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Unidentified Orbital Debris: 
The Case for a Market-Share Liability Regime

BY MARK J. SUNDAHL, PH.D.*

Introduction

We stand today on the threshold of a new space age. Public interest in space activity is strong and signs of vitality in space are everywhere. The Space Shuttle continues to fly regularly, NASA’s program to explore Mars has been aggressive, and the construction of the International Space Station has commenced. Private industry also has a firm first foothold in space. Telecommunication companies, for example, plan to envelop the Earth with satellite constellations in order to make global wireless broadband Internet access a practical reality. With the development of a reusable launch vehicle, the cost of achieving orbit will fall and the full vigor of the free market will be unleashed. At that point, various space

* J.D. candidate, Hastings College of the Law, 2001; Ph.D. (Classics), Brown University, 2000; B.A., University of California, Los Angeles, 1993. I would like to extend my gratitude to Professor Dr. Walter Flury of the European Space Agency for providing me with the most recent scientific data on space debris. My thanks also go to Scott Blumin for encouraging me to pursue my vision of the new space age. I dedicate this Note to my wife and friend, Ms. Angela Bailey-Sundahl.

1. See Mars Trip is Declared a Success, L.A. TIMES, Aug. 9, 1997, Metro, at 1. The NASA webcast of the Mars rover mission in 1997 was “the largest Internet event in the history of the world.” Id.


3. See ESA SPACE DEBRIS MITIGATION HANDBOOK, at 4.2-1, European Space Agency (Release 1.0, 1999) [hereinafter ESA HANDBOOK].

4. A reusable launch vehicle, or RLV, does not rely on disposable rocket
industries, such as meteor mining, zero gravity manufacturing, and tourism, will emerge.  

Our fledgling space industry, however, faces a grave danger. The volume of orbital debris has become so great that collisions are already commonplace. As the debris population continues to grow, the costs resulting from collisions will eventually smother the industry.

The most effective way to protect the space industry from the crushing costs of orbital debris is to internalize the costs so that those who are responsible for creating the hazard pay for any damage to innocent parties. This internalization can be achieved by assigning liability to those responsible for creating the debris. The United Nations Convention on International Liability for Damage Caused by Space Objects (Liability Convention) already internalizes some debris-related costs by means of a fault-based liability regime for damage caused by space objects. The Convention only partially succeeds in internalizing debris-related costs, however, because its provisions only reach damage caused by larger pieces of debris. The scope of the Liability Convention is limited in this way because the fault standard requires that the owner of the harmful space object be identified. Identification, in turn, requires that the debris fragment be

boostersto break free of Earth's gravitational pull, as does the Space Shuttle. The mass-production of RLVs may be close at hand due to the establishment of the X-Prize, a privately funded contest which offers an award in excess of ten million dollars to the inventor of the first RLV. See X PRIZE Foundation, X-Prize Homepage (visited Mar. 5, 2000) <http://www.xprize.org>. Eighteen teams from around the world have entered the competition and a winner is on the horizon. See id. The aerospace establishment as well as entrepreneurs unaffiliated with the X-Prize have also taken up the RLV challenge. See Erick Schonfeld, Going Long, FORTUNE, Mar. 20, 2000, at 172-92. Lockheed, for example, has developed a prototype RLV called the X-33. See id. at 174.


5. See Schonfeld, supra note 4, at 174, 179. In fact, space tourism has already begun. See Former JPL Scientist to Visit Mir Space Station as Tourist, L.A. TIMES, June 17, 2000, at B7. The first space tourist, Dennis Tito, will pay approximately twenty million dollars to spend ten days on the rehabilitated Mir space station, now owned by the Dutch company MirCorp. See id.


7. See discussion infra Part III.
continuously tracked from Earth throughout its orbital lifetime. Currently, however, governments only track debris fragments with a diameter over ten centimeters.\(^8\) Smaller fragments are not tracked and therefore nobody can be held liable for any damage caused by these fragments. This problem of identification is a very serious matter because small objects make up by far the largest and most dangerous class of debris. These objects already number in the trillions and are ever increasing.

Market-share liability solves the unidentified orbital debris problem. Market-share liability has been successfully applied in situations where several parties contribute to a dangerous condition but where no clear causal link ties a particular party to the harm caused by the condition. This solution has been proposed by a handful of commentators over the years but no mechanism for imposing market-share liability in outer space has yet been devised.

This Note explores the threat of unidentified orbital debris and proposes a mechanism for imposing a form of market-share liability. Part I describes the nature of the unidentified debris threat. Part II describes how various agencies track debris and explains the limitations of debris identification. Part III discusses international law relevant to space debris.\(^9\) Part IV exposes the weaknesses of some previously proposed solutions to the unidentified debris problem. Part V argues that market-share liability is the best way to internalize the costs of unidentified debris damage. Finally, Part VI proposes an amendment to the Liability Convention that applies market-share liability to damage caused by unidentified orbital debris.

This Note comes on the heels of UNISPACE III, the third annual conference of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), which took place in July 1999.\(^{10}\) At the meeting, the Scientific and Technical Subcommittee made public the fruits of a five-year study of the orbital debris problem.\(^{11}\) In

\(^8\) See discussion infra Part II.


\(^{11}\) See TECHNICAL REPORT ON SPACE DEBRIS, Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer
April 1999, the European Space Agency also released a detailed study of space debris and debris mitigation. These new studies will provide the technical foundation for the next generation of orbital debris scholarship. I was fortunate to have access to these sources while writing this Note.

I. The Nature of the Debris Threat

The United Nations will only address the unidentified debris problem when the international community is convinced that space debris poses a significant threat to our future in space. This Part describes the current state of the debris problem and explains how this problem, if ignored, will eventually reach crisis levels.

A. The Debris Population

The phrase "space debris" refers to all non-functional man-made space objects. There are four categories of debris: (1) inactive payloads, (2) operational debris, (3) fragmentation debris, and (4) microparticulate debris. Inactive payloads are defunct satellites that drift through space. Operational debris includes anything released into space during the course of a mission, such as spent rocket stages, exploding bolts, and lens caps ejected prior to camera operation. Fragmentation debris, which makes up the greatest segment of the debris population, consists of fragments born of collisions and explosions. Microparticulate debris consists largely of paint chips from deteriorating surfaces and particles created by the burning of solid rocket fuels.

