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Small Satellites and Liability Associated With Space Traffic Situational Awareness

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Small Satellites and State Responsibility Associated With Space Traffic Situational Awareness (Space Situational Awareness)

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I. Introduction

There is not yet an authoritative definition for space traffic management.[1] A working definition developed by the International Academy of Astronautics defines the concept as "the set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference."[2] The essence of space traffic management, therefore, is "to provide appropriate means for conducting space activities safely and without harmful inference."[3] A challenge to space traffic management is emerging from a category of space assets commonly referred to by the commercial space economy as Small Satellites ("SmallSats"). A SmallSat can be deployed and operated singularly or as part of a group referred to as a constellation or swarms which together operate toward a common goal.[4] These space assets are also referred to by designations other than SmallSats. For instance, the U.S. Defense Advanced Research Projects Agency refers to SmallSats as "LightSats," the U.S. Naval Space Command calls them SPINSat's (Single Purpose Inexpensive Satellite Systems), while the U.S. Air Force refers to them as TACSat's (Tactical Satellites).[5]

The SmallSat industry now markets build it yourself "satellite kits" for less than $10,000 which price includes the cost of placing the SmallSat into orbit.[6] This circumstance has led to the recognition that the "knowledge of how to make and use SmallSats has passed the tipping point," and is fostering a global generation of satellite builders and engineers which can even include a teenager who buys a CubeSat kit and a soldering iron."[7] Passing the "tipping point" is also unleashing "the most powerful force in the universe - human creativity." [8] This aspect of SmallSats have is viewed as having "democratized" space access by lowering the cost of placing space assets in orbit as well as opening additional avenues of access to space.[9] Despite this democratization, SmallSats have generated reverberation from some in the space economy who foresee them as creating a hazard in the space environment despite their benefits if left unsupervised or unregulated by governments.[10] It has even led some to view them as being "space junk" regardless of their benefits and contributions unless they can be removed from orbit upon retirement.[11]

SmallSats are becoming a staple of the space economy that present and will continue to present scenarios requiring the United States and other countries to balance its nationals access to and use of space with the avoidance of harmful interference to the space activities of others. This paper will explore State responsibility for space traffic management associated with certain orbital hazards perceived as being created by the proliferating deployment of SmallSats.

II. Back To The Future with SmallSats

Smallsats are not new. Rather they are the contemporary reincarnation of the initial artificial space satellites. Sputnik 1, the first space asset was launched and entered Earth orbit on October 4, 1957. It was a 58.0 cm-diameter aluminum sphere having a mass of 83.6 kg.[12] Sputnik 1 was followed in space by other small artificial satellites.[13]

This initial generation of SmallSats eventually ceded space to large satellites. The transition to large satellites not only made space access expensive but it essentially created a limited portal for space access controlled by a small cadre of nations consisting principally of the United States, Russia, China, Japan and certain western European countries.[14] Within the last decade non-state actors began developing their own spacecraft,[15] launch vehicles,[16] and launch facilities.[17] The escalation of space activity by non state actors has lessened the dependence on States for access to outer space and future develop of space commerce. This opening of the space access portal has led to the recent re-emergence of SmallSats.

SmallSats are a generic category which generally refer to satellites having a mass of less than 500 kg.[18]
This encompasses a range of space assets designated as Mini Satellites ("Minisats"), Micro Satellites ("Microsats"), Nano Satellites ("Nanosats") , Pico Satellites ("Picosats"), Femto Satellites ("Femtosats") [19] and Spires.[20] Although the definitions for these varying sub-categories of SmallSats are arbitrary, they are generally differentiated on the basis of mass.[21] This mass determination is based on the SmallSat's in-orbit fully fueled mass.[22] Minisats are smallsats having a mass between 100 and 500 kg.[23] Microsats have a mass between 10 and 100 kg.[24] Nanosats have a mass of 1 to 10 kg.[25] Picosats possess a mass of 10g to 1 kg while the mass of Femtosats is less than 10 g.[26] Spires are about the size of a postage stamp and they contain all the essentials for a satellite such as a radio, aerials a solar cell and instruments.[27] It is estimated that about 100 Spires can fit inside a CubeSatellite. [28] While Cube Satellites ("CubeSats") come within the SmallSat classification, they are not truly a distinct sub-category as their name derives from their design and not their mass. Cubesats normally fall within the nanosat or picosat classification.[29] The cubesat design, however, is the standard most utlized by smallsats.[30] A newer design known as a Tube Satellite ("TubeSat") is emerging to compete with the CubeSat design.[31] A TubeSat is a low cost alternative to a CubeSat which has a maximum mass of 0.75 kg.[32]

