. EXISTING LAW

A. *International Law: The Outer Space Treaty*

The United States and all other space-faring nations have signed the Outer Space Treaty (OST).⁴⁷ In executing this Treaty, all signatories have relinquished sovereignty over the outer space domain and have concurred that the use and exploration of outer space shall be carried out for the benefit, and in the interest, of all countries.⁴⁸ Undoubtedly, this provision resonates an underlying

42. *Id.* at 83.

43. *Id.*

44. *See supra* notes 30, 36-37 and accompanying text.

45. "Virtually anyone can now place a satellite or experiment package in orbit. National governments and large corporations are particularly anxious to launch geosynchronous communications satellites because they can transmit a continuous flow of information between any two points within their range." *See infra*, note 96 and accompanying text. Scheraga, *supra* note 17, at 8.

46. *See, e.g.,* Uehling, *supra* note 8, at 82-83 (discussing undervaluation of space debris in the space station design).

47. The Outer Space Treaty has been ratified by more than ninety states, including all space capable nations. *See* SPACE LAW: BASIC LEGAL DOCUMENTS A.I.2, at 1-3 (Karl-Heinz Böckstiegel & Marietta Benkö eds., 1991).

48. The Outer Space Treaty mandates this relinquishment of sovereignty regardless of the country's degree of economic or scientific development. Outer space is designated as the province of all mankind. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *opened*

philosophy that no one country or group of countries may freely pollute outer space. Nonetheless, the OST contains no provision specifically prohibiting countries from littering the extraterrestrial environment.

Under Article VI of the OST, signatories bear international liability for damage to another State Party, or to its natural or juridical persons, resulting from national activities in outer space.⁴⁹ Littering the outer space environment does not, per se, give rise to international liability. The only provision of the OST that might be interpreted as addressing the introduction of rubbish into the outer space environment is Article IX, which provides that States shall conduct space studies and exploration so as to avoid harmful contamination of outer space, including the moon and other celestial bodies.⁵⁰ The OST does not define "harmful contamination"; as a result, whether and when the generation of space debris rises to the level of "harmful contamination" is unclear.⁵¹

Article IX further directs State Parties, where necessary, to adopt national measures to avoid harmful contamination of the outer space environment.⁵² Absent clarification of what

for signature Jan. 27, 1967, art. I-II, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter OST].

49. This provision applies equally to governmental and non-governmental space activities. "States Parties [sic] to the Treaty shall bear international responsibility for national activities in outer space . . . whether such activities are carried on by governmental agencies or by non-governmental entities . . ." *Id.* art. VI.

50. The language of this treaty provision is broad enough to cover both the introduction of contaminants into the space environment that would result in harm to the Earth's environment, as well as contaminants that will remain in space. *Id.* art. IX.

51. Obviously, debris that ultimately causes damage would be "harmful"; there is nothing in the OST to guide space-faring nations as to what debris might rise to that level. Indeed, because even the smallest microparticulates can cause substantial damage in space, seemingly the introduction of any debris in space would constitute "harmful contamination." See, e.g., *supra* note 10 and accompanying text.

52. State parties to the OST shall, where necessary, adopt appropriate measures to prevent harmful contamination of outer space, including the moon and other celestial bodies. OST, *supra* note 48, at art. IX.

constitutes harmful contamination, this provision is virtually meaningless. Moreover, the provision vests each state with discretion to determine whether domestic legislation is necessary to accomplish the OST's avoidance goal.⁵³

Under the OST, when a party to the Treaty has reason to believe that an activity or experiment will cause *potentially* harmful interference with another nation's space activities, it shall undertake appropriate international consultations before proceeding.⁵⁴ In light of previous encounters with space debris, it would be practically impossible for a nation to take the position that missions generating space debris will not potentially cause harmful interference with another nation's activities in space.⁵⁵ Nonetheless, OST signatories have not attempted to invoke the OST's consultation provision prior to space missions that will discharge additional, potentially life-threatening debris into space.⁵⁶

The OST puts the responsibility on the nation conducting the potentially harmful activity to initiate the consultations.⁵⁷ The

53. For a discussion of the United States' regulatory and statutory obligations that could be used as a basis for imposing the OST's avoidance goal see text *infra* accompanying notes 123-131.

54. OST, *supra* note 48, art. IX.

55. See *supra* notes 11-17 and accompanying text.

56. Article IX states:

A State Party to the Treaty which has reason to believe that an activity or experiment planned by another State Party in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities in the peaceful exploration and use of outer space, including the moon and other celestial bodies, *may* request consultation concerning the activities or experiment.

OST, *supra* note 48, art. IX (emphasis added).