Debris can also be divided into three size groups: (1) "large"
objects with a diameter over ten centimeters, (2) "medium" objects with a diameter between ten centimeters and one millimeter, and (3) "small" objects less than one millimeter in diameter.\textsuperscript{19} As a result of the almost 3900 space missions launched since 1957,\textsuperscript{20} there are now approximately 15,100 "large" pieces of debris adrift in Low Earth Orbit (LEO).\textsuperscript{21} Smaller debris is far more numerous: tens of millions of "medium"-sized pieces of debris float in space while trillions of "small" pieces wash across the orbits like waves of sand.\textsuperscript{22}

Medium and small fragmentation debris is particularly dangerous because this debris typically travels much faster than large debris and can be shot in any direction by the explosive force of a collision.\textsuperscript{23} An individual piece of debris may reach speeds up to fifteen kilometers per second (54,000 kilometers per hour).\textsuperscript{24} At this speed, a fragment the size of a bullet could torpedo a space station or destroy a satellite.\textsuperscript{25} A much smaller fragment would easily pierce an astronaut's suit.\textsuperscript{26} Even small particles traveling at a relatively low speed can over time degrade the surfaces of spacecraft components.\textsuperscript{27} Disturbingly, ninety-nine percent of all orbital debris is composed of this deadlier class of debris with a diameter under ten centimeters.\textsuperscript{28}

\textbf{B. The Risk of Collision}

Any spacecraft that spends a significant amount of time in orbit will inevitably collide with some type of debris.\textsuperscript{29} A partial list of

\begin{itemize}
\item \textsuperscript{20} See ESA HANDBOOK, supra note 3, at 2.0-1.
\item \textsuperscript{21} See id. at 2.4-1. The Low Earth Orbit (LEO) is the most heavily utilized orbit. Objects in LEO orbit between 200 kilometers and 2000 kilometers above the surface of the earth. In Geosynchronous Earth Orbit (GEO), spacecraft typically orbit approximately 36,000 kilometers above the earth. Objects in GEO have orbital periods of twenty-four hours, matching the Earth's rotational period, which allows them to remain constantly positioned within view of a chosen point on earth, such as a communications station. See Limperis, supra note 19, at 320-21.
\item \textsuperscript{22} See ESA HANDBOOK, supra note 3, at 2.4-1.
\item \textsuperscript{23} See id. at 2.4-3.
\item \textsuperscript{24} See id. at 9.0-1.
\item \textsuperscript{25} See Richard Berkley, \textit{Space Law Versus Space Utilization: The Inhibition of Private Industry in Outer Space}, 15 WIS. INT'L L.J. 421, 431 (1997); see also Seymour, supra note 9, at 896.
\item \textsuperscript{26} See id.
\item \textsuperscript{27} See Limperis, supra note 19, at 328.
\item \textsuperscript{28} See Seymour, supra note 9, at 910 n.146.
\item \textsuperscript{29} See Limperis, supra note 19, at 326. The probability of collision is a function
orbital collisions and near collisions involving debris shows that the danger is real:  

1. In July 1996, a fragment of the European Ariane rocket struck the French Cerise spy satellite.  
2. Damage to Japan’s Midori satellite was likely to have been caused by debris.  
3. The Space Shuttle has had 27 windows damaged by debris during 18 flights.  
4. In 1998, orbital debris destroyed the expended third stage of a Minuteman 2 intercontinental ballistic missile (ICBM).  
5. The Hubble telescope’s solar panels have been pierced numerous times by debris.  
6. The Space Shuttle took evasive maneuvers to avoid debris on seven missions.  
7. In 1997, both the ERS-1 satellite and the CNES spacecraft SPOT-2 were forced to maneuver in order to avoid collision with debris.  
8. Debris detectors placed in orbit to test debris density have shown many thousands of craters.  
9. Various other retrieved space objects have shown debris-related degradation.

This list includes only those episodes which are known to have involved debris. The unexplained malfunctions of a great number of satellites may well have been caused by debris damage. Perhaps the
most telling indication of the high probability of collision is the prediction made by NASA that the International Space Station stands a one-in-five chance of being critically damaged by debris during its first ten years in orbit.41

Not only is the threat posed by orbital debris real, but it is also increasing. Debris volume has grown by three to five percent every year and will continue to increase due to vigorous space activity.42 One project that promises to add considerably to orbital congestion is the proposed deployment of multiple satellite constellations to optimize wireless global communication.43 The proposed Teledesic constellation will surround the Earth with 288 satellites.44 Fourteen other constellation projects have been proposed by companies such as Hughes and General Electric.45 These projects could add approximately 700 new satellites to "regions of peak debris density."46 The effect on the orbital debris threat will be two-fold. First, the placement of more satellites in the path of orbital debris will increase the probability of collision. Second, the deployment of these constellations will itself increase the debris population by creating operational debris and, if any mishaps occur, fragmentation debris. Computer-modeling programs predict that even if only a fraction of the proposed constellation projects are successfully implemented, the number of catastrophic collisions in orbit will triple by the year 2050.47

The United States government also intends to accelerate the testing of its orbital missile interception system, known as the National Missile Defense.48 When conducting these tests, the government first launches an ICBM.49 A second rocket is then

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41. See Limperis, supra note 19, at 326. NASA intends to employ over two hundred shields to protect the space station from debris. See TECHNICAL REPORT, supra note 11, at 35.

42. See Smith, supra note 14, at 53.

43. See ESA HANDBOOK, supra note 3, at 4.2-1.

44. See id.

45. See id. at 4.2-3.

46. Id. at 4.2-1.

47. See id. at 4.2-2.

48. See Seymour, supra note 9, at 893-94, 903 n.92; Lampertius, supra note 40, at 462.

launched that carries the experimental exoatmospheric kill vehicle (EKV) into orbit. As the rocket nears the target missile, the EKV is released and collides with the ICBM in orbit. The resulting explosion releases vast amounts of fragmentation debris.

This increased space activity may bring about the most frightening future scenario of all: the Kessler effect, also known as the "cascade effect." The Kessler effect describes a point in time when the volume of space debris will become so great that one collision will trigger a cataclysmic chain of self-perpetuating collisions. These collisions will eventually produce an impenetrable cloud of fragmentation debris that will encase Earth. This is a worst case scenario that would make space travel, as one commentator has put it, "a thing of the past" and would obstruct our dream of colonizing outer space. If no concerted international action is taken to reduce debris, it will only be a matter of time before the critical volume is reached. In the absence of aggressive debris reduction, critical mass will be achieved first in the highly congested LEO. Although computer modeling cannot generate precise predictions, critical mass in LEO may occur within the next one hundred years. Once collisions begin, it will be impossible to stop the chain reaction. In the event that cascading does occur, the use of space will be derailed for hundreds of years until the debris particles are eventually pulled into the Earth’s atmosphere and vaporized.

