to make redundant systems. Making solar panels and antennas some 10 to 20 percent larger would compensate for losses from collisions with small debris.[88]

Providing shielding, redundant systems, and extra large systems adds considerable extra weight to payloads and therefore increases overall operating costs. Hence, more accurate characterization of the space environment that would allow spacecraft designers to determine more precisely the protection needs of particular spacecraft could reduce costs accordingly.

Geostationary Orbit

GEO represents a special case because objects placed there remain for millions of years, and because certain segments of the orbit are used more intensively than others.[89] To reduce the chances of accidental collisions between inactive and active satellites, some organizations, including agencies of the U.S. Government, just prior to retiring a satellite from service have used a satellite's last remaining fuel to place it in a higher orbit beyond GEO. Just how effective this practice will prove to be is currently under study. Analysts do not yet know the minimum safe distance necessary to prevent objects drifting back through GEO years afterward, but believe that inactive satellites should be boosted into a circular orbit at least 300 kilometers farther outgo If a satellite in an orbit less than 160 kilometers beyond GEO were to breakup, roughly half of its fragments would eventually drift back through GEO, posing a greater hazard to active satellites along the orbital band than if the satellite had remained in GEO.[91] However, because boosting satellites out of GEO reduces their potential lifetime on orbit, and therefore their economic value, operators are reluctant to spend more fuel than necessary on this procedure. Additional theoretical modeling analysis would assist in determining the most economical removal orbit.

Other hazards may pose greater threats. For example, the explosion of a single upper stage (orbital transfer stage), used to carry a communication satellite to GEO, could create more pieces of fragmentation debris passing through GEO than would be removed by hundreds of end-of-life maneuvers.[92] Yet, because orbital transfer stages follow a highly elliptical orbit that takes them between LEO and GEO altitudes after they have deposited their satellites in GEO, it may be possible to control the stage's perigee and place it low enough that the upper reaches of the atmosphere will slow it down every time it cycles through perigee. Eventually, the upper stage would tumble back into the atmosphere and bum up.

LEGAL IMPLICATIONS

Domestic and international law regulating space activities began to develop in the late 1950s and early 1960s. Yet only recently have managers of space systems recognized that the hazards of space debris might require some sort of regulatory regime. Earlier law, including the international treaties and agreements on space, failed to address orbital debris explicitly. Any domestic and international legal regimes for debris should address the generation of debris, its removal from or-

[88] If appropriately design the solar panels could suffer losses of individual cells without causing total loss of the Panel'scalability.

[89] In orbital arcs serving the United States, trans-Atlantic traffic, and Europe, where the volume of digital, video, and voice traffic is particularly high and of high economic value, the density of communications satellites is particularly high.

[90] V.A. Chobotov, "Disposal of Spacecraft at End-of-Life in Geosynchronous orbit," AAS/AIAA Astrodynamic Specialist Conference, StOwe, Vermont, Aug. 7-10, 1989 (paper No. AAS 89-378).

[91] Kessler, op. cit., footnote 56.

[92] Ibid.

bit, the question of jurisdiction and control over space debris, detection and identification of space debris, international responsibility for space debris, and possible remedies for damage caused by debris. This section explores the legal implications of orbital debris and suggests areas where new international agreements may eventually be needed.

The Definition of Orbital Debris

One of the impediments to developing new laws to address the problems posed by space debris is the lack of an adequate definition of space debris. Existing national laws and international space treaties and agreements (box 5) contain neither a definition nor a description of orbital debris. While orbital debris maybe divided into four classes for descriptive purposes (table 4), legal experts disagree whether the legal scope of orbital debris includes all technical classes.

The seriousness of the debris problem for space operations, the possible confusion over the literal meaning of "debris," and the need to define the scope of debris all suggest the need for a legal term of art. Such a term would provide a starting point for discussing the legal issues arising from the orbital debris problem.

An explicit definition of orbital debris might not be necessary, however, if that term were subsumed under an existing space law treaty definition. Although the term "contamination," found in Article IX of the *Outer Space Treaty,* might be thought to serve this purpose, it refers only to harmful microbiological organisms of terrestrial origin, which might be accidentally released in the aftermath of a collision or explosion in outer space.[93] The term "space object" is more promising. The *Liability Convention* provides that "space object" includes a spacecraft, the launch vehicle, and the component parts of both. The *Registration Convention also* contains this description. However, existing international law does not define space object.

