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THE AUTONOMOUS SPACE PROCESSOR FOR ORBITAL DEBRIS (ASPOD) PROJECT AND THE LAW OF OUTER SPACE: PRELIMINARY JURISPRUDENTIAL OBSERVATIONS

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ABSTRACT

The problems posed by space debris in Earth orbit have been widely recognized and studied by the international aerospace community. Measures to alleviate these problems generally have been focused on reducing the rate of growth of the debris population, especially by means of de-orbit or disposal orbit maneuvers incorporated into mission profiles. Although these measures may provide short-term solutions in regards to satellites which have completed their intended mission and reached the end of their useful life, they do not effectively address the problems posed by the substantial existing quantity of orbital debris. Moreover, the impact of debris with other objects, functioning or otherwise, may create innumerable smaller fragments and further impacts, dramatically increasing the debris population. An effective, economical engineering solution to this problem has been proposed in the form of an Autonomous Space Processor for Orbital Debris (ASPOD).

The ASPOD project incorporates advanced robotics to retrieve, dismantle and dispose of some of the largest individual items of debris, that is, spent satellites and other objects of more

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than 1000 pounds. The ASPOD is intended to maximize *in situ* resources, such as abundant solar energy, microgravity, near-vacuum, and even components of removed objects, thereby realizing a level of cost-effectiveness which heretofore has been unattainable. A 1/3 scale model of the ASPOD has been built by the Department of Aerospace and Mechanical Engineering of the University of Arizona, and the technical feasibility of the project has been demonstrated.

This article examines the proposed ASPOD project against the backdrop of the *corpus juris spatialis*. Particular emphasis is given to the issues of jurisdiction and control over derelict satellites and other objects, as well as questions of international responsibility and liability. In addition, analogies to the rights of salvage in aviation and maritime law briefly are identified. Finally, preliminary recommendations are made as to the manner in which the ASPOD project can be conducted consistent with international law.

INTRODUCTION

The pollution of the outer space environment by man-made debris has received increasing attention over the past several years. The problems posed by space debris to present and future space missions are well documented.[1] It has been estimated that approximately 800 papers, articles, newsletters and books have been authored on this topic.[2] Although there is virtual unanimity among the commentators that a viable resolution must be found, there is no consensus as to the specific means or methods which should be employed, nor even the manner in which the issues are defined and articulated. Debris reduction strategies can be very costly, both in terms of economics as well as operational options for particular missions.[3] However, the continued production of orbital debris threatens the pursuit of science from space, human safety in space operations, the economic viability of commercial satellites, and ultimately, the national security interests of states.[4]

One partial solution to this problem which has been proposed focuses on the removal of large items of debris utilizing resources in orbit to achieve economic viability.[5] Known as the Autonomous Space Processor for Orbital Debris, the ASPOD is designed to remove, dismantle, and reuse component parts of large objects of debris sharing a common orbital inclination. The technical feasibility of the ASPOD has been demonstrated by the construction of a one-third scale model by the Department of Aerospace and Mechanical Engineering of the University of Arizona in Tucson. See Figure 1. This article examines the legal issues which may be presented by the establishment of an operational ASPOD program, and makes suggestions on ways in which the ASPOD can be operated consistent with the *corpus juris spatialis*. It begins, however, with a brief description of the physical and technical characteristics of the proposed spacecraft, as well as potential mission profiles.

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1. *See generally* INTERNATIONAL ACADEMY OF ASTRONAUTICS, POSITION PAPER ON ORBITAL DEBRIS (1995)[hereinafter referred to as "IAA Position Paper"]; NATIONAL RESEARCH COUNCIL, ORBITAL DEBRIS A TECHNICAL ASSESSMENT (1995)[hereinafter referred to as "NRC Technical Assessment"]; PROCEEDINGS OF THE FIRST EUROPEAN CONFERENCE ON SPACE DEBRIS (1993); Liu Ya-Ying, *Capture and Measurement of Space Debris*, in PROCEEDINGS OF THE FIRST CONFERENCE ON SPACE TECHNOLOGY AND DEVELOPING COUNTRIES, Conference Paper No. STC-95-173 (1995); McInnes, *An Analytical Model for the Catastrophic Production of Orbital Debris*, 17 ESA JOURNAL 293 (1993).

2. IAA Position Paper, *supra* note 1, at 24.

3. *See* Williamson & Obermann, *New Challenges in International Orbital Debris Policy*, in PROCEEDINGS OF THE 37TH COLLOQUIUM ON THE LAW OF OUTER SPACE 289 (1995).

4. *Id; see also* Baker, *Current Space Debris Policy and Its Implication*, in PROCEEDINGS OF THE 32ND COLLOQUIUM ON THE LAW OF OUTER SPACE 59 (1990).

5. Ramohalli & Jackson, *Space Debris: An Engineering Solution With an Autonomous Space Robot*, IAF Paper No. IAA-94-IAA.6.5.695 (1994), presented to the 45th Congress of the IAF, Jerusalem, Israel, 1994.