II. Registration and Tracking: “Identified” vs. “Unidentified” Debris

Debris is “identified” if the international community knows who is responsible for launching it into space. Identification requires that the launch of the object be duly registered and that the object be continuously tracked in orbit. Several powerful Earth-based tracking

50. See Burns, supra note 49.
51. ESA HANDBOOK, supra note 3, at 4.6; see also Berkley, supra note 25, at 431; Seymour, supra note 9, at 914.
52. See ESA HANDBOOK, supra note 3, at 4.6.
53. Seymour, supra note 9, at 914.
54. See ESA HANDBOOK, supra note 3, at 4.6-1. For a definition of LEO, see discussion supra note 21.
55. See ESA HANDBOOK, supra note 3, at 4.6-2.
56. See id. at 4.6-1.
57. See id. Orbital lifetimes in LEO can span several hundred years.
stations are currently tracking almost 10,000 objects in orbit.\textsuperscript{58} These stations use either optical technology, i.e. telescopes, or radar to track debris.\textsuperscript{59} Radar technology is superior to telescopes not only because radar is far more sensitive (and therefore allows detection of smaller debris) but also because radar, unlike telescopes, can operate during the day as well as during inclement weather.\textsuperscript{60}

The United States Space Command (USSPACECOM) and its Russian counterpart have used tracking technology to catalogue space objects since Sputnik was launched in 1957.\textsuperscript{61} These entities, however, do not track debris smaller than ten centimeters in diameter.\textsuperscript{62} Therefore, the vast majority of space debris, which is composed of fragments less than ten centimeters in diameter, has been left "unidentified."

This failure to track smaller objects cannot be attributed to a lack of technology. The United States government's Haystack, Haystack Auxiliary (HAX) and Goldstone radar facilities have the ability to detect debris as small as 5 millimeters in diameter in orbit 1000 kilometers above Earth.\textsuperscript{63} The government entities have simply drawn the line at ten centimeters and do not track smaller objects. However, even if the United States government decided to use the HAX to track smaller objects, this would not necessarily mean that the government would be able to identify the "owners" of small debris. The origin of small debris is virtually impossible to determine because the fragments are typically created by explosions and collisions between larger debris in orbit. The orbits have become a soup of debris fragments that collide and create new smaller fragments which then shoot off in various directions. Keeping track of who owns each particle of debris would be a task of overwhelming complexity. As explained in the following section, this inability to identify the origin of smaller debris poses a serious challenge to the current international liability regime.

\textsuperscript{58} See TECHNICAL REPORT, supra note 11, at 5-8.
\textsuperscript{59} See id. at 4, 7.
\textsuperscript{60} See id. at 4, 6.
\textsuperscript{61} See id. at 5.
\textsuperscript{62} See id.
\textsuperscript{63} See id. at 6-7. An experimental radar system under development in Germany may be able to detect objects in orbit that are no larger than a speck of dust. See id.
III. Liability Under Current International Law

Four international agreements govern outer space activities: (1) the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (Outer Space Treaty), (2) the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Space (Rescue and Return Agreement), (3) the Liability Convention, and (4) the Convention on Registration of Objects Launched into Outer Space (Registration Convention). As we shall see, the spirit of these agreements suggests that the launching state has perpetual responsibility for any damage caused by its space objects. Nevertheless, the current treaty regime fails to provide a fair compensation mechanism for damage caused by debris. This lacuna is most glaring with respect to damage caused by unidentified debris.

The Outer Space Treaty was the international community’s first effort to assign liability for space activities. Article VII states that “each state party to the treaty that launches or procures the launching of an object into outer space . . . is internationally liable for damage [caused] by the object or its component parts.” However, the absence of any clear standard of liability renders this provision so vague as to be practically worthless. The treaty also fails to create a procedural mechanism for seeking compensation. Another weakness, which recurs in later treaties, is the vague definition of “space object.” This term may only encompass active spacecraft and satellites while excluding defunct objects such as debris. On the other hand, commentators have argued convincingly that the term “object” has a broader meaning that may include man-made debris

67. Outer Space Treaty, supra note 64, art. VII.
68. See Limperis, supra note 19, at 330.
69. See id. at 333.
because the provision mentions "component parts."70 Despite the vague nature of the liability provision, it does give the impression that a launching state should be perpetually liable for any and all damage caused by its space objects.71

Article IX of the Outer Space Treaty also requires states to avoid "harmful contamination" of outer space.72 This provision reveals an international awareness that space use could cause hazardous environmental conditions, such as debris pollution, and suggests that the launching state is responsible for reducing these hazards. Similarly, the Rescue and Return Agreement requires a state "to take effective steps . . . to eliminate possible danger of harm [by its space objects when they are returned to Earth]."73 Although this obligation does not extend to objects still in space, the provision suggests that states have a continuing responsibility for defunct objects.74

The Liability Convention was enacted in 1972 to elaborate on the extent and nature of a state's liability for damage caused by its space objects. The liability scheme imposed by the Convention has two prongs: Article II renders a state strictly liable for all damage caused by its space objects that occurs either on Earth or in airspace, while Article III creates fault-based liability for all damage that occurs in orbit.75 The Convention also provides that the injured state can submit a claim for damages directly to the launching state.76 If the states fail to reach a resolution, Article XIV calls for the appointment of a Claims Commission to arbitrate the matter.77

The Liability Convention has a number of weaknesses which have been addressed in recent legal literature. First, it is still not clear that "space object" includes debris and therefore the question remains whether the Convention extends to damage caused by orbital debris.78 The definition of "space object" provided in Article I,

70. Smith, supra note 14, at 55.
71. See id. at 57.
72. Outer Space Treaty, supra note 64, art. IX.
73. Rescue and Return Agreement, supra note 65, art. V.
74. See Seymour, supra note 9, at 899-900.
75. Liability Convention, supra note 6, arts. II, III. Article III states that "[i]n the event of damage being caused elsewhere than on the surface of the earth to a space object of one launching State or to persons or property on board such a space object of another launching State, the latter shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible." Id. art. III.
76. Id. art. IX.
77. Id. art. XIV.
78. See Limperis, supra note 19, at 331.
however, includes "component parts of a space object." This language may support an interpretation bringing debris damage within the scope of the Convention. Second, the Convention lacks a clear standard of care for determining when a state would be liable for damage. The vague wording of the Convention leaves unanswered certain questions regarding the duty of the launching state and how a breach of that duty would occur. For example, would the launching state be liable if damage to a third party results from the launching state's failure to follow construction guidelines? And is the fault standard objective or subjective? The third and most troublesome flaw, a flaw which this Note attempts to cure, is the Convention's failure to assign fault in those cases where the destructive object cannot be identified. This issue is the sword onto which the Liability Convention will ultimately fall. Unidentified debris poses the greatest risk of damage in outer space and yet the Convention provides no compensation to its victims.