57. Article IX further provides:

If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space, including the moon and other celestial bodies, it *shall* undertake appropriate international consultations before

present trend likely will continue, because there is no consultation-forcing mechanism that affected nations can implement in such situations.

Despite the OST, space-faring nations continue to litter the outer space environment with impunity. No nation has attempted to invoke the OST to address the spiraling space junk problem. Although the OST contains directives that arguably relate to intentional creation of space debris, these provisions are ambiguous and lack real enforcement capabilities.

The Outer Space Treaty forms the basis for all other rules of international space law that have been refined in the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space,⁵⁸ the Convention on International Liability for Damage Caused by Space Objects,⁵⁹ the Convention on Registration of Objects Launched into Outer Space,⁶⁰ and the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies.⁶¹ With the exception of the Moon Agreement,⁶² which has been signed by only two space-faring nations, these treaties nowhere expressly deal with pollution of the outer space environment, nor do they provide any law for countries to apply to regulate, prevent, or penalize a country contributing to the ever-increasing space debris problem.

B. *United States Law: NASA's Space NEPA*

NASA has developed rules for environmental protection that are based upon the National Environmental Policy Act (NEPA)⁶³ and its accompanying regulations.⁶⁴ Under NASA's

proceeding with any such activity or experiment.

Id.

58. *Opened for signature* Apr. 22, 1968, 19 U.S.T. 7570, 672 U.N.T.S. 119.

59. *Opened for signature* Mar. 29, 1972, 24 U.S.T. 2389, 11 I.L.M. 250.

60. *Opened for signature* Jan. 14, 1975, 28 U.S.T. 695, 14 I.L.M. 43.

61. *Opened for signature* June 21, 1968, 29 U.S.T. 783.

62. *Id.*

63. 42 U.S.C. §§ 4321-4370 (1988 & Supp. 1991).

64. 40 C.F.R. §§ 1500-1517 (1992).

NEPA regulations,⁶⁵ all NASA actions "which may have an impact on the environment" must comply with the regulatory requirements.⁶⁶ More specifically, all NASA actions involving "[d]evelopment and operation of space vehicles likely to release substantial amounts of foreign materials into the earth's atmosphere, or *into space*" require an environmental impact statement (EIS).⁶⁷ Consequently, if NASA proposes a project or mission that will *likely* emit substantial amounts of foreign materials into space, it must prepare an EIS.⁶⁸ This language is problematic for several reasons.

First, the regulation sets forth an undefined standard. What constitutes substantial amounts in the space environment and how does NASA determine whether the emissions are substantial? If NASA ascertains the substantiality of the emissions mission by mission, rather than accounting for the cumulative impact of several different but related missions or programs, it is less likely that the emissions will be deemed substantial. The EIS requirement will therefore not be triggered. However, given the serious harm that could result even from micro-space debris striking an astronaut or space vehicle, the smallest of discharges could be substantial if NASA chooses to ignore cumulative impacts.⁶⁹

65. 14 C.F.R. §§ 1216.300-1216.321 (1992).

66. 14 C.F.R. § 1216.301(b) (1992).

67. 14 C.F.R. § 1216.305(c)(2) (1992) (emphasis added).

68. *Id.*

69. Indeed, every time NASA undertakes a mission, manned or unmanned, there is a likelihood of some microparticulate debris in the form of chipped coatings from the surfaces of orbiting objects and manned spacecraft. As noted earlier, most microparticulate debris is untrackable, but is estimated to be in the trillions. See Eberhart, *supra* note 3, at 29. In light of the estimated human-generated space debris that already exists, presumably, NASA should prepare an EIS for every mission (regardless of its size). NASA must prepare an EIS if the past, present, and reasonably foreseeable future missions create impacts that, while individually may be insignificant, combine to have a cumulatively significant impact on the space environment. See *Fritiofson v. Alexander*, 772 F.2d 1225, 1241-47 (5th Cir. 1985) (holding that NEPA may require an EIS where cumulative effects will affect a regional or comprehensive environment).

In addition to NASA-specific definitions, NASA's NEPA regulations incorporate the definitions found at Part 1508 of the Council on Environmental Quality's NEPA Regulations.⁷⁰ Neither the NASA regulations nor NEPA regulations define "substantial" or "substantial amount." However, NEPA regulations define "significantly" and this definition could be used as a guideline for determining what constitutes a "substantial amount" under NASA's regulations.⁷¹ Logically, a substantial amount would have a significant impact and, therefore, would require that NASA prepare an EIS.

Second, neither national nor international law defines outer space. As a result, there is currently no lower boundary where the international space domain begins and there is no upper boundary where the international space domain ends.⁷² Conceivably, nations could attempt to set the boundaries of space so as to subject portions of it to territorial claims.⁷³ Likewise, when determining whether to prepare an EIS, NASA could take a very narrow view of what constitutes outer space to avoid its responsibilities to prepare an EIS and to escape the associated delays and potential challenges inherent in the EIS process.