During the debates over the terms of the *Liability Convention,* negotiators could not agree on a description for "space object," nor was the question of whether orbital debris is included in "space object" specifically addressed. Negotiators were primarily concerned with which artificial objects should be considered "space objects," not with the effects of those objects following their active lives. During these debates, legal experts put forward two definitions of "space object."[94] The narrow definition included the object itself and its component parts, as well as the means of delivery and its component parts. Although some delegates offered a much broader definition, which would have included articles on board the space object and articles detached, thrown or launched from the space object, the narrower interpretation was adopted. Consequently, it is unclear which classes of space debris, if any, are included implicitly in "space object." Consider, for example, inactive payloads. The *Liability Convention* is silent on whether a payload must be active to qualify as a "space object" capable of causing damage. If inactive payloads are included, then they are space debris, with liability for compensation attaching to the launching state.

Orbital debris may also be considered a "space object" if it falls under the term "component parts." Yet what exactly constitutes "component parts" is not settled. According to the description of space object in *the Liability Convention, all* operational debris except

*Howard Baker, *Space Debris:* h@/ *and Policy Implications* (Dordrecht: Martinus Nijhoff Publishers, 1989), p. 103.

[94]The history of relevant U.S. national positions, and the negotiation of relevant UN treaties involving issues related to debris, pollution, and contamination can be found in Carl Christol, *The Modem International Law of Outer Space (New* York, NY: Pergamon Press, 1982), chap. IV, pp. 129-151; For a detailed discussion of this issue, see Baker, op. cit., footnote 92, pp. 83-85.

Box 6 – Internatwnal Space Treaties and Agreements

1. The ***Outer Space*** Treaty of 1967,[1] to which the United States and more than 100 countries are signatories, provides that a State party assumes international responsibility for space activities conducted by its government agencies and non-government entities.[2] The Treaty establishes that State parties are internationally liable for damages to the persons or property of other State parties, if the damage is caused either by an object launched into outer space or its component parts, whether the damage occurs on the ground, in air space or in outer space. This liability applies to States launching and procuring launches, and to States whose territory or facilities are used for launches.[3] Of great importance to environmental considerations is the treaty's statement obligating States to engage in appropriate international consultation in circumstances where it can be established that there is a reasonable belief that a space activity of one State party would cause potentially harmful interference with space activities of other State parties.[4]

2. ***The Liability Convention of 1972***[5] provides that both intergovernmental organizations and State parties are liable on the basis of fault for damage of their space objects, launch vehicles, or component parts thereof may cause in outer space.[6] States collaborating in launch activities are also jointly and severally liable for damages.[7] The standard of compensation is to be in accordance with international law and principles of justice and equity.[8] Because the ***Liability Convention*** defines a "space object" as "including component parts of a space object as well as its launch vehicle and parts thereof, "[9] the launching State's liability would continue whether its "space object" was functional or had reached the non-functional status of "space debris. "[10]

3. ***The Registration Convention of 1976***[11] provides a system whereby any space object launched into Earth orbit or beyond is to be registered with the United Nations.[12] In the case of two or more launching States, an agreement among or between those States will determine who registers the object.[13] Where identification of debris causing damage cannot be obtained from the registration information, the Convention requires other parties with space monitoring and tracking facilities to assist to the greatest extent feasible in identifying the space object.[14]

4. ***The Rescue and Return Agreement of 1968***[15] establishes State party obligations regarding the return to Earth and recovery of space objects or their component parts.[16] A State party discovering such material must notify the launching authority and the United Nations.[17] The discovering State shall take practical steps to recover returned material in its territory if the launching authority so requests. If a discovering State reasonably believes that the returned material is dangerous or hazardous, the launching authority, under the direction and control of the discovering State, is to take immediate effective action to eliminate possible danger or harm.[18]

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[1] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, 18 U.S.T. 2410, T. I.A.S. No. 6347,610 U. N.T.S. (Apr. 22, 1968).

[2] Article VI.

[3] Article VII.

[4] Article IX.