The Registration Convention makes the fault-based liability scheme more effective by aiding in the identification of space objects. Article II requires states to keep a registry of all objects launched into space. In theory, powerful tracking systems will then keep track of registered objects after launch. Thus, any objects involved in an orbital collision will be instantly identifiable and the party "at fault" will be liable. The Convention also urges states with tracking capabilities to assist others in tracking their space objects. Unfortunately, compliance with the convention has been poor. A larger problem is that these provisions help assign liability only insofar as an object can be tracked and, as explained above, most orbital debris cannot be tracked. Therefore the Liability Convention, even when assisted by the provisions of the Registration

79. Liability Convention, supra note 6, art. I.
80. See Berkley, supra note 25, at 440.
81. See Lampertius, supra note 40, at 456-57.
82. See id. at 456.
83. See Smith, supra note 14, at 58.
84. See Lampertius, supra note 40, at 456.
85. See id. at 455.
86. See id. at 459.
87. Registration Convention, supra note 66, art. II.
88. Id. art. IV.
89. See Lampertius, supra note 40, at 460.
90. See discussion supra Part II.
IV. Two Previously Proposed Solutions:
Insurance and the Liability Pool

As the damage caused by unidentified orbital debris increases, the cost of space use will increase correspondingly. If international law does not allocate this cost to the responsible parties, the injured parties will be forced to absorb the cost. At some point, this cost will be so great that space ventures will become prohibitively expensive and any hope of private industry in space will evaporate. The challenge is to design a mechanism for internalizing the cost of unidentified debris so that the burden on innocent space venturers is lifted and private industry can flourish. In addition to market-share liability, which will be discussed in the next section, legal commentators have proposed two mechanisms for providing compensation to parties damaged by unidentified orbital debris: (1) insurance, and (2) a "liability pool." Neither of these mechanisms, however, provides an acceptable solution to the debris problem.

The less attractive of the proposed solutions is insurance. Insurance could be purchased to cover any damage caused by unidentified debris. This is a palatable solution for the time being since the risk may be spread, for instance, among a number of satellite owners. As long as the pool of insured satellite owners is large enough, the insurance premiums will be affordable. However, as the debris population grows, the premiums will rise with the probability of collision. Eventually, the insurance premium itself will become a significant barrier to entering the space industry. More importantly, the insurance solution is unsatisfactory because it does not internalize the cost of harm caused by debris but only spreads the cost among the parties at risk.

Commentators have also proposed the creation of an international compensation fund, or "liability pool." Each launching entity would contribute to the fund in proportion to the amount of debris that its mission would be likely to create. The fund would then

91. See Smith, supra note 14, at 64-66.
92. See id. (synopsis of various satellite insurance provisions).
be used to pay compensation for any damage caused by unidentified orbital debris. While this solution does internalize the costs of debris, it does so imperfectly due to the impossibility of determining prior to launch how much debris an individual mission will create. There are many unforeseen events that may result in debris creation. For example, a navigator on Earth may make an error when guiding a satellite to its orbit. If a collision results and thousands of new debris fragments are created, according to the per-launch schema, the company will not have to pay more into the fund at that point. Therefore, the cost of that new hazard created by the collision is not internalized. It is also unfair to charge a launching entity for damage which has not yet, and may never, occur. For example, a given company may launch, operate, and then retrieve a satellite without the creation of any significant amounts of debris. That company would have already paid into the liability pool even though it ultimately made no contribution to the debris hazard.

Furthermore, if instituted now, a liability pool funded by a per-launch fee would be sorely underfunded for many years to come. It would take several years for the pool to collect the funds needed to meet the demands for compensation. If a string of collisions were to occur early on, the fund would be quickly depleted. One commentator has suggested that contributions for prior space pollution should be demanded from the United States government and other polluters in order to build a sufficient pool of funds quickly. Such a request would most likely be rejected out of hand.

V. Market-Share Liability as a Solution

Market-share liability provides the only fair and effective solution to the unidentified debris problem. This theory of liability, which was created in the context of a pharmaceutical case in 1980 by the California Supreme Court, holds each party liable in proportion to its contribution to the dangerous condition. The application of this theory of liability to the unidentified debris problem was first

94. See id.
95. See generally Glenn H. Reynolds & Robert P. Merges, Outer Space: Problems of Law and Policy 177 (1989); Lampertius, supra note 40, at 466; Roberts, supra note 93, at 70-73; Berkley, supra note 25, at 440; Limperis, supra note 19, at 339-41.
97. See discussion infra Part V.A.
proposed in 1989 by Professors Glenn Reynolds and Robert Merges. Recently, this idea has enjoyed a resurgence in space debris scholarship. Two articles published in 1992 touted the idea as a possible solution to the unidentified debris problem. In 1997, Richard Berkley again put forth market-share liability as a potential solution. Most recently, Peter Limperis made a forceful argument for the application of market-share liability to orbital debris. Despite the popularity of market-share liability, none of the commentators mentioned above has explored the feasibility of applying the theory to orbital debris.

A. A Brief History of Market-Share Liability

Market-share liability first emerged in a tort case in which the plaintiffs suffered harmful side effects from diethylstilbesterol (DES), a synthetic form of estrogen. During the thirty-year period between 1941 and 1971, the drug was administered to pregnant women for the purpose of preventing miscarriage. Over two hundred pharmaceutical companies manufactured the drug during this period. It was later discovered that women whose mothers had ingested DES suffered a high incidence of vaginal and cervical cancer as a side effect of the drug. However, due to the passage of time and, more importantly, due to the fungible nature of the product, the victims were unable to identify the specific manufacturer that produced the pills prescribed to their mothers. Because the pills were perfectly substitutable, pharmacists routinely filled prescriptions for DES with pills produced by any of the two hundred manufacturers. This inability to create a clear causal link between the harm and a particular manufacturer raised a new challenge for the California Supreme Court.

The court in *Sindell* first considered, but ultimately rejected,

98. See Reynolds & Merges, supra note 95, at 177.
99. Lampertius, supra note 40, at 466; Roberts, supra note 93, at 70-73.
100. See Berkley, supra note 25, at 440.
101. See Limperis, supra note 19, at 339-41.
102. See Sindell, 26 Cal. 3d at 593.
103. See id.
104. See id. at 602.
105. See id. at 594.
106. See id. at 595, 610.
107. See id. at 595.
three traditional tort theories of multiple causation. The first of
these theories was "alternative liability," which had been espoused
previously by the court in Summers v. Tice. In Summers, the
plaintiff had been hit by buckshot after two hunters fired shotguns
simultaneously in his direction. Because both defendants were
negligent and both were in a better position than the plaintiff to
determine who fired the harmful bullet, the court shifted the burden
to the defendants to absolve themselves of blame individually. Under
this theory, if the defendants are unable to isolate the liable
party, all defendants are held jointly and severally liable.