Another troubling aspect of the NASA regulations is the categorical exclusions section found at 14 C.F.R. § 1216.305(d)(1)-(8).⁷⁴ These exclusions exempt a broad category

70. 40 C.F.R. §§ 1508.1-1508.28 (1992).

71. NEPA requires an EIS for all "major Federal actions significantly affecting the quality of the human environment." 42 U.S.C. § 4332(c) (1988). "Significantly," as used in NEPA, requires considerations of both context and intensity. 40 C.F.R. § 1508.27 (1992).

72. The definition of outer space suggested by most nations sets the lower boundary at 100 kilometers plus or minus 10 kilometers above sea level. Gijsbertha C.M. Reünen, *UTILIZATION OF OUTER SPACE AND INTERNATIONAL LAW* 33-34 (1981).

73. For example, eight equatorial countries have claimed the geostationary orbit as airspace. *See, e.g.*, Declaration of First Meeting of Equatorial Countries, completed Dec. 3, 1976, ITU Doc. WARC-BS, 81-E (1977) (declaring that the geostational orbit is airspace, which is claimed by the eight equatorial countries that attended the meeting).

74. Under the CEQ Regulations categorical exclusion is defined as "a category of actions which do not individually or cumulatively have a significant effect on the human environment and which have been found to have no such

of projects that otherwise would require an environmental assessment or an EIS.⁷⁵ Under this broad exclusionary provision, any project that fits within a sub-element of an approved, broad-based level-of-effort NASA science and technology program is excluded from the EIS requirement.⁷⁶ This exclusion includes ongoing missions which are managed relatively independently of other related sub-elements by means of separate task orders. This categorical exemption could well vitiate the requirement that an agency prepare an EIS assessing cumulative impacts of individually minor but collectively significant actions taking place over a period of time.⁷⁷

Although agencies are permitted to develop their own methods and procedures for implementing NEPA, they must interpret and administer those policies and regulations in accordance with NEPA's mandates.⁷⁸ To permit NASA to segment, and therefore exempt, incrementally insignificant but cumulatively significant proposals and projects from the EIS requirement would be inconsistent with NEPA's legislative directive.⁷⁹

In accordance with NEPA, NASA's regulations require NASA to consider whether its actions will have an environmental effect abroad.⁸⁰ When making this determination, NASA also

effect in procedures adopted by a Federal agency in implementation of these regulations . . . and for which, therefore, neither an environmental assessment nor an environmental impact statement is required." 40 C.F.R. § 1508.4 (1992).

75. 14 C.F.R. § 1216.305(d) (1992).

76. *Id.*

77. "'Cumulative impact' is the impact on the environment resulting from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (federal or non-federal) or person undertakes such other actions." 40 C.F.R. § 1508.7 (1992).

78. 42 U.S.C. § 4332.

79. See *Fritiofsen v. Alexander*, 772 F.2d 1225, 1241-47 (5th Cir. 1985) (holding that NEPA may require an EIS where cumulative effects will affect a regional or comprehensive environment).

80. 14 C.F.R. § 1216.321(a) (1992). NEPA requires a state agency or official to "recognize the worldwide and long-range character of environmental problems and, where consistent with the foreign policy of the United States,

must consider whether the proposed action affects the global commons environment.⁸¹ Because nations cannot subject outer space to sovereign claims, space should be viewed as part of the global commons.⁸²

Interestingly, when the NASA regulations discuss NASA's responsibility to look at potential environmental effects on the global commons, *outer space* is conspicuously absent from the defined areas.⁸³ Under its regulations, NASA need not even consider environmental effects on the global commons if the agency determines that the action will not have a significant environmental effect abroad.⁸⁴ Even when NASA finds an environmental effect abroad, it has discretion to determine whether and when to inform the affected nation.⁸⁵ Consequently, as addressed below, this is a specious component of NASA's regulations that pays only lip service to NEPA.⁸⁶

Several loopholes contained in the NASA regulations turn what could be an effective national and international outer space planning and decisionmaking mechanism into an ineffectual tool. To effectuate NEPA's goal of fully informed decision-making, the loopholes must be closed and the ambiguities must be eliminated.

lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of mankind's world environment." 42 U.S.C. § 4332(2)(F).

81. 14 C.F.R. § 1216.321(a)(1) (1992).

82. Outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means. OST, *supra* note 48, art. II.

83. When examining the environmental effects abroad, NASA is to consider "[p]otential environmental effects on the global commons (*i.e.*, oceans and the upper atmosphere)." 14 C.F.R. § 1216.321(a)(1) (1992).