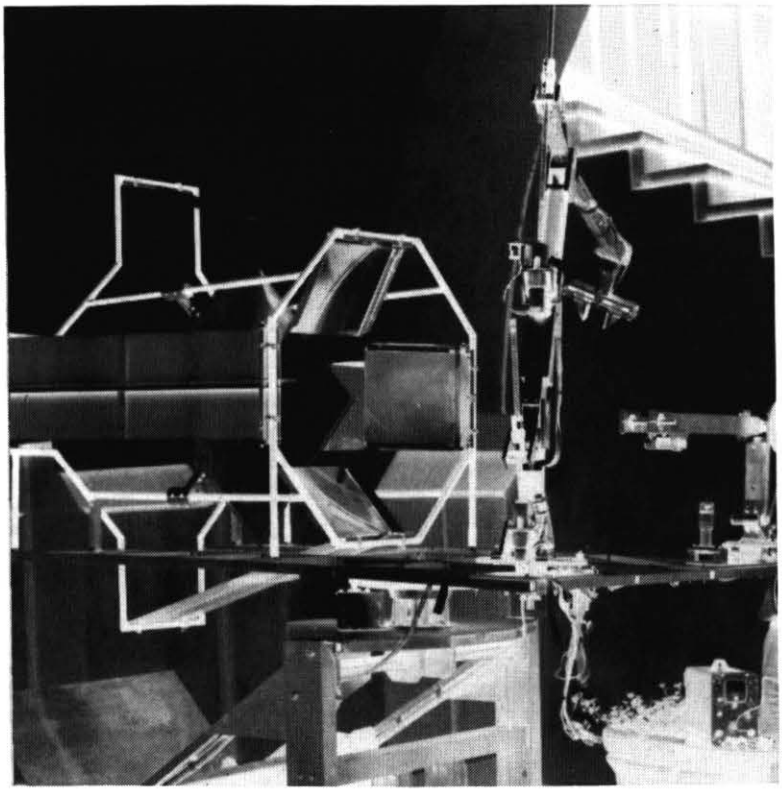

Figure 1 Scale Model of ASPOD

CHARACTERISTICS OF ASPOD AND POTENTIAL MISSION PROFILES

Analytical Rationale

At the present time, there are approximately 3,000,000 kg of man-made material in Earth orbit.[6] Active satellites account for a small quantity of this orbiting matter, most of which is comprised of spent and uncontrolled satellites, rocket bodies, and other non-functioning objects, components, parts, and fragments. The larger items of debris constitute a well catalogued and relatively small population of objects, and it is estimated that ten percent of the debris comprises ninety percent of the total mass.[7] Collisions between items of debris and functioning space objects, or between items of debris themselves, can lead to a cascade of subsequent collisions, each creating an ever increasing number of smaller fragments. According to the ASPOD proponents, the "large debris are best removed while they are still in large individual pieces. After they break up and spread, it will be a hopeless task to remove the millions of pieces produced."[8]

Proposals for the active removal of orbital debris have been criticized as being prohibitively expensive, particularly in relation to the relatively small reduction in the debris hazard which would be obtained thereby.[9] The ASPOD program achieves a greater measure of cost effectiveness by utilizing resources which are found in orbit.[10]

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6. Ash, O'Donoghue, Chambers & Raney, *A Methodology for Selective Removal of Orbital Debris*, 13 ADV. SPACE RES. (8)243 (1993).

7. ASPOD Mission Analysis and Subsystems Integration (MASI) Team, *Final Mission Statement and List of Parameters* (1994)[hereinafter referred to as the "MASI Report"](unpublished report, copy on file in the Law Offices of Sterns and Tennen). There are approximately 23,000 items in orbit which have been catalogued by the U.S. Space Surveillance Network (SSN). *See* NRC Technical Assessment, *supra* note 1, at 20. For descriptions and relative populations of the different categories of orbiting items, *see generally id.* at 63-78.

8. Ramohalli & Jackson, *supra* note 5, at 1.

9. *See* NRC Assessment, *supra* note 1, at 153-54.

10. Ramohalli & Jackson, *supra* note 5, at 1-2.

Natural resources which are available in orbit include: solar energy, microgravity conditions, solar and lunar gravitational cycles, and charged particles and fields. Potential material resources which could be available include metals, components, unspent fuel, and electronic and mechanical components of removed debris.[11] The utilization of resources in orbit to remove the debris by active robotic craft will result in greater efficiency than could be achieved by passive measures such as proposed "space vacuum cleaners."[12]

Physical and Mechanical Characteristics of ASPOD

The ASPOD craft is comprised of several main assemblies. In addition to internal control systems and solar energy panels, the ASPOD consists of a gripping apparatus, a solar cutting array, and storage bins. The gripping apparatus is comprised of two or more robotic arms, with full 3-way axis maneuverability. See Figure 2. The cutting array is constructed of a light weight epoxy composite frame, and uses 5 Fresnel lenses to concentrate the sun's energy into a 2-cm focal point. See Figure 3. The lenses are shielded to protect them from monatomic oxygen corrosion.[13]

A typical mission profile for an ASPOD will involve the rendezvous with the target debris object. After the target has been de-spun or otherwise stabilized, the ASPOD will grip the debris with robotic arms, and maneuver the object toward the focal point of the cutting array. When the debris is cut, the pieces are deposited into a storage bin.[14] Options for disposal of the pieces include retrieval by another craft for return to Earth, ocean splashdown, reentry burnup, and transfer to parking orbits.[15]

A majority of the large pieces of debris are located in only a few orbital inclinations. Thus, according to the ASPOD proponents, the opportunity exists to "clean up" space one inclination at a time. Although satellites may share an inclination, they do not necessarily share a common orbital plane. An active method to move the ASPOD from one longitudinal plane to another is expensive in terms of propellant and therefore the weight of the spacecraft at launch. Thus, the ASPOD employs a passive method of transferring from longitudinal planes while minimizing the total ΔV and propellant requirement. This passive method utilizes natural nodal perturbations, *i.e.*

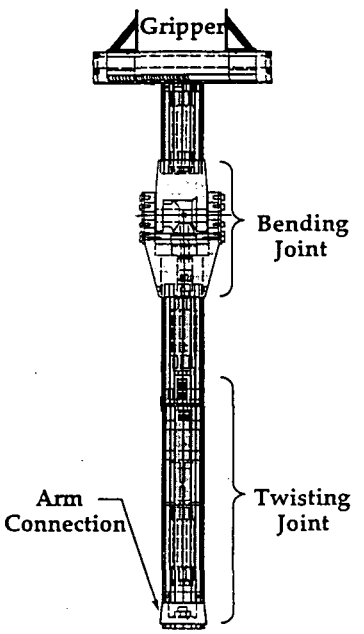

Figure 2 Gripper Arm Assembly

> natural perturbation causes the location of the ascending node to regress westward if the satellite has a direct orbit ($0° < i < 90°$) and eastward if the satellite has a

11. *Id*; MASI Report, *supra* note 7, at 2.

12. Ramohalli & Jackson, *supra* note 5, at 1. The use of various types of robotic craft to remove debris from orbit has been criticized as technologically infeasible and economically prohibitive. NRC Technical Assessment, *supra* note 1, at 153-54.