The court in Sindell refused to apply alternative liability to the
DES situation for two reasons. First, the drug manufacturers had no
special information that would have given them an advantage over
the plaintiffs in determining which company had made the pills
ingested by each plaintiff's mother. Second, the probability that an
individual drug manufacturer had actually produced the drug ingested
by each plaintiff's mother was very low, unlike the situation in
Summers where a fifty percent probability existed that each of the
defendants had fired the harmful bullet. Therefore, the court
concluded that it would be unfair to hold a company jointly liable for
harm it most likely did not cause.

The second approach rejected by the court in Sindell was the
theory of "concert of action liability." Under this theory, multiple
tortfeasors can be held jointly liable for the actions of the group if
they collaborated, either expressly or implicitly, in committing a
tortious act, or else knowingly provided substantial assistance in the
commission of the tort. The court found no such collaboration or
common plan among the various drug manufacturers and rejected
this theory of liability.

Finally, the court in Sindell refused to find the defendants liable

108. Id. at 598-610.
110. Id. at 82.
111. See id. at 86.
112. See id. at 88.
113. Sindell, 26 Cal. 3d at 601.
114. Id. at 602-03.
115. See id. at 603.
116. Id. at 603-06.
117. See id. at 604.
118. See id. at 605.
under the theory of "enterprise liability." Enterprise liability, also known as "industry-wide liability," requires that each of the manufacturers follow the safety guidelines issued by a central trade association. In such cases, the individual manufacturers in effect shift their responsibility for ensuring the safety of their product onto the trade organization. When such an organization is negligent in the formulation of safety standards and these inadequate standards result in the production of goods that cause harm, each of the manufacturers is held jointly liable. However, because no such centralized trade organization existed in the DES industry, the court in Sindell dismissed this theory of liability.

Having rejected these traditional theories of liability, yet being unwilling to let the victims go uncompensated, the court decided to create a novel tort theory. The court explained that the realities of the modern marketplace, replete with fungible products, demanded a new theory of liability that would permit victim compensation without requiring the identification of a specific tortfeasor. Under this new theory, later dubbed "market-share liability," the court held that each of the drug manufacturers would be liable in proportion to their share of the DES market. Each company's resulting liability, the court reasoned, "would approximate its responsibility for the injury caused by its own products." The court permitted an individual defendant company to exculpate itself by proving that its product could not possibly have caused harm. In fact, one defendant in Sindell succeeded in exculpating itself by showing that it did not begin producing the drug until after the victims were born.

Since the decision by the California Supreme Court in Sindell, the high courts of several states have adopted market-share liability. The high courts of Washington, New York and Florida applied

119. Id. at 607-10.
120. Id. at 607-08.
121. See id.
122. See id.
123. Id. at 609.
124. See id. at 610.
125. See id. at 612.
126. Id.
127. See id.
128. Id. In the DES cases, the victim was harmed as a fetus as a result of medication taken by the mother.
market-share liability in DES cases similar to Sindell. Taking market-share liability beyond the context of DES for the first time, Hawaii’s Supreme Court adopted market-share liability to compensate plaintiffs who contracted the human immunodeficiency virus (HIV) from a tainted blood product manufactured by a number of companies.

When the Wisconsin Supreme Court was faced with a DES case, it ostensibly rejected market-share liability but then applied another theory of liability, “risk contribution liability,” which differed only in name from market-share liability. The court held that a manufacturer of DES should be held liable for damages on the grounds that it had contributed to the risk posed by the drug.

Other jurisdictions have refused to accept market-share liability. The high courts of Missouri, Iowa, Illinois and Ohio have rejected market-share liability on the basis of one or more of the following criticisms: (1) the theory abolishes the common law requirement of a clear causal link, (2) the task of determining market-share is difficult and can lead to the unfair apportionment of liability, and (3) market-share liability is a form of social engineering best left to the legislature. For the same reasons, the First and Third Circuits have refused to hold paint manufacturers liable under a market-share theory for brain damage in children caused by exposure to lead paint.


133. See Drummond, supra note 132, at 1341.

134. See id. at 1342-43.


Although market-share liability has been most successful in the context of DES cases, plaintiffs have made attempts to apply the theory to other areas of product liability. As mentioned above, the Hawaii Supreme Court adopted market-share liability to permit the recovery of damages for a tainted blood product. California has also applied the theory to allow compensation for victims of a defective polio vaccine. Efforts to extend market-share liability to health problems caused by asbestos and lead paint have failed so far. Potential areas of tort litigation that may in the future lend themselves to market-share liability are cases targeting tobacco companies and gun manufacturers. One reason for the infrequent use of market-share liability outside of the DES cases is that truly fungible products are rare.

B. The Application of Market-Share Liability to Orbital Debris

Orbital debris poses an unusual liability problem that resembles the challenge faced by the California Supreme Court in Sindell. Like DES tablets, small fragments of space debris are indistinguishable, i.e., debris is fungible. When unidentified debris causes damage, the specific party responsible for producing the harmful debris fragment cannot be identified. As in the DES cases, the current debris threat demands a creative solution. The fault-based scheme of the Liability Convention may work in those instances when the debris is identified, but when the debris is untrackable, the owner cannot be identified, fault cannot be attributed, and thus liability cannot be assigned. A form of market-share liability, however, can circumvent this problem of identification. Under such a scheme, each launching entity, whether public or private, will be partially liable for any damage caused by unidentified debris in proportion to the percentage of the unidentified debris population for which it is responsible.

aff'd, 3 F.3d 546 (1st Cir. 1993); City of Philadelphia v. Lead Indus. Ass'n, 994 F.2d 112, 115 (3d Cir. 1993); see also Lepage, supra note 135.

137. See Morris v. Parke, Davis & Co., 667 F. Supp. 1332 (C.D. Cal. 1987); see also Nace, supra note 130, at 416-18.

138. See Nace, supra note 130, at 414-16; Lepage, supra note 135, at 175.


140. See Nace, supra note 130, at 416 n.164.

141. Perhaps “risk-contribution liability” would be a more appropriate name since there is no market in space debris. Nonetheless, I will use the phrase “market-share liability” for the sake of simplicity.