SmallSats are mostly used for terrestrial and extra-terrestrial observation and data collection purposes as well as for testing of new technologies.[33] This has resulted in their being used by "super secret agencies," militaries, and national space agencies of space faring nations, but also by governments of non-traditional space faring countries and non-State entities such as academia and juridical persons which had previously lacked the economic and technological means to access space.[34] The access and human creativity is leading some to envision SmallSats as eventually following the trend of personal ownership of technological devices such as radios, televisions, computers and mobile phones with individuals having their own personal SmallSat[35] which will consist of a SmallSat or a constellation of SmallSats with their own "IP addresses controlled through the Internet and providing individualized positioning, communications, social and multimedia capability."[36] Some even view SmallSats as being the appropriate mechanism for space burials and other personal social and commercial activities.[37] Such visions raises space traffic management concerns as they can lead to a proliferation of SmallSats in Earth orbit.
Prior to discussing a few of the space traffic management problems associated with a proliferation of SmallSats, it will be beneficial to understand the concept of State responsibility and how it differs from international liability within the context of the space law regime.

III. The Intersection of State Responsibility and Space Traffic Management

State responsibility "embraces all aspects of obligations incumbent upon States vis-'a-vis other States, whether voluntarily contracted or imposed by custom."[38] 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")[39] is the cornerstone of the international space legal framework. Article VI of the treaty imposes State responsibility for all national activities in outer space and for "assuring" that all national activities in outer space conform with the treaty provisions. Article VI, therefore, imposes responsibility on a State for space traffic management involving the space activities of its nationals. The scope of Article VI's State responsibility for space traffic management is best seen by contrast with international liability established by Outer Space Treaty Article VII and its prodigy the Convention on International Liability for Damages Caused By Space Objects ("Liability Convention").[40]

Article VII extends international liability for States that launch and procures the launch of an object into outer space. The Liability Convention provides guidance on the application and scope of the international liability imposed by

Outer Space Treaty Article VII. The Liability Convention limits liability to a launching state(s) for third party damage caused by its "space object." Article 1(a) defines "damage" to mean "loss of life, personal injury or other impairment of health; or loss of or damage to property of States or of persons, natural or juridical, or property of international intergovernmental organizations. Pursuant to Article 1(c) a "launching State" is a State which launches or procures the launch of the space object and the State from whose territory or facility the space object is launched. There can be more than one launching State for a space object. The term "space object" has a redundant definition. Liability Convention defines Article 1(d) reads as follows "[t]he term 'space object' includes component parts of a space object as well as its launch vehicle and parts thereof."

Articles II through VII allocate fault and set the criteria for applying absolute or strict liability, shared liability, apportioned liability and exoneration of liability. The *loci* of the damage occurrence determines which liability scheme applies. For instance, if a space weather event causes a space object to crash to Earth, each launching state will have absolute liability for all damage it causes on the Earth's surface.[41] Exoneration from absolute liability can occur if a launching State proves that the damage resulted either, wholly or partially, from gross negligence or an intention act or omission by the claimant State or natural or juridical persons on whose behalf it has brought the claim.[42] However, such exoneration is not available if the activities of a launching State were not in conformity with international law or the space law treaty regime.[43]

Absolute liability for each launching State will also exist for any and all damage and injury the space object causes to an airline in flight or people or property aboard the airplane.[44] However, it is unclear if this absolute liability applies if the space object damages a space transport craft while it is transiting the atmosphere heading into outer space. It seems this will depend upon whether such a craft is deemed to be an airplane prior to crossing the boundary into outer space. Nevertheless, this absolute liability is subject to the same exoneration principles as those applicable to damage a space object causes on Earth.