13. Ramohalli & Jackson, *supra* note 5, at 7.

14. *Id.* at 6.

15. *Id.* at 2. One study has concluded that it is most economic, in terms of propulsive mass penalties, to de-orbit objects with an altitude of less than 25,000 km, and to boost to a higher orbit those objects located above 25,000 km. IAA Position Paper, *supra* note 1, at 15.

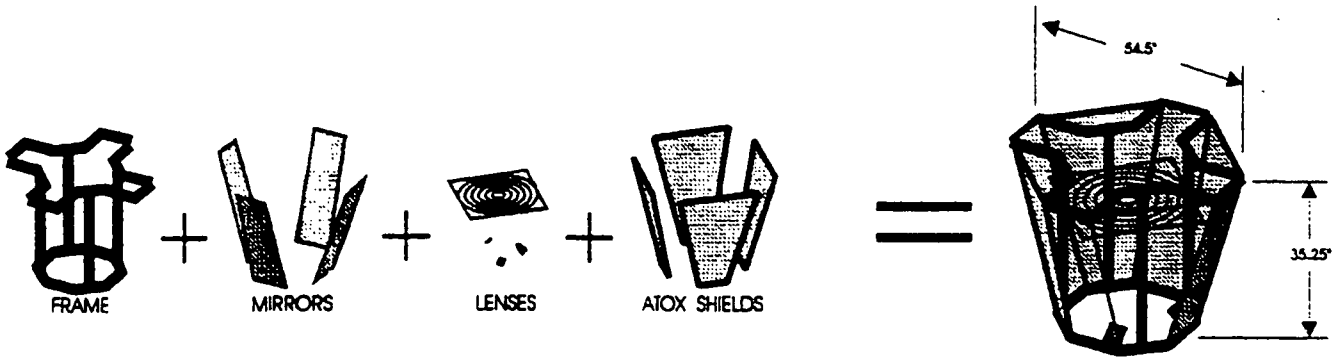

Figure 3 Cutting Array Assembly
(Reprinted from Ramohalli & Jackson, note 5)

> retrograde orbit (90° < i < 180°) . . . Since the nodal regression rate at a given inclination is primarily a function of altitude, by establishing an ASPOD orbit at a different altitude than the debris orbit, the planes of the two orbits will eventually coincide.[16]

The use of a "parking orbit and waiting for nodal regression to gradually bring the debris within the reach of the clean-up craft is shown to require only 20% (of the mass to be removed) in propellant mass."[17]

As described by the ASPOD proponents:

> the criterion was established to loiter at an altitude that will result in a difference in nodal regression rates between the ASPOD's orbit and the target orbit of at least 0.5°/day. Thus, the ASPOD will not have to loiter for more than 1 year before an alignment of orbital planes will occur. . . The most economical mission sequence is to rendezvous with the piece of debris that is at the highest altitude and work back down to the piece of debris at the lowest altitude. . . Therefore, the mission may be on the order of 2-3 years. Since most of the debris in the 600-km to 1500-km altitude range have lifetimes of 100 years or more, a 2- or 3- year mission is not an inhibiting circumstance.[18]

Potential Mission Profiles

One group of four orbital debris targets identified by the ASPOD proponents is the Orbiting Astronomy Observatory (OAO) telescopes and rocket bodies. Located at 35° inclination, these target objects have an average mass of 1956 kg. Furthermore, they are orbiting within a narrow range of altitude which averages 754 km. These characteristics are consistent with the parameters which will promote and enhance the cost-effectiveness of a single ASPOD mission to retrieve and remove this quartet of target objects from orbit.[19]

A second example of a potential target class of debris for an ASPOD mission can be found in the rocket bodies of the Soviet C-1B, also known as the Cosmos second stage, or the Department of Defense designation SL-8.[20]

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16. Ramohalli & Jackson, *supra* note 5, at 3.

17. *Id.* at 9.

18. *Id.* at 4-5.

19. *Id.* at 4-5.

20. *See* Ash, O'Donoghue, Chambers & Raney, *supra* note 6, at (8)244. It should be noted that the Russian Federation apparently has assumed