84. *Id.* § 1216.321(b).

85. *Id.* § 1216.321(f).

86. Apparently in response to court cases attempting to apply NEPA extraterritorially to federal agency actions abroad, President Jimmy Carter issued Executive Order 12,114, "Environmental Effects Abroad of Major Federal Actions." As its title suggests, President Carter ordered federal agencies to apply NEPA and to consider environmental impacts of their actions in foreign jurisdictions. Exec. Order No. 12,114, 44 Fed. Reg. 1957 (1979), *reprinted in* 42 U.S.C. § 4321 (1988).

1. NASA's Implementation of Its NEPA Regulations

NASA has been conducting some type of NEPA-like environmental analysis of certain outer space missions and projects since at least 1982.⁸⁷ Under its own regulations, NASA must conduct an environmental assessment and determine whether an environmental impact statement is required before proceeding from the conceptual/study phase to the detailed planning/definition phase of the proposed action.⁸⁸

Because of the stated, as well as the unstated exemptions (*e.g.*, excluding space from the global commons and sanctioning segmentation of projects), NASA's regulations lack clarity as to when an EIS is required.⁸⁹ Therefore, an examination of how NASA implements its regulations is critical to determining whether and to what extent NASA's regulations are affecting the outer space environment and the generation of space junk.

Most recently, NASA has prepared a draft Generic EIS on the Space Station Freedom Program.⁹⁰ In NASA's initial Notice of Intent to prepare an Environmental Impact Statement, it stated that "[t]he initial assessment of environmental effects indicates that there are likely to be no significant environmental consequences to the terrestrial environment resulting from the program."⁹¹ Although NASA plans to address on-orbit space debris generation and disposal of waste generated on the station in the EIS, it found

87. For example, NASA made a finding of no significant impact regarding the first operational flight of the Space Transportation System Space Shuttle from Kennedy Space Center in Florida. The purposes of the mission were to provide new capacity to two existing communications networks and to conduct research in the properties of materials. Notice of Finding of No Significant Impact, 47 Fed. Reg. 51,026 (1982).

88. 14 C.F.R. § 1216.304(a).

89. See *supra* notes 74-77 and accompanying text.

90. Notice of Availability of Final Impact Statement, 55 Fed. Reg. 86226 (1990). On January 5, 1984, the President of the United States directed NASA to develop a permanently manned space station within a decade. Notice of Intent to Prepare Environmental Impact Statement, 52 Fed. Reg. 15,789 (1987).

91. 52 Fed. Reg. 15,789.

no significant consequences to the terrestrial environment.⁹²

When conducting its environmental analyses and assessments, NASA consistently has found that space debris will not significantly affect the space environment.⁹³ Frequently, NASA has issued Findings of No Significant Impact (FONSIs) for projects and missions where space debris will be generated.⁹⁴ When making these findings, NASA has concluded that the amount of space junk generated by specific missions and projects is not substantial enough to require an EIS. However, on several such missions, the addition of debris to the extraterrestrial environment could have been avoided through the no action alternative for segments of the mission, while retaining the significant scientific components of the mission.⁹⁵

92. *Id.*

93. *See, e.g.*, Finding of No Significant Impact, 49 Fed. Reg. 41,122 (1984) (FONSI on Space Shuttle operation and launching of 928 payloads that NASA recognized would increase the space debris population); Finding of No Significant Impact, 50 Fed. Reg. 41,964 (1985) (FONSI on solar terrestrial research project releasing chemicals and trace amounts of hazardous materials); Finding of No Significant Impact, 48 Fed. Reg. 27,465 (1983) (FONSI on release of communication satellites which would add two solid rocket motors and two ultimately abandoned communications satellites "to an already large population of manufactured space debris").

94. *See, e.g.*, Finding of No Significant Impact, 47 Fed. Reg. 51,026 (1982); Finding of No Significant Impact, 48 Fed. Reg. 27,465 (1983); Finding of No Significant Impact, 48 Fed. Reg. 39,186 (1983); Finding of No Significant Impact, 49 Fed. Reg. 4285 (1984); Finding of No Significant Impact, 49 Fed. Reg. 13,772 (1984); Finding of No Significant Impact, 49 Fed. Reg. 41,122 (1984).