142. See Limperis, supra note 19, at 340.
Who then would pay for damage caused by unidentified debris? Under the market-share scheme, the liability for such damage will fall almost exclusively on the United States and Russia for a long time to come. These states are the great pioneers in space use but they are also the primary contributors to the debris problem. The United States and Russia have sent over ninety percent of all catalogued space objects into orbit. The remaining portion is attributable to thirty-six other states and private entities.

The greatest obstacle to extending market-share liability to orbital debris is the difficulty in determining the contribution of each spacefaring state and private entity to the existing debris hazard. The total unidentified debris population can be estimated by sampling methods and mathematical models, but it is impossible to determine with any precision what portion of that population is attributable to the activities of a particular state. In the DES cases, the courts were able to calculate the market-share of each of the defendant drug manufacturers by simply measuring the volume of medication each defendant sold at the time the victims purchased the drug. Sales records provided fairly precise evidence of market-share. But even with the sales records in hand, the court in Sindell still showed some concern that exact calculation of market-share was not possible and might therefore lead to an unfair apportionment of liability. Despite these misgivings, the court felt that the risk of unfairness was acceptable because the risk was, in essence, no different from the risk of misapportionment of liability that results when a jury is asked to determine liability in cases involving comparative fault.

When extending market-share liability to orbital debris, the central question is whether the risk of unfair apportionment of liability is too great. In other words, can a state's contribution to the unidentified debris hazard be calculated with acceptable accuracy? The answer is yes. Although it is impossible to identify the owner of each particle of debris, there are measurable indices that would allow us to approximate with some accuracy each state's contribution to the total unidentified debris population. The possible indices that might

143. See ESA HANDBOOK, supra note 3, at 2.1-3. For the sake of simplicity, this Note assumes that Russia will take responsibility for space debris created by the former U.S.S.R.
144. See id.
145. See, e.g., Sindell, 26 Cal. 3d at 612.
146. Id. at 613.
147. See id.
be used for this purpose are (1) the number of operational objects each state currently has in orbit, (2) the total number of objects each state has placed in orbit, and (3) the number of identified debris fragments currently in orbit for which each state is responsible. Of these three possible indices, we should use the one that would provide the most accurate estimate of each entity's contribution to the unidentified debris population.

The first index, based on existing operational objects in orbit, bears virtually no relation to the unidentified debris population. If, for example, the United States were to deorbit all of its current spacecraft and satellites, it would own zero percent of the operational objects in orbit. If the operational vehicle index were then used to determine "market-share," the United States' market-share would be zero and the United States would thus be immunized from liability for unidentified debris damage. This would clearly be unfair because the United States is a primary contributor to space debris.

The second option would give a more reliable indication of unidentified debris risk contribution. Because every mission creates debris and objects in LEO can remain in orbit for hundreds of years, the number of missions launched by each state since 1957 should, it seems, provide a fairly accurate indication of each state's contribution to orbital debris. This index, however, has two distinct flaws. First, not every space mission creates the same amount of debris. Second, it is difficult to determine how much of the debris created in the year 1961, for instance, remains in orbit and how much has reentered Earth's atmosphere. Therefore, the number of missions launched has only a tenuous connection to the current debris population.

The third possible index, based on the number of identified debris fragments currently in orbit, is the best indicator of unidentified debris market-share. Unidentified debris is composed largely of fragmentation debris created by the collision and explosion of larger debris bodies. Larger debris, in effect, becomes smaller debris. Therefore, if a state is responsible for creating a large portion of the known body of large debris, it is also likely that the same state is responsible for creating an equal portion of the unidentified debris fragments.

Assuming that the third option is selected as the index of a state's contribution to the unidentified debris population, the remaining

148. See discussion supra Part I.A.
steps for determining liability would be simple. The first step would be to determine each state’s contribution to the identified debris population (hereinafter “contribution index”) using current catalogues of identified debris. We would then assume that each state has contributed in the same proportion to the unidentified debris population. The USSPACECOM catalogue can provide the figures for these calculations. As of December 31, 1997, the catalogue showed that the total number of identified debris fragments was 6186. Of these, the United States owned 3272 objects, which make up 52.9% of the total population, thus giving the United States a contribution index of 52.9%. Russia was identified as being responsible for 2526 fragments, or 40.8% of the total population. Responsibility for the remaining 6.3% of the fragments was divided among ten other states and entities.

When unidentified debris causes damage in orbit, the contribution index of each state and private entity would be used to allocate liability. This process is straightforward: if a satellite suffers $10,000,000 of damage, the United States would be liable for 52.9% of the costs, or $5,290,000. Other states and private entities would be similarly liable in proportion to their share of the identified debris population.

As in the DES cases, exculpation will be possible if a spacefaring state or private entity can prove that it could not possibly have produced the debris that caused the damage. Such exculpation would be difficult but is conceivable under certain circumstances. Imagine, for instance, that a space station was pierced by a large fragment of unidentified debris that left a hole half a meter wide. It would be clear that the fragment must have had a diameter of approximately fifty centimeters. A state that had sent only a few satellites into orbit and had closely tracked all pieces of its debris over ten centimeters would be able to exculpate itself by showing that the large debris for

149. See ESA HANDBOOK, supra note 3, at 2.1-3.
150. See id.
151. See id.
152. See id.
153. These ten states and entities are the ESA with 197 fragments (3.2%), the People’s Republic of China with 103 fragments (1.7%), Japan with 58 fragments (0.9%), France with 16 fragments (0.3%), India with 4 fragments (<0.1%), Italy with 3 fragments (<0.1%), Australia with 2 fragments (<0.1%), Germany with 1 fragment (<0.1%), the United Kingdom with 1 fragment (<0.1%), and Iridium with 1 fragment (<0.1%). See id.
which it was responsible was nowhere near the point of collision. This opportunity for exculpation will provide an additional incentive for states to track debris closely. States might also exculpate themselves by means of chemical analysis. This method would require that the damaged object be retrieved from space in order to test for any traces that the debris fragment may have left behind. These tests would reveal the exact chemical composition of the fragment. States could then exculpate themselves by showing that they had never launched anything made of that material into space.

C. The Benefits of Market-Share Liability

Market-share liability will benefit the space industry by (1) providing compensation to the injured party where none existed before, (2) creating an incentive for states to mitigate debris production, (3) creating an equal incentive to remove existing debris, (4) promoting the registration and tracking of space objects, (5) encouraging states to cooperate in the prevention of collisions, and (6) ultimately lowering the economic barrier to entering the space industry.