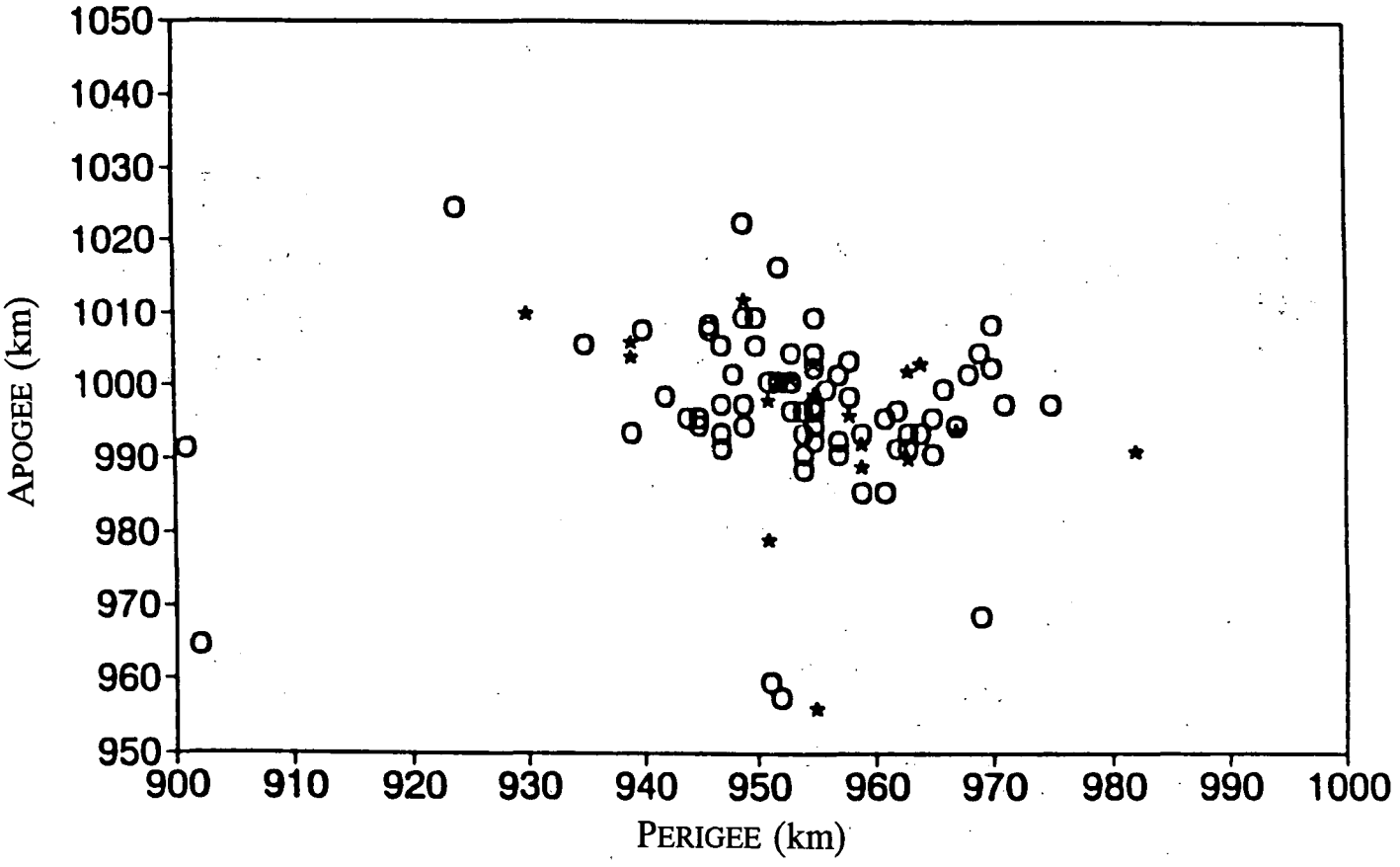

Figure 4 Distribution of C-1B boosters between 82.9° (o) and 83.0° (★) inclination near 1000 km (Reprinted [with modification] from Ash, O'Donoghue, Chambers & Raney, note 6)

Seventy-five per cent of the identified mass orbiting near 1000 km altitude is comprised of rocket bodies, the majority of which are C-1B boosters. Indeed, 100 undamaged C-1B rocket bodies have been located at orbital inclinations between 82.9° and 83.0°, and with apogees between 950 and 1050 km. Fifty-six of these rocket bodies were orbiting in an apogee band of only 20 km. The C-1B is 7.5 meters in length and 2.4 meters in diameter, and has an orbiting mass of 2200 kg. See Figure 4. Thus, "approximately 200,000 kg of 'strategic debris' (C-1B's) is clustered in a narrow band of inclinations (83°) and apogees (1000 km) which is known to be subject to catastrophic collisional cascades."[21]

Both the OAO and the C-1B objects appear suitable as candidates for ASPOD missions in terms of loiter, retrieval and other operational requirements. The desirability of an ASPOD mission could significantly increase, and the cost - benefit ratio could be enhanced, for use in low and middle altitude orbits. Demand for personal communications and other services by constellations of satellites in these orbits is expected to mushroom in the next several years. However, the growth of debris in these orbits "is significantly greater than was anticipated."[22]

responsibility for space objects designated to the former Soviet Union in the international registry maintained pursuant to the Registration Convention. *See* Note Verbale dated 12 May 1992 from the Permanent Mission of the Russian Federation to the United Nations, U.N. Doc. ST/SG/SER.E/253 (1992).

21. Ash, O'Donoghue, Chambers & Raney, *supra* note 6, at (8)245.

22. *See* Williamson & Obermann, *supra* note 3, at 3.

ASPOD AND THE *CORPUS JURIS SPATIALIS*

Jurisdiction and Control over Space Objects

It is a fundamental principal of the *corpus juris spatialis* that an object launched into outer space remains the property of the state of registry, and continues to be within the jurisdiction and control of that authority irrespective of the presence of the object in space.[23] States are prohibited from interfering with the objects of other entities in space.[24] This prohibition against interference also applies to private entities authorized to conduct activities in space.[25] In addition, there is no duty imposed upon launching states to remove inactive satellites from orbit.[26] Thus, the prohibition against interference extends to non-functioning objects, such as rocket bodies, as well as to operational satellites and other craft. Of course, the consent of the launching authority can be sought, and the rights and obligations of the parties to a retrieval and removal mission determined through negotiations. However, absent such consent, the central legal issues facing the operators of an ASPOD program relate to a determination of what limitations, if any, there are to the substance and duration of the exclusive jurisdiction and control of the launching authority.

The exercise of jurisdiction and control becomes attenuated when considered in relation to components, fragments and other pieces of space objects. The law of outer space expressly recognizes that the jurisdiction and control of a launching authority over a space object extends to component parts as well as to the intact object.[27] Nevertheless, there is no consensus as to whether "fragments" and "debris" are "component parts," and therefore, subject to the jurisdiction and control of the launching state.[28] Moreover, the application of such rights would appear to be dependent upon the ability to identify the constituent debris.[29] In the absence of such identification, the registry state would not be able to establish that it had placed the object in orbit and acquired the rights of jurisdiction and control under international law. In such an event, it may be questioned whether the rights of any launching entity are violated by the removal of unidentifiable or unattributable fragments.

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23. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *opened for signature* January 27, 1967, art. VIII, 18 U.S.T. 2410, T.I.A.S. No. 6347, 610 U.N.T.S. 205 [hereinafter referred to as the "Outer Space Treaty"]. For purposes of this discussion, no distinction will be made between the state of registry and the launching authority. *Compare id. with* Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched Into Outer Space, *opened for signature* April 22, 1968, art. 6, 19 U.S.T. 7570, T.I.A.S. No. 6599, 672 U.N.T.S. 119 [hereinafter referred to as the "Return and Rescue Agreement"]; Convention on International Liability for Damages Caused by Space Objects, *opened for signature* March 29, 1972, art. I(c), 24 U.S.T. 2389, T.I.A.S. No. 7762, 961 U.N.T.S. 187 [hereinafter referred to as the "Liability Convention"]; Convention on Registration of Objects Launched Into Outer Space, *opened for signature* January 14, 1975, arts. I(a), I(c), 28 U.S.T. 695, T.I.A.S. No. 8480, 1023 U.N.T.S. 15 [hereinafter referred to as the "Registration Convention"]; *and* Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, *entered into force* July 11, 1984, art. 12(1), 1363 U.N.T.S. 3, *text reproduced in* Report, Committee on the Peaceful Uses of Outer Space, 34 U.N. GAOR Supp. (No. 20), U.N. Doc. A/AC.105/L.113 Add 4 (1979); UNITED NATIONS TREATIES ON OUTER SPACE 27 (1984); *and* 18 I.L.M. 1434 (1979)[hereinafter referred to as the "Moon Treaty"].