The measure of recovery for damage is "determined in accordance with international law and the principles of justice and equity, in order to provide such reparation in respect of the damage as will restore the person, natural or juridical, State or international organization on whose behalf the claim is presented to the condition which would have existed if the damage had not occurred." There is not any financial limitation on the amount of recovery. However, it is unclear whether the recovery is limited to direct damages or whether it can include indirect damages.[45]

While international liability under Outer Space Treaty Article VII is limited in its scope and application, that is not the circumstance with respect to State responsibility imposed by Outer Space Treaty Article VI. Traditionally, State responsibility represents the classic concept for dealing with a state's violation of customary international law which causes injuries to another state or to nationals of another State.[46] A State suffers a distinct and separate injury when one of its nationals is injured by another state.[47] To this extent, the act does not have to be committed directly by a State as it is sufficient if the act or conduct can be attributable to the State.[48] A breach can be attributable to a State if the State plays an active role in causing the injury,[49] omits to perform an act[50], or having knowledge of a hazardous condition fails to warn others of the hazard.[51] When a breach of international law attributable to a State inflicts injury on nationals of another State, the duty is to make reparations.[52] Reparations are a mandatory duty which attaches to a State violating an international obligation.[53] The remedy is generally owned only to another State as individuals and other non-state entities traditionally lack standing under international law to pursue or collect reparations under State responsibility jurisprudence.[54] Reparations are meant to restore the injured party to the condition that existed prior to the breach of the international obligation.[55] If that is not possible, then a monetary payment corresponding to the value of the restitution is appropriate. If neither of these are totally sufficient, then reparations can take the form of an apology,[56]official recognition of the injury,[57] or promises or guarantees of nonrepetition of the injurious act or conduct.[58]

Article VI's State responsibility obligation is much broader in scope and application than international liability assessed pursuant to Outer Space Treaty Article VII and the Liability Convention. First, State responsibility is not limited to launching States. It extends to any State with "national activities in outer space." The exact breath of this coverage is uncertain in as much as "activities in outer space" is an undefined term. The lack of a definition creates uncertainty on scope in as much as it is unresolved if the phrase "national activities in outer space" is restricted to acts performed in space or if it includes activities in space remotely controlled by a person on Earth. The lack of a restrictive definition suggests that Article VI's responsibility encompasses "all the concomitant activities associated with what actually occurs in outer space, both before and after."[59] Moreover, even a narrow reading of Article VI can reasonably lead to the conclusion that the supervising responsibility includes "terrestrial activities directly related to concurrent activities in outer space."[60] This suggests that State responsibility for national activities in space not only applies to conduct which actually takes place in space, but also includes conduct on Earth which is integrally related to acts or events which transpire in space. Additionally, Article VI imposes responsibility to supervise "space activities" on the appropriate State. As with the term "national activities in outer space" the Outer Space Treaty does not define or explain how to determine what is an "appropriate State."[61]

Another divergence between State responsibility and international liability in space law is that the Liability Convention limits recovery to damage as defined in Article 1(a). Outer Space Treaty Article VI does not impose any such limitation. This means reparations for breach of Article VI can encompass economic harm and injury excluded by the Liability Convention.[62] Moreover, the Liability Convention limits recovery to third party damage claims arising from a space asset colliding with other space objects in space or an airplane in flight or anything on Earth.[63] Recovery for breach of State responsibility obligation is not limited to such third party claims.[64] A further distinction between the Liability Convention and Outer Space Treaty Article VI is that the Liability Convention imposes a one year limitations period for initiating a claim for damage.[65] Article VI does not contain any limitation period.

Lastly, while the Liability Convention limits its remedy to the payment of compensation, State responsibility under Outer Space Treaty Article VI includes non compensatory remedies.[66] Even more so, State responsibility incorporates an obligation of "due diligence"which requires a State to take prophylactic measures to prevent harm or injury to another State or its nationals[67] or a part of the global commons[68] which includes outer space.[69] This due diligence obligation is not limited to State action, but it also extends to taking preventive measures in connection with the conduct of a State's nationals.[70] A breach of the due diligence standard gives rise to State responsibility and the reparations requirement.[71] Whether a State has exercised due diligence is a flexible standard which varies depending upon the particular facts and circumstances[72] taking into consideration a few objective factors.[73] The objective criteria consists of 1) the degree of foreseeability or predictability of the harm, 2) the importance of the interest needing protection,[74] and 3) the State's capability.[75] Thus, due diligence is a sliding scale adjusted according to a State's ability and resources.[76] This spectrum suggests that the United States, as a major traditional space faring country, bears greater obligation for space traffic management of SmallSats than other less capable countries.