[5] Convention on International Liability for Damages Caused by Space Objects, 24 U.S.T. 2389, T. I.A.S. No. 7762 (Mar. 29,1972, effective Oct. 9, 1973).

[6] Articles I, III, IV, and XXII.

[7] Article V.

[8] Article XII.

[9] Article I.

[10] There is no retirement i„either the Liability Convention or the Outer Space Treaty that space objects, launch vehicles, or any components must be functional when damages occur in order for liability of the launching State/State of Registry to attain.

[11] Convention on Registration of Objects Launched into Outer Space, 28 U.S.T. 695, T. I.A.S. No. 8480, U. N.T.S. 15 (Oct. 9, 1973.)

[12] Articles I-IV.

[13] Article II, paragraph 2.

[14] Article VI.

Continued on next page

5. The Moon *Agreement of 1979*[19] entered into force on July 11, 1984. However, none of the major spacefaring nations, including the United States, is party to the Agreement. The Agreement establishes obligations of States parties and international organizations regarding environmental protection.[20] Measures must be taken to prevent the disruption of the existing balance of the environment of the Moon, other celestial bodies in our solar system, and orbits around or other trajectories to or around them, and to avoid harmfully affecting the environment of Earth.[21] Notice is to be given to the Secretary-General of the United Nations of the placement and purpose of radioactive materials.[22] Mandatory consultation procedures and subsequent means for settling disputes are provided.[23]

[15] *Agreement on the Rescue and Return of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, 19* U.S.T. 7570, T.I.A.S. No. 6599,672 U. N.T.S. (Apr. 22, 1968).

[16] Article V.

[17] Article V, paragraph 1.

[18] Article V, paragraph 4.

[19] *The Agreement Governing Activities of States on the Moon and Other Celestial Bodies*, United Nations General Assembly, Resolution 34/6S (Dec. 5, 1979).

[20] Article VII and Article XVI.

[21] Articles I, paragraphs 1 and 2; and Article VII, paragraph 1.

[22] Article VII, paragraph 2.

[23] Article xv, paragraphs 2 and 3.

Table 4- Classes of Space Debris

- Payloads that can no longer be controlled by their operators;
- Operational debris (objects produced as a *result* of normal space activities, remaining in outer space);
- Fragmentation debris (products o fexplosions and collisions); and
- MicroParticulate matter (micron-size objects such as solid-propellant rocket motor effluent, paint flakes, and thermal coatings).

SOURCE: Office of Technology Assessment, 1990.

litter appears to be "component parts," although jurists do not agree on this point. Whether all fragmentation debris and microparticulate matter are included is even more problematic, even if the broader interpretation of "space object" is invoked. This fuzziness is unfortunate because fragmentation debris represents about half of the orbital debris population.

Summarizing, the only classes of orbital debris included in current treaty law, with any degree of certainty, are operational debris, to the exclusion of inactive payloads, fragmentation debris, microparticulate matter, and litter. The degree of difficulty already manifest in attempting to obtain international agreement on the definition of debris clearly suggests that early voluntary national action to limit and reduce debris may be far more effective than attempting to obtain any international agreement on debris reduction procedures in the near term.

Jurisdiction and Control

Who has jurisdiction and control over space debris? If remedial action is to be included in any regulatory scheme for orbital debris, consideration should be given to the issue of who is authorized to remove orbital debris. Article VIII of the *Outer Space Treaty* provides that the State of registry of "an object launched into outer space" has the right to make and enforce domestic law in relation to that object and "any personnel thereof," and that ownership of a space object is not affected by its presence in outer space. Two legal issues raised by this provision are whether orbital debris falls within the scope of Article VIII and the extent to which jurisdiction and control over space objects is permanent.

Legal analysts agree that both active and inactive payloads fall under Article VIII. They do not agree, however, on an appropriate method for distinguishing active payloads from inactive ones. Although a test of "effective physical control" has been proposed, successfully applying this test is hampered by several obstacles. First, legal opinion favors the view that jurisdiction and control of a State over its space objects is permanent.[95] Moreover, because ownership of a space object also is permanent, regardless of its use and condition, and because the owner retains the rights of possession, use, and disposal, states or other legal entities would require the consent of the State of registration in order to interfere in any way with that space object.