24. *Id.* at art. IX.

25. *See id.* at art VI.

26. Jasentuliyana, *Regulation of Space Salvage Operations: Possibilities for the Future*, 22 J. SPACE L. 5, 15 (1994).

27. *See* Outer Space Treaty, *supra* note 23, at art. VIII; *see also* Liability Convention, *supra* note 23, at art. I(d); Registration Convention, *supra* note 23, at art. 1(b).

28. Diederiks-Verschoor, *Legal Aspect of Environmental Protection in Outer Space Regarding Debris*, in PROCEEDINGS OF THE 30TH COLLOQUIUM ON THE LAW OF OUTER SPACE 131 (1988).

29. Jasentuliyana, *supra* note 26, at 19.

The definition or classification of "components" or "fragments" in this regard may be moot in context of an ASPOD mission directed at objects of more than 1000 pounds.[30] Presumably, it would be possible to identify such a large item, whether by its markings, physical characteristics, and/or orbital properties. Nevertheless, there are no sharp distinctions in the *corpus juris spatialis* between "debris" and non-functioning, derelict space objects.[31] The proponents of ASPOD themselves have characterized the target space objects as "debris."

The legal significance of characterizing an object as "debris" is not clear, although it generally implies that the launching state cannot be identified, or if identification is possible, that the launching state is disinterested in the object. The efforts to define "debris" as a term of independent legal significance may be viewed as a means of deeming the right of jurisdiction and control of the launching authority to be subject to termination, notwithstanding the absence of any express limitations in the space treaties and the lack of any act or omission of the launching authority which reasonably may be considered as acquiescing therein.[32] Commentators have offered numerous definitions of "debris," several of which have been sufficiently broad to include relatively intact but non-functional craft.[33] Nevertheless, states may have continuing interests in asserting their legal right to exclusive jurisdiction and control over an object in space even when such object has become non-functional.[34]

Launching authorities may have legitimate concerns regarding industrial or trade secrets and other intellectual property incorporated into the design or hardware or software of the craft. Similarly, the launching state may desire to limit or control the transfer or disclosure and dissemination of complex technologies utilized in the craft. In addition, the mere fact that a craft has become non-functional, or possibly fails to become functional after launch, does not necessarily mean that the launching authority will not attempt to rescue and/or refurbish the craft. Nor does it mean that the rights of third parties, if any, in the craft are automatically terminated.[35] As a practical matter, however, it is subject to question whether a launching state would express any objection to a clean-up mission to retrieve and remove satellites which have reached the end of their useful life, especially where the launching authority has no plans to attempt to retrieve or refurbish such objects. Nevertheless, the interest of the launching state in asserting and protecting its rights could be piqued in the event the intent of an ASPOD mission was to utilize and or sell the components and material resources of the target craft.

ASPOD and the Return and Rescue Agreement

In the event that a derelict craft is retrieved and removed from orbit without the

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30. *See* Ramohalli & Jackson, *supra* note 5, at 9.

31. Kopal, *Some Remarks on Issues Relating to Legal Definitions of "Space Object", "Space Debris" and "Astronaut"*, in PROCEEDINGS OF THE 37TH COLLOQUIUM ON THE LAW OF OUTER SPACE 99, 103-05 (1995).

32. *See* Jasentuliyana, *supra* note 26, at 13.

33. *See generally* Christol, *Scientific and Legal Aspects of Space Debris*, in PROCEEDINGS OF THE 36TH COLLOQUIUM ON THE LAW OF OUTER SPACE 368 (1994); Perek, *Technical Aspects of the Control of Space Debris*, in PROCEEDINGS OF THE 33RD COLLOQUIUM ON THE LAW OF OUTER SPACE 400 (1991).

34. *See* Diederiks-Verschoor, *The Increasing Problems of Orbital Debris and their Legal Solutions*, in PROCEEDINGS OF THE 32ND COLLOQUIUM ON THE LAW OF OUTER SPACE 77 (1990) [hereinafter referred to as "*Problems of Orbital Debris*"]; Dudakov, *On International Legal Status of Artificial Earth Satellites and the Zone Adjacent to Them*, in PROCEEDINGS OF THE 24TH COLLOQUIUM ON THE LAW OF OUTER SPACE 97 (1982); Fasan, *Space Debris - A Functional Approach*, in PROCEEDINGS OF THE 35TH COLLOQUIUM ON THE LAW OF OUTER SPACE 281 (1993).

35. These third party rights could include contract rights, insurable interests, and financing liens. *See* Sterns & Tennen, *Security Interests and Creditors' Remedies in the Law of Outer Space*, in PROCEEDINGS OF THE 33RD COLLOQUIUM ON THE LAW OF OUTER SPACE 102 (1990) [hereinafter referred to as "*Security Interests and Creditors' Remedies*"].

consent of the state of registry, it may be questioned whether the object is subject to mandatory return to the launching authority,[36] and if so, would the launching authority be required to pay reimbursement for the cost thereof? Article VIII of the Outer Space Treaty obligates states to return objects or component parts found "beyond the limits" of the state party on whose registry the objects or parts are carried to such state of registry. Article 5(3) of the Return and Rescue Agreement refines the scope of that obligation, which is expressed in terms of the return of objects "found beyond the territorial limits of the launching authority." The Return and Rescue Agreement further provides that expenses incurred in recovering and returning a space object shall be borne by the launching authority.[37] Both the Outer Space Treaty and the Return and Rescue Agreement speak in terms of space objects which are "found." This terminology suggests a somewhat passive or involuntary role for the "finding" state, rather than more active participation such as the volitional act of seeking out a specific target craft and removing it from orbit. In other words, the operations of an ASPOD may be outside the scope of these provisions of the Outer Space Treaty and the Return and Rescue Agreement.