Outer Space Treaty Article VI imposes international responsibility on a State for the space conduct of its nationals and for "assuring" that national activities in outer space are carried out in conformity with all provisions of the Outer Space Treaty. This supervisory responsibility includes a State assuring that its nationals space activities comply with Outer Space Treaty Article IX which requires conducting all space activities with due regard to the corresponding interests of all other States. Thus, State responsibility rather than international liability is more attuned to space traffic management as it concerns supervising conduct whereas international liability only concerns who pays for damage.[77]

IV. Collisions, Weather and Maneuverability: SmallSat Concerns In Space Traffic Management

A. Collisions In Space

Currently, SmallSats are normally placed in low earth orbit ("LEO"), [78] which is an orbit less than 1,240 miles above the Earth and is the orbit used by larger space objects such as the International Space Station ("ISS"), government communication satellites and earth observation satellites.[79] LEO is an orbit particularly known for being at high risk for collisions between space objects[80] as well as being overly saturated with artificial space debris.[81] A looming issue with respect to the proliferation of SmallSats is the potential for their colliding with a space object. The collision concern posed by SmallSats in LEO is evident by how the International Space Station deploys SmallSats. Being cognizant of the collision risk, when ISS personnel deploy SmallSats, the SmallSats are deliberately deployed in a LEO lower than that occupied by the ISS "to avoid the risk of 'recontact' with the station."[82] While there is disagreement over whether the Liability Convention applies to a collision involving a SmallSat,[83] there can not be any dispute that such an incident can trigger State responsibility under Outer Space Treaty Article VI intertwined with space traffic management concerns caused by the creation of additional space debris.

The ISS deploys SmallSats in an orbit lower than its own because the two most important characteristics of SmallSats are "the comparatively less precise orbital fidelity and more limited orientation control and pointing precision."[84] The lack of orbital fidelity and maneuverability is the product of SmallSats not possessing any propulsion system.[85] Unlike their Sputnik ancestor, SmallSats are generally launched as secondary payloads on rockets carrying larger space objects.[86] In being secondary payloads, SmallSats are generally placed in the orbit of the primary payloads which they accompany into space.[87] Thus, the growing use of SmallSats to access space only increases the potential for collisions and resulting pollution of LEO with space debris.[88] In a presentation at the 65th International Astronautical Congress in Toronto, Canada, Dr. Hugh Lewis, a space debris expert, stated that since 2005 SmallSats have been involved in more than 360,000 close approaches of less than 5kg with other orbiting objects.[89] Extrapolating this data over the next 30 years, Dr. Lewis estimates there will be over one million close approaches involving SmallSats during the next three decades "with a handful leading to a collision."[90] The greatest risk of collisions involve SmallSats orbiting at an altitude of 750 kg or above as SmallSats at that altitude have a longer orbital lifespan.[91]

To alleviate LEO congestion, it is suggested that SmallSats be deployed in a higher orbit. A higher orbit only transfers the congestion problem from LEO to another orbital plane. A higher orbit means that at the end of life, the SmallSat will be subject to much less atmospheric drag, if any at all, which will result in the SmallSat becoming space debris as opposed to being consumed by the Earth's atmosphere during a fall from LEO.[92] Moreover, higher orbits will more directly expose SmallSats to space weather anomalies.