95. For example, the two major purposes of the seventh flight of the Space Shuttle (STS-7) were to launch communications satellites and their associated Propulsion Assist Modules and to conduct a variety of research experiments. The research experiments were non-debris-producing. The communications satellites not only created space debris, but their propellants also posed a major hazard source (*i.e.*, the most likely cause of a catastrophic space shuttle accident). NASA recognized that there were terrestrial methods of providing the communications relay capacity provided by the satellites at a higher economic cost. NASA also recognized the growing space debris population, the fact that this would increase the already high numbers, and the potential for a catastrophic occurrence if the resulting debris collided with a manned spacecraft. Nonetheless, NASA found the risk acceptable in view of

When finding no significant impact, NASA acknowledges that placing space debris into the terrestrial environment constitutes a "long-term adverse environmental impact."⁹⁶ NASA further recognizes that an "already large population of space debris abandoned in orbit by the nations with space launch capabilities" exists and that a collision with a manned spacecraft or an astronaut would likely result in death and destruction.⁹⁷ Nonetheless, NASA routinely determines that the potential consequences of adding to the space debris population is an acceptable risk, even when a similar goal could be accomplished using earth-based technology and when the sole benefit is relatively low-cost communications services.⁹⁸

NASA consistently minimizes the space debris problem to vindicate its findings and routinely issues FONSI's, noting that, although most missions generate space debris, the increase in space debris on any given mission poses little threat to the terrestrial environment. NASA states that the problem is not yet severe, while acknowledging that continued use of space without regard to the consequences of populating the extraterrestrial environment with additional objects may have a significant and adverse effect on space operations over the next thirty years.⁹⁹ In NASA's opinion, the potentially catastrophic risks are acceptable in light of the benefits.¹⁰⁰

For some missions, the generation of additional space debris may, indeed, be justifiable in light of achievable scientific benefits. However, NASA's findings are questionable and subject to legal challenge when the threats posed by additional space debris outweigh the sole benefit of relatively low-cost communications capabilities.¹⁰¹

As a rule, NASA has assessed the impacts of projects and

the benefits achievable through improved communications capabilities. 48 Fed. Reg. 27,465 (1983).

96. See, e.g., 47 Fed. Reg. 51,026 (1982).

97. *Id.*

98. See *supra* note 94.

99. 49 Fed. Reg. 4285 (1984).

100. E.g., 48 Fed. Reg. 39,186 (1983).

101. See *supra* note 95 and accompanying text.

missions generating space debris on an individual basis without considering cumulative impacts. Several missions have launched communications satellites and their associated debris into the outer space environment. Based on the collisions and encounters with space junk that have already occurred, it is difficult to imagine how any addition to the space debris population for non-essential purposes or non-scientific experimentation could be justified. At this point, any addition to the space debris population would seem to be significant and, thus, substantial. Therefore, even without assessing cumulative impacts, the no action alternative would appear to be the only real option in many instances, particularly in light of NASA's recent adoption of a space debris avoidance policy.¹⁰²

NASA's stated policy of avoidance contradicts its actions. NASA recommends instituting programs to control the rate of debris deposition as the most effective, near-term alternative to controlling the debris hazard,¹⁰³ while concomitantly launching additional objects into space, thereby exacerbating the space junk problem.¹⁰⁴ Moreover, for some missions generating space debris, NASA does not even examine the effects of the debris on the terrestrial environment.¹⁰⁵ Consequently, a consistent policy or procedure is difficult, if not impossible, to discern based on NASA's past actions.

One thing is clear; NASA regularly finds that, regardless of whether space debris is generated and regardless of the amount, the risks posed by the increased amount of space junk are outweighed by the benefits. Given this conflict between policy and action, the time is ripe for challenging NASA's analyses and

102. See *supra* text accompanying note 44.

103. 49 Fed. Reg. 4285 (1984).

104. 49 Fed. Reg. 41,122 (1984) (finding no significant impact of launching 928 payloads into space over a 10 year period that will result in at least 340 additional pieces of space debris).

105. See, e.g., Finding Of No Significant Impact, 50 Fed. Reg. 41,964 (1985) (FONSI for the program entitled "The Combined Release and Radiation Effects Satellite," which would release "a large number" of chemical release canisters into outer space, as well as 200 sounding rocket probes, did not discuss the space debris' environmental effects resulting from the deployment of these objects into space).

justifications for its continued use of the outer space environment as a dumping ground for debris resulting from non-essential space activities.

III. SUGGESTIONS UNDER EXISTING LAW

A. *Challenge NASA's Findings Using NEPA*

Some of the problems that could exist in applying NEPA to NASA's space activities are resolved by the fact that NASA has voluntarily assumed responsibility to conduct a NEPA-like analysis for outer space missions. Having incorporated NEPA into its regulations, NASA has acknowledged, through policy, practice, and regulatory procedure, that environmental impacts on the outer space environment are subject to NEPA and must be addressed in any environmental assessment.¹⁰⁶ As a result, interested persons and, perhaps, even foreign nations may be able to challenge NASA's environmental findings under several theories.¹⁰⁷

Notably lacking in NASA's environmental analyses to date has been consideration of cumulative impacts. NASA has seemingly attempted to exempt itself from the requirement of considering cumulative impacts of missions and projects by its rule

106. NEPA is limited to the human environment. 42 U.S.C. § 4332(2)(C). "'Human environment' shall be interpreted comprehensively to include the natural and physical environment and the relationship of people with that environment." 40 C.F.R. § 1508.14. However, by applying NEPA to the outer space environment, NASA has expanded NEPA's scope to include outer space.