Applying a doctrine of permanency to debris objects appears to impede attempts to minimize the quantity of orbital debris as it only accounts for inactive payloads, and it applies only to identifiable space objects. There may be two possible exceptions to this doctrine, however: the analogy to abandonment, and sentence 1 of Article IX of the *Outer Space Treaty*.[96]

In maritime law, abandonment arises where no personnel remain on board a vessel and there is no intent to return and reactivate it. Then the vessel becomes a derelict subject to salvage. It is not yet clear, however, whether the hazard posed by orbital debris is sufficient justification for its removal without the consent of the State of registration. Sentence 1 of Article IX of the *Outer Space Treaty* provides in part that State parties to the Treaty have obligations to cooperate, to provide mutual assistance, and to have due regard for the corresponding interests of other State parties. Although some have suggested that these legal obligations fetter the absolute nature of jurisdiction and control and ownership, application of sentence 1 may be limited. First, some have argued that corresponding interests exclude threats posed by orbital debris.[97] Second, the *Outer Space Treaty* provides for competing interests among states, but does not lay down any rules for designating priority among these interests, which include a right to hazard-free space navigation as well as a right to leave an inactive payload in orbit.

Suggestions providing for timely removal of hazardous space objects, without consent of the State of registration, are limited in their effectiveness. They refer at best to inactive payloads and other identifiable space objects, and offer no preventive measures, but only compensation after the fact. Given the inchoate nature of the law regarding orbital debris, a rigorous analysis of analogous provisions in other legal regimes would probably be quite useful.

Detection and Identification

To remove orbital debris from outer space and to hold States accountable for damage caused by their orbital debris entails a method of identifying the State responsible for the debris. Identification of space objects is addressed in the *Registration Convention*.

Identification of space objects involves two phases: detection of the object and identification of its State of registry. The *Registration Convention* contains no provisions for detection and does little to establish a system that

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[95] See, for example, I. Diederiks-Verschoor, "Legal Aspects of Environmental Protection in Outer Space Regarding Debris," 30th *Colloquium on the Law of Outer Space*, 1987, p. 131.

[96] In the exploration and use of outer space, including the Moon and other celestial bodies, States Parties tothetreaty shall be guided by the principle of cooperation and mutual assistance and shall conduct all their activities in outer space, including the Moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty.

[97] Carl Q. Cristol, *The Modern International Law of Outer Space* (New York, NY: Pergamon Press, 1982), p. 139.

would identify the States of registry of space objects that do not appear in the registration lists.[98] Consequently, this treaty is of little use in identifying orbital debris, especially in its untraceable manifestations. Without proper identification, the *Liability Convention* cannot be invoked because the State of registry cannot be ascertained. Another possible weakness of this treaty is the absence of a provision for compulsory markings, although markings must be registered if they are used. Therefore, what would be the most obvious and convenient method for identifying space objects is voluntary. Large components could be identified relatively easily. Very small components and microparticulate debris cannot readily be marked.

Liability for Damage Caused in Outer Space

The *Liability Convention* sets out a legal regime to provide compensation for damage caused in outer space by space objects. In outer space, liability is based on fault. It is significant to note that negotiations for the *Liability Convention* did not consider the question of the risks posed by orbital debris. As a result, the negotiators did not address several liability issues of extreme importance related to damage caused by orbital debris. These issues include the meaning of "damage" and the reasonableness of a fault-based liability[99] regime for damage caused in outer space by orbital debris.

Experts generally agree that damage to the outer space environment per se is not within the scope of the *Liability Convention.* Consequently, launching States cannot be held liable for the mere presence of orbital debris in outer space. In this regard, microparticulate matter and very small pieces of fragmentation debris are of particular concern because launching States have no legal incentive to avoid generating these types of orbital debris, although they have enormous operational incentives to do so. It would be possible to amend the *Liability Convention so* as to include damage to the outer space environment per se, based on the fact that outer space is a global commons. Yet, even if accepted, resolution of three significant legal issues beyond the scope of space law would still remain: legal standing for claimant States (who is going to speak for mankind?), assessment of damages, and the nature of the liability.