B. Weather

"Space weather" is defined as the "conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and that can affect human life and health."[93] It encompasses solar events such as solar wind, coronal mass ejections (CMEs)and solar flares[94] which cause space weather phenomena hazardous to space objects such as electrostatic discharge by space objects and geomagnetic storms,[95] and increased radiation exposure.[96] However, the Earth's magnetic field and atmosphere shields satellites in LEO from most but not all of the adverse effects of solar weather events and cosmic radiation. This natural protection and the short lifespan of SmallSats in LEO together with the drive to maintain low cost for SmallSats, mean SmallSats lack the shielding and protection from space weather as other space assets.[97] Indeed, in designing satellites for space, engineers seek to strike a reasonable balance between sufficient design against the natural space environment factors and designs viewed as immensely expensive and counterproductive.[98] SmallSats are not an exception to this economic balancing consideration.[99]

Given SmallSats limited lifespan of a few weeks to a few years depending on the altitude in LEO, space weather events are not viewed as a significant factor. It is assumed that the SmallSats will not be in orbit for a sufficient amount of time for the natural space environment to degrade its systems or operation. Whatever the merits of this perspective, it conveniently disregards the occurrence of a single upset event which can impair a satellite's function.

A single event upset normally corresponds with a Solar Proton Event ("SPE").[100] A SPE occurs when protons are accelerated to very high energies by a solar flare accompanied by a CME which electrically charges a space object and generates electrostatic discharge better known as ESD.[101] Although an ESD is a random occurrence in the space environment,[102] it is the most prevalent hazard to space assets.[103] An ESD occurs when energetic electrons penetrate a spacecraft's external surface or skin and builds up a charge in the internal circuitry.[104] "If the charge builds up faster than its dissipation, this breaks down the shielding and produces an electrostatic discharge."[105] An ESD can temporarily or permanently disrupt electronic components or even cause the launching of a "phantom command" which results in a space object engaging in uncontrolled functions.[106] An ESD is said to have caused the total loss of a Telstar 401 satellite in January 1997.[107] More recently, an ESD is said to have crippled or transformed an Intelsat Galaxy 15 satellite into a "zombie" for an eight month period between April 2010 and December 2010.[108] During this"zombie" stage, the Intelsat Galaxy 15 was unresponsive to command controls and drifted from its GEO but continued to transmit its broadcast transmissions.[109] Although it is said there was never a threat of the satellite colliding with another space object, the satellite operator did take measures to minimize the satellite's broadcasting transmission signals from interfering with other satellites.[110]

The Intelsat Galaxy 15 and Telstar 401 are large satellites that suffered adverse consequences due to an ESD. SmallSats in LEO are most susceptible to a single upset event or an ESD when their orbit passes through the aural zone.[111] Given that SmallSats are not engineered or constructed to confront space weather events, it is reasonable to conclude that SmallSats will not readily survive an ESD experience. Likewise, deploying SmallSats in higher orbits remove them from the natural protection afforded by the magnetosphere and atmosphere meaning they will be even more susceptible to space weather events thereby increasing the opportunity of their being converted into an inoperable asset or debris.

C. Maneuverability

The lack of fidelity to a particular orbit and maneuverability gives rise to the concept of adding miniature propulsion systems or thrusters to SmallSats.[112] Generally, launch operators disfavor secondary payloads like SmallSats from carrying hazardous fuel or propellants.[113] Moreover, heritage space propulsion systems tend to be too cumbersome and bulky for SmallSats.[114] Now that SmallSats are becoming a staple of the space economy, engineers have the reason and motivation to design "tiny spaceship engines using safer fuel."[115] Engineering SmallSats with propulsion systems or thrusters will give them maneuverability which will assist in their adhering to a precise orbit and in end of life debris mitigation for those in orbits above 600 kg.[116] It will also allow them to be serve as "garbage collectors" by using them to "pull larger retired satellites down to a lower orbit and eventual degradation in the Earth's atmosphere.[117] While such maneuverability increases the beneficial functions of SmallSats, it also opens the door to a more hideous peril of an adverse seizure of command and control better known as hijacking.