Some commentators have asserted that states may have an affirmative duty to remove an object from orbit which is believed to be of a hazardous or deleterious nature. Pursuant to art. 5(4) of the Return and Rescue Agreement: "a Contracting Party which has reason to believe that a space object discovered in territory under its jurisdiction, or recovered by it elsewhere is of a hazardous or deleterious nature may so notify the launching authority, which shall immediately take effective steps, under the direction of the said Contracting Party, to eliminate possible danger of harm." If the launching authority is unwilling or unable to perform such "effective steps," does it thereby lose certain possessory rights in the space object or component parts? Does the avoidance of possible grave consequences justify the removal, dismantling and/or destruction of the object, even without the consent of the launching state?[38]

It is open to question whether an ASPOD type mission would be an appropriate mechanism to counteract and respond to the potential threat posed by an inherently hazardous craft, such as a nuclear generator in orbit. Yet the phraseology of "hazardous,""deleterious" or "grave consequences" are subject to interpretation, particularly as they relate to matters of degree. Thus, it may be argued that the mere presence of derelict objects in specific orbits is potentially hazardous, deleterious and could result in grave consequences by causing obstacles for future missions, and potentially by igniting a cascade of collisions, resulting in the creation of innumerable particles of debris. As noted by one commentator:

> With regard to the issue of removal there is support in international law's general principles for States to engage in reasonable and proportionate protective measures. The law is not novel. Only the application of this traditional law to space debris would be new.[39]

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36. *See* Return and Rescue Agreement, *supra* note 23, at art. 5.

37. *Id.* at art. 5(5); *see also* Kopal, *Summary of Replies to the Questionnaire Which Included Issues Concerning Space Debris*, in PROCEEDINGS OF THE 36TH COLLOQUIUM ON THE LAW OF OUTER SPACE 394, 402 (1994) (statement by Gorove).

38. *See* Jasentuliyana, *supra* note 26, at 12; *see also* Diederiks-Verschoor, *Problems of Orbital Debris, supra* note 34, at 79. Dr. Diederiks-Verschoor suggests modification of the space treaties to provide that if the registry state refuses to remove the offending debris after consultations pursuant to article IX of the Outer Space Treaty, then the object would be open to salvage, removal or destruction. She notes, however, that the removal of a space object without consent of the state of registry could violate the peaceful purposes provisions of the *corpus juris spatialis.*

39. Christol, *supra* note 33, at 378. "New international space law for man-made debris is required because of the tension existing between the general principle of sovereign self-protection and the treaty-based principle of national jurisdiction and control over national space objects." *Id.*

Viewed in this light, the removal of derelict craft could be justified on the basis of national security concerns,[40] or in a broad sense, an ASPOD mission could be viewed as in furtherance of and for the benefit of all mankind.[41] States could, in turn, delegate the removal operations to a private entity. Although the provisions of article 5(4) of the Return and Rescue Agreement seem to refer to the sequence of recovery of an object followed by the discovery of its hazardous or deleterious nature, there is nothing to suggest that such a sequence is required to justify or authorize the removal or destruction of the object. Moreover, such an interpretation is consistent with the traditional principles of international law regarding reasonable and proportionate protective measures referenced above.

Liability Issues and ASPOD

The retrieval and removal of an object by ASPOD raises the issue whether the launching authority of the object may assert a claim for damages. That is, would the retrieval and removal by de-orbit or boosting to a higher orbit of a derelict craft constitute damage to the launching authority as that term is used in the Outer Space Treaty and the Liability Convention. The term "damage" generally relates to a particular detriment or demonstrable harm, which would not necessarily be present in this circumstance. However, "damage" is defined in the Liability Convention to include "loss of" as well as "damage to" property.[42] Nevertheless, the "damage" by the "loss" of a non-functional craft which the launching authority had no intention to rescue or refurbish would be nominal, and there is no provision in the Liability Convention expressly permitting or authorizing an award of nominal damages.[43] A launch authority may be able to establish a measurable and demonstrable harm where a retrieved object, or the component parts thereof, were to be reused, at least equal to the revenues produced or avoided by such sale or use, respectively. Moreover, a launching authority could claim a right of priority in or to the usable components of a retrieved craft.

Liability Concerns and the Disposal of Debris

The removal of a derelict object to a lower orbit for re-entry and disintegration in the atmosphere poses a risk of contamination and damage to the Earth's environment. Fragments of the craft may also survive atmospheric re-entry, and cause damage to persons or other juridical entities on the surface of the Earth or to aircraft in flight. Pursuant to the Liability Convention, in such circumstances, the state of registry of the object nominally would be held to absolute liability for compensation for damages sustained.[44] Should the object or its fragments collide with another space object, the registry state similarly would be held liable for damages, however such liability would be based on fault.[45] The Liability Convention, however, generally relates to an impact or interference by an object without action by a third party.

In the event of damage resulting from a collision with an object retrieved by ASPOD and another space object, it is open to question whether the damage is "caused" by launching state leaving the derelict craft in space, or is it "caused" by ASPOD setting a particular course of events into motion. Should liability be apportioned between the respective launching authorities of the ASPOD craft and the derelict object? Further, should the state with primary international liability be able to subrogate *vis-a-vis* the operators of a privately conducted ASPOD mission? In the event of damage caused on the surface of the Earth or to aircraft in flight, is it

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40. These could include concerns over economic interests. *See* Williamson & Obermann, *supra* note 3.

41. *See* Outer Space Treaty, *supra* note 23, at art. I.

42. Liability Convention, *supra* note 23, at art. 1(a).

43. *See id.* at art. XII, which provides that "amount of compensation shall be determined in accordance with international law and the principles of justice and equity in order to . . . restore the [claimant] to the condition which would have existed if the damage had not occurred." This definition, however, could be interpreted to allow an award of nominal damages under appropriate circumstances.

44. *Id.* art. II.