107. Foreign nations that are signatories to the OST could use NASA's assessments as a means to request an international consultation concerning the particular activity or experiment proposed. Many of NASA's previous assessments and findings have contained information suggesting that the proposal would result in potential harmful contamination to outer space. Thus, the consultation process, if invoked, could be a means of requiring an examination of various alternatives to the proposal, which have heretofore been very cursory and conclusory. See, OST, *supra* note 48, art. IX. Private individuals have been liberally granted standing under NEPA to challenge an agency's decisions to act, provided that the persons have participated in the process leading up to the agency's ultimate decision. See, e.g., *Kleppe v. Sierra Club*, 427 U.S. 390 (1976).

expressly allowing segmentation.¹⁰⁸ However, such a unilateral agency exemption presents a strong basis for a legal challenge, since it disobeys the congressional directive that all federal agencies interpret and administer their projects and develop their regulations in accordance with NEPA.¹⁰⁹

When looking at the NASA projects to date and at the underlying United States policy that civil, commercial, and military activities increase in space, a general policy toward increased utilization of outer space emerges.¹¹⁰ As the United States expands its presence in outer space, the opportunities to challenge NASA's proposals on the basis of cumulative impacts will increase.

For example, Space Station Freedom will present an opportunity to attempt to force NASA to examine and assess the effects of the agency's cumulative actions in space. NASA plans to use the space station to conduct scientific experiments and to provide a base for commercial ventures, such as manufacturing.¹¹¹ In the EIS, NASA has recognized that operation of this space station will produce waste and debris.¹¹² However, NASA has failed to account for the cumulative impact of these activities over the life of the space station. NASA has also failed to account for the impacts of past activities in space.

108. 14 C.F.R. § 1216.305.

109. 42 U.S.C. § 4332 (1), (2). *See also* Calvert Cliffs' Coordinating Comm., Inc. v. United States Atomic Energy Comm'n, 449 F.2d 1109 (D.C. Cir. 1971) (holding that the AEC's rules did not comply with congressional policy and remanding to the agency for further rulemaking).

110. *See also Growth Trends: U.S. Space Sales*, AVIATION WK. & SPACE TECH., Mar. 18, 1991, at 45. ("Space operations will expand in 1991 and 1992 on increased funding for NASA, more than off-setting a recession-induced slow down in sales to the commercial space sector.")

111. NASA, FINAL TIER 1 ENVIRONMENTAL IMPACT STATEMENT FOR SPACE STATION FREEDOM, § 1.0 (1991) [hereinafter SPACE STATION EIS].

112. *Id.* § 1.5. Significantly, the five areas identified in the EIS where significant environmental impacts could arise did not include impacts from space debris currently in the terrestrial environment. The five areas identified are: Space Station Freedom's orbital maintenance strategy; decommissioning strategies; impacts of debris which survives reentry; return and disposal of waste material, including toxic waste; and impacts from the payload mission set to be flown on Space Station Freedom.

Rather than reviewing the entirety of the space station's operations during its operational life, NASA focuses on a very narrow segment of the operations over a short time frame.

Similarly, in the past numerous missions have launched communication and other types of satellites into space. At the time of these launchings, NASA knew that certain propulsion segments of these satellites would almost immediately become space junk.¹¹³ Viewed in this light, NASA should have prepared an EIS addressing the cumulative impacts of satellite launchings over the years. The resultant debris-generating cumulative impact of these launchings has been significant, at the very least.¹¹⁴

NASA plans to continue using space for civil and commercial purposes.¹¹⁵ While courts have held that an agency may not artificially segment projects for the purpose of avoiding a cumulative EIS, neither have courts required agencies to consider cumulative impacts of projects that may not ever come to pass.¹¹⁶ Consequently, to successfully challenge an EIS, or perhaps even more likely, a FONSI, a litigant must establish that NASA intends to propose several individual actions that, standing alone, might not require an EIS, but when taken together will result in a significant impact on the extraterrestrial environment.¹¹⁷

As the space debris problem grows, NASA will have an increasingly difficult time finding that individual missions do not significantly impact the extraterrestrial environment. At some point in the near future, the number of space objects will have grown to such a number that any intentional addition to the space

113. See *supra* note 93 and accompanying text.

114. See *supra* note 95 and accompanying text.

115. NASA has listed as program objectives: "To provide long-term, cost effective operation and utilization of improved facilities for . . . commercial and operational activities enabled or enhanced by the presence of humans in space" and "[t]o create and expand opportunities for private sector activity in space." SPACE STATION EIS, *supra* note 111 at § 1.1.2.