The principle of fault-based liability is a further impediment to compensation for damage caused in outer space by orbital debris. Application of the fault-based outer space liability regime of the *Liability Convention* to orbital debris is doubtful because the Convention "appears to be primarily concerned with a possible collision between [active] space objects."[100] Even if damage caused by orbital debris were within the scope of this regime, several other important legal issues, such as proof of negligence, and contributory negligence, among others, would remain unresolved.

Article III of the *Liability Convention* does not specify whether the damage caused must be reasonably foreseeable, that is, whether the damage caused by orbital debris is of a kind that specialists in the field would expect to occur. It has been argued that, as a result of the impossibility of foreseeing all the different situations that could lead to damage in outer space, only two factors need to be established –the damage, and a cause-and-effect rela-

[98] As long as an object is intact, and has been registered by the launching State, as required by the convention, the State of registry can be established by observing its orbital parameters. However, the State of registry of most space debris, especially debris that cannot be tracked by existing technology, is uncertain.

[99] Fault-based liability is liability based on the ability to establish direct or indirect fault for damage.

[100] United States Congress, Staff of Senate Committee on Aeronautical and Space Sciences, 92d Cong., 2d Sess., *Report on the Convention on International Liability for Damage Caused by Space Objects: Analysis and Background Data* (Comm. Print 1972), p. 27.

tionship between the damage and the incident giving rise to the damage.

The terms of the *Liability Convention* place restrictions on who may seek compensation for damage caused in outer space by orbital debris. For example, compensation is unavailable for any damage resulting from a collision between two space objects, each owned by a different private entity, if both entities are under the jurisdiction of the same launching state.[101] The same result would follow if one of the space objects were a piece of identifiable orbital debris. Nor is compensation available under the convention to injured parties who are either nationals of a launching State or foreign nationals participating in any phase of a space activity. This restriction extends to nationals of all States participating in any one launch activity, and to nationals of all States entering into joint ventures with any State participating in any launch activity. Additionally, certain provisions of NASA launch agreements that allocate risk among the participating parties further limit eligible claimants by arranging reciprocal cross-waivers of claims among participants.

One serious shortcoming of the decision to base damage in outer space on fault has been that the rationale for fault-based liability must be applied to damage caused in outer space by orbital debris. This rationale, ostensibly based on the equality of States in undertaking space activities, makes three fundamental assumptions: States participating in space activities accept the risks involved; States are free to conduct any space activity as long as fault-based damage does not result; and absolute liability[102] for damage to space objects in outer space would lead to absurdities and inequities.

Although the fault rationale may well be justified in the event of collisions between two active, and therefore controlled, satellites, its application seems unreasonable where damage in outer space is caused by orbital debris. In this situation, application of the rationale for absolute liability may be more appropriate. First, space flight and space activities may be considered ultrahazardous or abnormally dangerous activities for which "responsibility [should be] imputed to the person or entity making the initial decision to engage in the activity which exposes others to risks where possibly no amount of foresight or feasible protective measures may avert injuries."[103] Therefore, in cases where orbital debris causes damage, those who create the risk should bear the cost of not only compensating for damage done to persons and property in outer space, but also protecting the space environment itself. Second, absolute liability is considered necessary when it is unlikely that fault can be established. In the outer space context, and particularly when orbital debris is being considered, problems of establishing the proof of fault necessary for satisfying the courts are magnified. The problems encountered with making the case under existing or even strengthened liability provisions make it essential to concentrate on establishing a preventive set of measures and enforcement mechanisms.

The Kosmos 954 incident illustrates how a claim may be based upon the *Liability Convention* and principles of international law. Canada's claim consisted of compensation for search, recovery, testing, and clean-up. Under principles of international law, Canada had a duty to take the necessary measures to prevent and reduce the harmful consequences of the damage (mitigation).[104] The settlement procedures of the *Liability Convention* were

[101] In that case, an injured party would have to seek redress under national laws of the State concerned.

[102] In other words, where liability is incurred by a party regardless of fault.

[103] U.S. Senate Report on Liability Convention, op. cit., footnote 99, p. 26.

[104] See Canada: Claim Against th, Union of Soviet Socialist Republics for Damage Caused by Soviet Kosmos 954, reprinted in *International Legal Materials, vol.* 18, 899, par. 15 & 17, 1979.