45. *Id.* at art. III.

justifiable and reasonable to hold the launching authority of a derelict craft to a strict liability regime where the orbital parameters of the offending object were altered by ASPOD? At a minimum, it could be expected that any claims would be asserted against both the original authority launching the retrieved object, as well as the state of registration of the ASPOD, and both such entities could be considered primarily liable.[46]

The boosting of a satellite to a disposal orbit may appear to be preferable to atmospheric disintegration, however it does not eliminate the problems of contamination and potential damage. Derelict craft in a disposal orbit above the geostationary ring could remain in space for thousands of years. As more and more objects are placed into such a disposal orbit, the probability of collisions between them, and the triggering of collisional cascades, increases. The presence of such non-functioning craft also could pose hazards to objects traversing the "disposal region" of space, as well as create potential interference with communications, astronomical observations, and other activities.[47] Moreover, future beneficial uses may be found for payloads launched into the disposal region, which could be foreclosed unless a method was discovered to clean up the debris and derelict objects therein. With regard to circumstances where damage which otherwise would be compensable under the Liability Convention is caused by an object maneuvered into the disposal region by an ASPOD, it may be questioned whether the original launching authority should be held to any liability, since it did not place the object in such location. Nevertheless, it clearly is foreseeable that the placement of an object in orbit could directly result in a potential hazard to other objects, particularly where the launching authority has failed to make any provision to de-orbit or boost the object at the end of its useful life. The change in orbital location may be merely one factor to consider in the context of the particular situation.

SALVAGE CLAIMS AND ABANDONED CRAFT

Recommendations have been made by several commentators for the international recognition of salvage rights in derelict satellites and other non-functional objects and debris.[48] In this context, salvors would acquire rights in objects retrieved without the consent of the launch authority. Both air law and maritime law provide analogous situations for examining the rights which salvors may acquire in vessels. However, salvage should not be used interchangeably with the term "abandoned" when discussing the context of craft or vessels. Traditionally, salvors are permitted only to claim a property right in the salvaged object, as opposed to rights of ownership therein.[49] Nevertheless, salvage rights can be judicially enforced and given priority over the rights of other parties in the craft.

Salvage Claims in Maritime Law

Salvage claims under maritime law are accorded priority over most other competing claims in vessels.[50] Specifically, claims for salvage, wreck removal, and contribution of general average have priority over registered ships mortgages, as well as other pre-existing maritime liens, but not such liens which attach subsequent thereto. Moreover, these maritime liens for salvage, wreck removal, and contribution of general average rank in *inverse* order of time in which the claim secured thereby accrued. A lien or right of retention is granted to shipbuilders and ship repairers for the building or repair of a vessel, which takes preference over registered ship mortgages, but not maritime liens.[51] For

46. *See id.* at art. IV.

47. Kopal, *The Need for International Protection of Outer Space Environment Against Pollution of Any Kind, Particularly Against Space Debris*, in PROCEEDINGS OF THE 32ND COLLOQUIUM ON THE LAW OF OUTER SPACE 107, 111 (1990).

48. *See* Jasentuliyana, *supra* note 26, at 8.

49. *Id.* at 17.

50. International Convention for the Unification of Certain Rules Relating to Maritime Liens and Mortgages, *done* May 27, 1967, art. 5, *text reprinted in* 6A BENEDICT ON ADMIRALTY, Doc 8-3 (7th ed. 1990)[also known as the Brussels Convention].

51. *Id.* at art. 8.

purposes of United States domestic law, a preferred maritime lien is any maritime lien which arises before the filing of a preferred mortgage. In addition, a preferred maritime lien will result from various claims, including claims for salvage.[52] Preferred maritime liens take priority over preferred mortgages without regard to the time in which the liens were incurred.

Salvage Claims in Aviation Law

A secured creditor executing a lien against an aircraft may not be entitled to priority for the proceeds of a forced sale. International law grants priority to claims for compensation due for salvage of the aircraft as well as for extraordinary expenses indispensable for the preservation of the aircraft which may be superior to the security interest.[53] These claims are valid to the extent recognized by the law of the state where the operations giving rise thereto were performed,[54] and are satisfied in inverse order in which they arose.[55] Claims of salvage or expenses indispensable for the preservation of the aircraft can be recorded in the U.S. Federal Aviation Administration Aircraft Registry, provided such activities occurred in a country that is a party to the Geneva Convention, and that the recording takes place within three months of the completion of the services which gave rise to the claim.[56]

Salvage Claims in Space Objects

A priority for claims of salvage, as recognized by both air law and maritime law, is inapplicable under the present law of outer space. There is no recognized right for a third party to obtain rights in a space object by the retrieval or removal of a space object without consent superior to the launching authority or other entities with an interest in the craft, even where the object can be considered as a "derelict" or a hazard to other objects.[57] Moreover, claims of salvage are but one *specie* of claims or rights of third parties in vessels or craft. Further, there is yet to be developed a substantial body of international law regarding creditors' remedies, and security interests and lien rights in space objects.[58]

The corollary to a claim of salvage is whether the *corpus juris spatialis* should provide a mechanism by which objects can be deemed or found abandoned.[59] It has been estimated that states would designate only 350 - 400 objects in orbit as "active or interesting."[60] Space objects falling within this classification would remain subject to the exclusive jurisdiction and control of the launching authority. Conversely, the thousands of objects not so designated would be available for scavenging or other disposal.[61] The

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52. 46 U.S.C. § 31301(5)(A - F).

53. Convention on the International Recognition of Rights in Aircraft, *opened for signature* June 19, 1948, art. IV(1)(b), 4 U.S.T. 1830, T.I.A.S. No. 2847, 310 U.N.T.S. 151, ICAO Doc. 7620 [also known as the Geneva Convention].

54. *Id.* at art. IV(1). The claims must be recorded within three months of termination of the salvage or preservation operations, or the priority therefor is lost unless the amount thereof is agreed upon or judicial action to enforce the claim commenced. *Id.* at art. IV(4).

55. *Id.* at art. IV(2).

56. 14 C.F.R. § 49.37.