116. See *Kleppe v. Sierra Club*, 427 U.S. 390, 414 n.26 (1976); *City of Rochester v. United States Postal Serv.*, 541 F.2d 967, 972-74 (2d Cir. 1976); *Alpine Lakes Protection Soc'y v. Schlapfer*, 518 F.2d 1089, 1090 (9th Cir. 1975); *Appalachian Mountain Club v. Brinegar*, 394 F. Supp. 105, 114-15 (D.N.H. 1975).

117. See *Kleppe*, 427 U.S. at 409-10.

junkyard will be substantial and unjustifiable due to the risks to humans in space.

An additionally available avenue with which to challenge NASA's environmental findings under NEPA is the agency's consideration of alternatives. Usually, the only alternatives considered by NASA are ones that will result in more debris and the no action alternative, which has been consistently rejected.¹¹⁸

Whether these alternatives are sufficient may be subject to challenge, especially in instances where the same result could be achieved using Earth-based technology. In such instances, the no action alternative may, in actuality, be the only viable option.

NEPA's alternatives discussion is subject to a construction of reasonableness and it must be more than mere conclusory and uninformative statements.¹¹⁹ Without a detailed analysis of the alternatives, there is no way to investigate the validity of NASA's conclusions.¹²⁰ In most instances, NASA has conducted only a cursory and conclusory review of alternatives, subjecting the alternatives analysis to a legal challenge that could result in enjoining the proposed action until NASA performs an adequate

118. For example, in a 1984 FONSI, NASA found that:

While the threat to space operations from the debris population is not yet severe, continued use of space without regard to the consequences of populating the environment with additional objects may have a significant and adverse effect on space operations over the next 30 years. Programs to control the rate of debris deposition represent the most effective near-term alternative to controlling the debris hazard.

49 Fed. Reg. 41,122 (1984). Nonetheless, NASA found that launching an additional 928 payloads, many of which were strictly for commercial ventures, "will not result in any significant adverse environmental impacts." *Id.*

119. See, e.g., *Life of the Land v. Brinegar*, 485 F.2d 460,472 (9th Cir. 1973); *Chelsea Neighborhood Ass'n v. United States Postal Serv.*, 516 F.2d 378, 389 (2d Cir. 1975); *Village of Palatine v. United States Postal Serv.*, 742 F. Supp. 1377, 1390 (N.D. Ill. 1990) (assessments explanation of rejection of alternative sites was so brief and perfunctory that court could not conclude that it reflected reasoned decision based on all relevant factors).

120. See *Calvert Cliffs' Coordinating Comm., Inc. v. United States Atomic Energy Comm'n*, 449 F.2d 1109, 1114 (D.C. Cir. 1971).

alternatives analysis.¹²¹

B. Combining NEPA and the Outer Space Treaty To Address The Proliferation of Space Debris

NEPA directs federal agencies to take into account environmental impacts on the world environment.¹²² Article IX of the OST requires nations to pursue studies and space exploration to avoid harmful contamination of outer space and, where necessary, to adopt domestic legislation to further this purpose.¹²³ NASA has applied NEPA's EIS requirement to the agency's activities that are likely to release substantial amounts of foreign materials in outer space.¹²⁴ An argument can be made that, in doing this, NASA has implemented the OST directive to adopt domestic legislation to further the purpose of avoiding harmful contamination of outer space.

The informed decisionmaking process imposed under NEPA theoretically should avoid unnecessary, intentional generation of space debris and, therefore, avoid harmful contamination of outer space. Whether intentionally or unintentionally, NASA has adopted regulations that could be used to fulfill the OST directive requiring consideration and evaluation of space activities and their resultant impacts on the outer space environment.¹²⁵ By infusing domestic law with international treaty obligations (*i.e.*, applying NEPA to outer space activities), the United States may have provided an avenue for OST nations to become involved in NASA's NEPA process.

For the OST to apply, space debris would have to constitute "harmful contamination."¹²⁶ Because most, if not all, of man-made space debris does not occur naturally in the outer space environment, it should be classified as a contaminant. Moreover, the destruction that has been caused by collisions with space debris

121. See, *e.g.*, *Village of Palatine*, 742 F. Supp. at 1396-98.

122. 42 U.S.C. § 4332(2)(F).