"Hijacking" of a space object is a silent but valid concern.[118] The fear is that a rogue space object can threaten or produce a debris field by causing a collision with another space object.[119] In addition to the property and economic loss of the involved objects, such an incident could produce enough debris to create a cascading effect which can exponentially magnify the potential of future collisions between artificial debris and other space objects.[120] Such a exponential risk of collisions already exists in LEO due to China's destroying one of its own satellites in 2007 and the collision between Cosmos 2251 and Iriduium 33 in 2009.[121] The 'hijacking" of a satellite is not fanciful science fiction as in 2007 and 2008 it is reported that command and control of different U.S. satellites were the subject of an unauthorized seizure.[122] According to the reports, in October 2007 unauthorized persons "gained access to a NASA Landsat- 7 satellite for about 12 minutes and for another 12 minutes in July 2008.[123] Then in June 2008 "a TerraAM-1 satellite was accessed for two minutes" and was again accessed for nine minutes in October 2008. It is said that "the hijackers of the Terra AM-1 satellite, 'achieved all the steps required to command the satellite,'" but the hijackers did not do so.[124] Although it is believed the seizures were the work of a foreign governmental entity,[125] the incidents establish that hijacking of a satellite or space object is a reality. More importantly though, is that if it command and control of United States governmental satellites is possible, then it seems seizing command and control of a SmallSat can be achieved by governmental and non-governmental entities. This is even more so since SmallSats do not have the command and control codes associated with large satellites.

IV. State Policing of SmallSats

Outer Space Treaty Article VI delegates to States the responsibility of policing the space activities of its nationals.[126] This obligation is normally viewed a State instituting the appropriate licensing schemes.[127] For instance, the United States has instituted a licensing scheme for SmallSats to use any part of the radio frequency [128]as well as a licensing scheme for SmallSats that have the capability to conduct remote sensing of the Earth.[129] These licensing schemes, however, apply to all satellites as the remote licensing requirement has a national security justification[130] while the frequency regulation stems from the governmental control of the radio frequencies of the electromagnetic spectrum.[131] Accordingly, in the United States, if a SmallSat will not use a radio frequency or have remote sensing capability, then "[a]nyone can put a small satellite into orbit if they can figure out how to engineer it and pay for the ride."[132] Similar to the United States, the international community essentially relies on the rules applicable to satellites in general to govern the use and activities of SmallSats. Basic economics suggest that this approach is not sustainable in the long term. For instance, the low acquisition cost, low launch cost and short lifespan of most SmallSats effectively make them a disposable space asset which is readily replaceable. This materially separates SmallSats from large satellites given the vast difference in cost and replacement logistics. This distinction will eventually necessitate the implementation of some rudimentary control standard for SmallSats.

At this juncture, specialized regulation of SmallSats will essentially be premised on concerns projected over the horizon as there is not a consensus that SmallSats constitute a harmful interference with space activities. Nevertheless, such future regulatory standards can entail a SmallSat owner being required to justify the need for placing a SmallSat in orbit. For instance, drones and weather balloons can be used for some of the same purposes as SmallSats.[133] It would seem that deploying a SmallSat may be discouraged, if not prohibited, when a drone or balloon could readily provide the same service. Discouragement can take the form of a government assessment for using a SmallSat when a drone or balloon will suffice. Alternatively, the government may implement a security screening protocol for those desiring to place a SmallSat in Earth orbit. While such a "tipping" point has not yet been reached, it will probably arrive in the near future especially if SmallSats are subsequently classified or viewed as a national security concern.

In the interim, regulatory measures may be necessary to ensure that SmallSats have a viable retirement program, use sufficient shielding to better withstand space weather effects such as ESD, have a certain level of maneuverability and have protocols in place to address the loss of command and control of the SmallSat whether the loss is attributable to the natural space environment or human intervention.

V. Conclusion

SmallSats allow easy and low cost access to and use of outer space. This has caused a steady growth in SmallSat deployment which will only escalate in the foreseeable and extended future. However, the benefits of this space access have to be "balanced with the greater risk of debris creation associated" with the use of SmallSats.[134] The balance has be reached through national regulation[135] until such time as a fortuitous event motivates the international community to agree on protocols addressing concerns particular to SmallSats.

FOOTNOTES

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32.*Id* at 2.

33.*Nanosats are go! supra* note 20 at 4 -5.

34.Leonard David, *supra* note 13.

35.*Id.*, at 3 - 4. *See* Zach Rosenberg, *supra* note 9 at 8.

36.Leonard David*, supra* note 13 at 3 -4.