The immediate benefit of market-share liability will be the creation of a compensation system where none now exists. Currently, the victims of unidentified debris damage must absorb the cost of any collision while the parties who created the debris incur no liability. A market-share liability amendment will fill this gap in the Liability Convention.

Of greater importance in the long run is the fact that market-share liability would create an incentive for states to reduce the production of large debris. The production of trackable debris will increase a state's contribution index and, hence, its liability exposure. Launching entities would therefore take measures to minimize large debris production in order to minimize liability. Venting excess fuel, for example, would reduce the risk of explosions in orbit. A state can also reduce its contribution index by deorbiting defunct satellites. This can be achieved by either retrieving the satellites or by propelling the "dead" satellites into the Earth's atmosphere so that they are vaporized.

Market-share liability will not only promote debris mitigation

154. See Seymour, supra note 9, at 911.
155. See id.
measures but also encourage the improvement of debris removal technologies. Entities will be able to reduce their contribution index, as explained above, by removing debris that is already in orbit. Currently, debris can be removed by sending the Space Shuttle to retrieve defunct satellites. Other options include using an Earth-based laser to push objects out of their orbits so that they reenter the Earth's atmosphere and are destroyed. The Orion laser is currently being developed for this purpose by the United States government. One commentator has even suggested using a "giant Nerf ball" to catch debris, in effect "sweeping" the orbits clean. Those states and private entities that do not have easy access to debris retrieval technology or do not have a laser of their own would be able to buy these services from the United States.

The United States and Russia, as well as other states, would also have a two-fold incentive to improve their systems for registering, tracking, and cataloguing space objects. First, states would strive to improve their tracking capabilities so that they would be able to show that another state owned a specific debris fragment that caused damage. Once the responsible state is identified, only that state would be liable. Second, the United States and Russia would be eager to identify as many pieces of debris as possible that belong to each other. The United States, for example, would want to increase the number of catalogued fragments identified as Russian. By doing so, the Russian contribution index would grow and the contribution index of all other states would simultaneously fall. Improvements in tracking capabilities would be beneficial because they would allow a fairer apportionment of liability and would assist in debris evasion.

Spacefaring states would also make efforts to improve debris evasion technology out of the fear of incurring liability. After all, the most effective method of avoiding liability is to ensure that collisions do not occur. More effective evasion capabilities could be achieved by establishing a communications system whereby states with tracking facilities, such as the United States, could warn other states when their satellites or spacecraft were in the path of approaching debris. Upon receiving this information, the spacecraft owner would be able to engage in evasive maneuvers. This warning system could make use

156. See Smith, supra note 14, at 66-67.
157. Seymour, supra note 9, at 908. The aerogel substance used in the MEEP program to capture debris may be suitable for this purpose although implementation of such a program would, at the moment, be prohibitively expensive. See id.
of sensitive ground-based debris detection technology as well as debris-detecting satellites.\footnote{158 See Technical Report, supra note 11, at 11. These debris detection satellites could use detection technology such as that currently employed by the MSX spacecraft which has already been placed into orbit by the United States.}

Ultimately, market-share liability would lower the economic barrier to entering the space industry. The costs associated with unidentified debris damage would be reallocated to those who created the hazard. This internalization of costs would eliminate a burden which would otherwise crush private space ventures. The costs of engaging in the space industry would drop dramatically and the risks of debris-related damage would also become more predictable, thus allowing companies to plan confidently for the future.\footnote{159 See Berkley, supra note 25, at 428.} The private space industry would therefore be able to expand unfettered and the accompanying benefits of private enterprise would follow.

**D. The Weaknesses of Market-Share Liability**

Along with its many benefits, market-share liability would also present a number of challenges that may threaten its success. These challenges include (1) the creation of a perverse incentive to halt all debris tracking, (2) the possibility that the international community may consider market-share liability unfair, (3) the weak incentive to reduce small debris, (4) possible weaknesses in the incentive to mitigate the production of large debris, (5) the expense of debris mitigation measures, and (6) political opposition from the United States and Russia. Although this list is long, cogent counterarguments or simple solutions exist in each case.

Using a state's contribution to the existing identified debris population as the index for determining liability may create a perverse incentive for states to scale down their debris tracking activities. Since liability would be tied to the number of debris fragments whose ownership is known, states may try to reduce their liability simply by halting their efforts to identify debris. However, because several nations would soon be engaged in debris detection, the desire of each of these states to increase the risk-contribution of other states (and thereby reduce their own contribution) would cause each of them to track each other's debris aggressively. The sum of this multinational effort would easily offset the perverse incentive to
reduce tracking one's own objects.

The international community may also complain that market-share liability is unfair because it relies on rough estimates of each state's contribution to the unidentified debris population. However, as discussed above, estimates of risk contribution based on certain indices will have to suffice and these estimates will probably be close enough to the real figures to avoid gross unfairness. Some countries may also raise the objection that the market-share analysis does not take into account the possibility that naturally occurring meteoroids could have caused the damage. In response, proponents of market-share theory can argue that it would be highly unlikely for an orbital collision to involve a meteoroid because meteoroids pass through the orbits very quickly before burning up in the Earth's atmosphere.

Opponents of market-share liability may also contend that the market-share scheme creates only a weak incentive to reduce unidentified debris, i.e. debris that is too small to track. Because a state's contribution index is based on the volume of identified debris created by that state, the creation of unidentified debris will not increase a state's liability exposure. Therefore, no incentive to mitigate small debris, such as paint chips or lens caps, will exist. In response to this complaint, one could argue that an incentive to reduce small debris will arise out of a state's desire to minimize the probability of future collisions for which it would be partly liable. Moreover, once tracking technology improves, it will become possible to assign ownership to smaller pieces of debris such as lens caps. At that point, an ejected lens cap will be catalogued as identified debris and will increase the launching state's contribution index. This will create an incentive to mitigate small debris. In the meantime, in order to ensure maximum reduction of small debris, the United Nations should require that states follow guidelines for mitigating operational and microparticulate debris.

Another potential problem with market-share liability stems from the fact that states and private entities that have contributed only a negligible amount to the debris population will continue to

160. See discussion supra Part V.B.
161. See Limperis, supra note 19, at 322; see also Seymour, supra note 9, at 893.
162. The guidelines should require spacecraft to be designed in ways that minimize debris. The absence of paint on external surfaces, for example, would eliminate paint chipping. Using non-explosive bolts and carefully avoiding the ejection of objects into space would reduce operational debris. See Seymour, supra note 9, at 910; see also Smith, supra note 14, at 61.
have a very small contribution index for many years to come. The European Space Agency, for example, is responsible for only a small share of existing debris and this share will not increase by much until the agency launches hundreds of objects. Therefore, the European Space Agency would not have an incentive to make efforts to mitigate debris knowing that it would be liable for only a very small percentage of any damages awarded. Just as the risk contribution of smaller space programs will not increase, the contribution indices of the United States and Russia will remain high for years to come regardless of how much they try to mitigate debris. This might discourage these states from working to reduce debris since their current liability exposure will persist for years despite any efforts at mitigation. NASA may see little benefit in attempting to reduce debris and throw up its hands in frustration. Mandatory international guidelines for debris mitigation, however, would remedy this potential problem.