57. *See* Sterns & Tennen, *Orbital Sprawl, Space Debris and the Geostationary Orbit*, 6 SPACE POLICY 221 (1990); *but see* text & notes 38 - 41, *supra.*

58. *See* Larsen, *Creditors' Secured Interests In Satellites*, in PROCEEDINGS OF THE 34TH COLLOQUIUM ON THE LAW OF OUTER SPACE 233 (1992); Sterns & Tennen, *Security Interests and Creditors' Remedies, supra* note 35; Stewart, *Should There be a Mortgage Convention for Space Activity Investors?*, in PROCEEDINGS OF THE 25TH COLLOQUIUM ON THE LAW OF OUTER SPACE 251 (1983).

59. Perek, *Legal Aspects of Space Debris*, IAF Paper No. IISL-95-IISL.2.01 (1995), at 6, in PROCEEDINGS OF THE 38TH COLLOQUIUM ON THE LAW OF OUTER SPACE ____ (1996), *citing* Martin, *Liability Issues in Space Debris*, IAF Paper No. IAA 7.193-760 (1993) presented to the 44th Congress of the IAF, Graz, Austria, 1993.

60. Perek, *Legal Aspects of Space Debris, supra* note 59.

61. In this regard, the status of "abandoned" would have a significance distinct from maritime law, which generally requires that a vessel or craft be

classification of an object as "abandoned," however, would not have any impact on the continuing liability and responsibility of the launching state therefor.[62]

The recognition of "abandonment" in the *corpus juris spatialis* could provide a significant economic incentive to conduct debris removal missions. Nevertheless, any mechanism for this purpose must be carefully constructed to prevent unlawful interference with active satellites and other objects. Additional considerations include whether the original launching authority is entitled to receive any share of monetary or other benefits obtained by the removal and scavenging of its spent craft, or is the entity removing the object entitled to retain any and all benefits it may be able to garner? Would all mankind have the right to participate in these benefits, and would these activities be subject to the doctrine of the common heritage of mankind, such that the international regime envisioned by the Moon Treaty[63] would have jurisdiction over any aspect of scavenging operations? Finally, which entity or entities legally may conduct the removal and disposition of abandoned spacecraft?

Future regulation in this area likely will come from both national as well as international sources. Unilateral regulation on a national level, however, will be insufficient to satisfactorily resolve the problems of debris. Rather, a concerted international effort will be necessary to control the creation of future debris, and reduce the existing debris population. This international effort could take the form of a treaty specifically drafted to address the pollution of the outer space environment.[64] Alternatively, the international community may establish or authorize a specific body to act in a regulatory manner. Such a regulatory body could be empowered to respond and react to changing circumstances and technological aspects, without the formal structure and processes associated with treaty development.[65] Whatever form ultimately is utilized, it is clear that the successful resolution of the problems posed by space debris will require a multifaceted and interdisciplinary approach as well as a broad base of authority from the international space community. The ASPOD project provides an important element for consideration in the search for these solutions.

CONCLUSIONS AND RECOMMENDATIONS

The Autonomous Space Processor of Orbital Debris has been proposed as an economical method of retrieving and removing spent satellites and other non-functional objects from Earth orbit. Pursuant to the *corpus juris spatialis*, however, the exclusive jurisdiction and control of the launching authority extends to such derelict and non-functional objects. Without the consent of the launching authority, the operators of an ASPOD mission could be found to be wrongfully interfering with the rights of that entity. These rights could be asserted irrespective of the functionality *vel non* of the target objects. Moreover, such rights, which otherwise might not be asserted, could be advanced depending on the disposition of the retrieved craft, particularly if commercial use was made thereof.

The rights of exclusive jurisdiction and control might attach only to objects which can be identified to a particular state of registry. The ASPOD is intended and designed to retrieve large objects of debris, with a mass over 1,000 pounds, which presumably can be identified. The Return and Rescue Agreement, arguably, may impose an obligation to return a retrieved object to the launching authority, although it is not clear that the "retrieval" of an object would be deemed to be "found." Nor is it clear that the state of registry would be obligated to pay the expenses incurred therein, especially on an involuntary basis. Nevertheless, there is authority for the proposition that states may have a right, independent of the Return and Rescue Agreement, to remove derelict or other non-functional objects

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abandoned before a third party may lay a claim of salvage thereto. *See* Jasentuliyana, *supra* note 26, at 16.

62. *Id.*

63. Moon Treaty, *supra* note 23, at art. 11(5).

64. *See* Christol, *A Universal Bill of Rights for Outer Space*, IAF Paper No. IISL-95-IISL.4.01 (1995), in PROCEEDINGS OF THE 38TH COLLOQUIUM ON THE LAW OF OUTER SPACE ____ (1996).

65. *See* Jasentuliyana, *supra* note 26, at 19-20.

which potentially are hazardous, on the basis of sovereign self-protection.

The operation of an ASPOD mission also could raise concerns over issues of liability. The retrieval and removal of a space object may be considered as damage under the provisions of the Liability Convention. In addition, damage caused to a space object of a third party by a derelict object or components thereof which are relocated or dismantled by ASPOD likely would be asserted against the launching authorities of both the derelict object and the ASPOD. Similarly, ASPOD may be subject to strict liability for damage on the surface of the Earth, or to aircraft in flight, caused by an object it has retrieved and removed from orbit. The launching authority of such object may be entitled to assert a right of subrogation against the ASPOD operators for any damage for which it is held liable.

The legal issues identified herein could and should be the subject of negotiations between the launching authority and the ASPOD operators. Although such negotiations could occur after a retrieval mission has commenced, whether pursuant to relevant provisions of the *corpus juris spatialis* regarding consultations or otherwise, it would be not only prudent but also essential to conduct the negotiations prior to embarking on the mission. Moreover, the concerns over liability can be narrowed and risks allocated during the negotiations. The risks required to be assumed or accepted by the ASPOD mission operators further may be reduced by appropriate insurance. Nevertheless, there is increasing attention to and consideration of the necessity for the international recognition of rights of salvage and/or abandonment in derelict space objects. Clearly, the technology and economic approach of ASPOD will contribute substantially to the development of an appropriate legal regime to address the problems of orbital debris.

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