123. OST, *supra* note 48, art. IX.

124. 14 C.F.R. § 1216.305(c)(2).

125. *Id.*

126. OST, *supra* note 48, art. IX.

supports a finding that the debris is, indeed, harmful. Logic and fact dictate that space debris constitutes harmful contamination of the outer space environment, bringing it within the purview of the OST.

Under the OST, if the proposed action will cause potentially harmful interference with an OST signatory's activities in the peaceful exploration and use of outer space, the aggrieved nation may have a basis under the OST and United States law to challenge the environmental analysis or EIS prepared by NASA. Given the destruction that has resulted because of space debris, a nation could make a strong argument in favor of harmful interference and an even stronger argument in favor of *potential* harmful interference. Such interference triggers the OST consultation provision, requiring international consultations before proceeding with the action.¹²⁷

Although the state proposing the activity determines whether it is necessary to invoke the consultation provision, the OST makes such an invocation mandatory when the state "has reason to believe" that the proposed activity would cause potentially harmful interference.¹²⁸ Factoring in NEPA's environmental assessment process would assure consultation if the affected OST nation(s) so desired.¹²⁹

NASA has repeatedly recognized in its environmental analyses that space debris is a growing problem.¹³⁰ NASA also has acknowledged that space debris has the potential to cause a serious or catastrophic accident. These acknowledgments establish that NASA "has reason to believe" that debris producing activities will result in potentially harmful interference with another nation's activities in space, thus triggering the OST consultation requirement.

The United States has signed the OST and has, therefore, agreed to be bound by its terms. However, a court might have

127. *Id.*

128. *Id.*

129. A State Party may invoke the consultation provision if they have reason to believe that the activity proposed by another would cause potentially harmful interference. *Id.*

130. See *supra* notes 93-95.

difficulty finding law to apply under the OST. The OST, together with NASA's regulations and NEPA, may form a basis for OST signatories to participate in and challenge the NASA EIS process. While Article IX does not expressly prohibit state parties from trashing outer space or render states liable for contamination, it, together with a signatory nation's domestic environmental law, may provide a mechanism for obtaining relief. Domestic legislation may provide applicable law when otherwise, there would be none.

IV. CONCLUSION AND RECOMMENDATIONS

Realistically, if humans continue to use outer space, some space debris is inevitable. Therefore, in accordance with the OST, all OST signatories must determine the amount of space debris that can be generated by each nation in the exploration and use of outer space while still carrying out those activities for the benefit and in the interest of all countries. While generating excessive amounts of space rubbish probably would be contrary to the interests of other states, generating some space debris might not.

The combined use of domestic and international law to supply an enforceable mechanism for an international agreement presents a viable means of making the United States accountable for its actions in space. The United States has developed law that, in theory, incorporates the OST mandate that signatories avoid harmful contamination of outer space. Using the OST and NEPA in tandem may provide OST countries with a consultation-forcing mechanism under the OST, as well as input into NASA's NEPA process.

Because NEPA is designed as a planning and informed decisionmaking law, it is relatively unintrusive. Consequently, international consent to a NEPA-like principle to govern the use of outer space may be a realistic goal. Moreover, such an international planning procedure would accord with the intent of the OST.

The existing space debris population has already reached a point where space activities are becoming dangerous. The United States and the Soviet Union are primarily responsible for the existing space debris population. To date, the technology to clean

up most of this debris has not been developed. Research is necessary to alleviate this problem. If all space faring nations cooperate in research efforts and pool their monetary and technological resources in proportion to their past and present presence in space, the possibilities of achieving a solution to the space debris problem will increase. Furthermore, such an effort would accord with the OST provision that directs state parties to cooperate in scientific space investigation. Absent a formal agreement and funding mechanism, it is unlikely that this cooperative effort toward cleaning up space will move forward.

Much of the space junk that presently exists could have been eliminated through careful planning and guarded utilization of the space environment. Many of the satellites, which comprise over half of the total debris now in space, were unnecessary and their purposes could have been accomplished through Earth-based technology. As is often the case, humans have failed to think ahead by addressing and recognizing the future implications of current actions.

If space is to remain a viable frontier for, *inter alia*, exploration, study, manufacturing, and habitation, prevention and planning are essential. Outer space cannot continue to be an intentional or unintentional dumping ground. The severity of the threats posed even by the most minute space debris are unknown on Earth and could effectively preclude further activity in space.

Although humans have come a long way since Copernicus displaced the Earth from the center of man's conceptual universe and determined that it orbits a stationary sun, humankind has only just begun to explore and understand the extraterrestrial environment. Space-faring nations must lead the way toward developing a coherent policy that will address the existing space debris problem and that will prevent, or at least deter, the exacerbation of that problem.