Another danger is that certain states may decide that the current risk of collision is too small to warrant concern. As a result, these states may not be compelled by the fear of liability to mitigate debris production.\(^\text{163}\) This would again have the effect of transferring the costs of orbital debris onto future generations who will inevitably be harmed if current space users do not take remedial action. The international enforcement of debris mitigation guidelines will help to solve this problem by compelling debris reduction when the specter of potential liability is not enough.

Although market-share liability would lower the barrier to market entry by reducing the costs related to debris damage, it may also create a new economic barrier by requiring companies to spend large amounts of money on debris mitigation.\(^\text{164}\) Companies would be compelled to implement debris mitigation techniques by either the fear of incurring liability or by the fact that mitigation would be required by supplemental laws. Designing satellites with debris-minimizing features, such as special boosters to deorbit the satellite at the end of its lifespan, would place an extra financial burden on companies. It must be kept in mind, however, that the cost of mitigation measures is minor when compared to the future costs of frequent collisions that the space industry will have to face if no such measures are taken.

\(^{163}\) See Roberts, supra note 93, at 71.

\(^{164}\) See Smith, supra note 14, at 69-70.
The greatest threat to the implementation of market-share liability is sheer political opposition. If a number of satellites are destroyed by unidentified debris, the cost to the United States and Russia could easily run into the billions of dollars. Why then would these states ever agree to implement such a system? The answer to this lies once again in the benefits of private enterprise. If the United States and Russia agree to pay for their fair share of debris damage, it will allow private industry to thrive in space. The benefits resulting from the free market (lower prices, more reliable technology, etc.) would become available for the governments of the world to enjoy as much as for the private individual. The United States and Russian governments must look forward to the day when they will be able to lease space on a private orbiter at a reasonable rate. In this way, private enterprise will ultimately save these governments money.

In the meantime, the United States and Russia may be required to pay large amounts in compensation for damage caused by orbital debris. A reorganization of the NASA budget would make this possible without placing any further economic burdens on the United States government. The government should begin to phase out portions of its orbital programs and allow private industry to take its place. The money that is now earmarked for the Space Shuttle and other programs should be used to pay for any debris damage suffered by private enterprises. We are at a crossroads in history when private industry must replace government in space. NASA and the Russian Space Agency have achieved a marvelous feat by opening space to humankind. Now it is time for these agencies to step aside and help private companies to take their place in space.

VI. A Proposed Amendment to the Liability Convention

In order to implement market-share liability for damage caused by unidentified debris, Article III of the Liability Convention must be amended. The following proposal for amending the convention imposes a market-share theory of liability and creates a mechanism for its implementation. The proposed definition of space debris is borrowed, with some modifications, from the Technical Subcommittee for UNCOPUOS. Proposed additions to Article III are in italics while strikethrough indicates deleted matter.

165. See Limperis, supra note 19, at 342; Reynolds & Merges, supra note 95, at 177; Lampertius, supra note 40, at 466; Seymour, supra note 9, at 903.
166. See supra note 13.
Article III

1. In the event of damage being caused elsewhere than on the surface of the Earth to a space object of one launching State or to persons or property on board such a space object by an identified space object belonging to or of another launching State, the latter shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible.

2. In the event of damage being caused elsewhere than on the surface of the Earth to a space object of one launching State or to persons or property on board such a space object by unidentified orbital debris, each spacefaring State will be liable for the damage in proportion to that State's recognized contribution to the total identified orbital debris population unless that State is able to exculpate itself.

3. For the purposes of this Article:

(a) "Identified" means that the State responsible for placing the object in orbit is known;

(b) "Unidentified" means that the State responsible for placing the object in orbit is not known;

(c) "Debris" means all man-made objects, including their fragments and parts, whether their owners can be identified or not, that are non-functional with no reasonable expectation of their being able to assume or resume their intended functions or any other functions for which they are or can be authorized;

(d) A State's "recognized contribution to the total identified orbital debris population" will be calculated in accordance with the current combined space debris data provided by those States that track debris;

(e) A State can "exculpate" itself by proving that the debris that caused the damage could not possibly have originated from any of its space objects or missions.

As discussed above, the United Nations should also adopt mandatory debris reduction regulations alongside the amendment in order to ensure maximum debris reduction.\textsuperscript{167} Such regulations should require that states (1) design spacecraft in accordance with debris mitigation guidelines, (2) use their best efforts to track and

\textsuperscript{167} See discussion supra Part V.D.
identify debris, (3) warn other states when a collision risk arises, (4) vent excess fuels to reduce the probability of explosion, and (5) deorbit defunct objects.¹⁶⁸

**Conclusion**

Space debris threatens our future in outer space. Thousands of fragments scream through the orbits at terrific speeds causing damage to operational satellites and spacecraft with ever-increasing frequency. This threat of expensive damage will stifle the growth of private industry in space unless companies are protected from the costs related to debris. The solution to this problem requires that these costs be internalized so that they are not borne by innocent parties.

Internalization can be achieved by assigning liability to the party that created the harmful debris. The fault-based compensation mechanism adopted in the Liability Convention adequately assigns liability when identified debris causes damage, but the Convention fails to assign liability in cases where the debris is unidentified. Under the Convention, fault cannot be assigned unless the owner of the harmful debris is identified. This limitation leaves a gaping hole in the Convention because the vast majority of space debris eludes identification.

To remedy this shortfall, this Note proposes an amendment to the Liability Convention that applies a form of market-share liability when unidentified debris causes damage in orbit. Under the amendment, each state would be liable for any damage caused by unidentified debris in proportion to its contribution to the debris hazard. Market-share liability would energize the private space industry by lowering the economic barrier to market entry. Although the costs of market-share liability would, at first, fall heavily on the governments of the United States and Russia, a robust private space industry would ultimately benefit the governments. Ultimately, market-share liability will allow private industry to usher in a new space age.

¹⁶⁸ The guidelines could be modeled on NASA’s Guidelines and Assessment Procedures for Limiting Orbital Debris. For a description of NASA’s guidelines see Seymour, *supra* note 9, at 905; see also *supra* note 162.