37.Jason Dorrier, *Tiny CubeSat Satellites Spur Revolution In Space*, singularityhub.com (June 23, 2013) http://singularityhub.com/2013/06/23/tiny-cubesat-satellites-spur-revolution-in-space/

38.Sompong Sucharitkul, *State Responsibility and International Liability Under International Law,* 18 Loy. L.A. Int'l & Comp. L.J. 821, 832 (1996)

39. entered into Force Oct. 10, 1967, 18 UST 2410; TIAS 6347; 610 UNTS 205; 6 ILM 386 (1967).

40. entered into Force Sept. 1, 1972, 24 UST 2389; TIAS 7762; 961 UNTS 187; 10 ILM 965 (1971).

41. Liability Convention Article II.

42. *Id.*, Article VI(1).

43. *Id.*, Article VI(2).

44. *Id*.

45.Carl Q. Christol, *International Liability For Damage Caused By Space Objects*, 74 American Journal of International Law 346, 360 - 362 (1980).

46. Sompong Sucharitkul, *supra* note 38 at 823.

47. *See Avena and Other Mexican Nationals (Mex. v. U.S.)*, 2004 I.C.J. 12, 36 (Mar. 31)[The court noted that could submit a claim in its own name for injuries “suffered both directly and through the violation of individual rights conferred on Mexican nationals.”]

48. Dan St. John, *The Trouble with Westphalia in Space: The State-Centric Liability Regime*, 40 Denv. J. Int'l L. & Pol'y 686, 706 (2012).

49. Dr. William C.G. Burns, *A Voice for the Fish? Climate Change Litigation and Potential Causes of Action for Impacts Under the United Nations Fish Stocks Agreement*, 48 Santa Clara L. Rev. 605, 644 (2008)

50. *United States Diplomatic and Consular Staff in Tehran (U.S. v. Iran)*, 1980 I.C.J. 3 (May 24)

51. *Corfu Channel, U.K. v. Albania, Judgment*, 1949 I.C.J. 4 (Apr. 9)

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53.Michael F. Blevins, J.D., M. Div., *Restorative Justice, Slavery, and the American Soul, A Policy-Oriented (Fnaa1) Intercultural Human Rights Approach to the Question of Reparations*, 31 T. Marshall L. Rev. 253, 276 (2006); Jon M. Van Dyke, *The Fundamental Human Right to Prosecution and Compensation*, 29 Denv. J. Int'l L. & Pol'y 77, 89 (2001)

54. Libby Adler and Peer Zumbansen, *The Forgetfulness of Noblesse: A Critique of the German Foundation Law Compensating Slave and Forced Laborers of the Third Reich*, 39 Harv. J. on Legis. 1, 46 (2002)

55.*Factory at Chorzow (Ger. v. Pol.)*, 1928 P.C.I.J. (ser. A) No. 17, at 29 (Sept. 13).

56. Dan St. John, *supra* note 48 at 706.

57.*Id*.

58. Daniel Bodansky, John R. Crook, et al, *Righting Wrongs: Reparations in the Articles on State Responsibility*, 96 Am. J. Int'l L. 833, 839 (2002)

59. Bin Cheng, *Article VI Of The 1967 Space Treaty Revisited: "International Responsibility," "National Activities," And The Appropriate State."* 26 Journal of Space Law 7, 19 (1998) .

60. Michael C. Mineiro, *Law And Regulations Governing U.S. Commercial Spaceports: Licensing, Liability, And Legal Challenges*, 73 Journal of Air Law and Commerce 759, 768 (Fall 2008)

61. Cheng, *supra* note 59 at 26 - 29.

62. See Sarah M. Mountin, *The Legality and Implications of Intentional Interference with Commercial Communication Satellite Signals*, 90 Int'l L. Stud. 101, 146 (2014).

63. Dr. Frans G. von der Dunk, *Passing the Buck to Rogers: International Liability Issues in Private Spaceflight*, 86 Neb. L. Rev. 400, 412 (2007).

64. Moreover, since Liability Convention Article XXIII indicates that it is not an exclusive remedy, if a damage occurrence can also be construed as flowing from a breach of Outer Space Treaty Article VI, a claimant State can conceivably seek reparations for breach of Article VI instead of pursuing the limited recovery allowed by the Liability Convention.

65. Liability Convention Article X(1). The limitations period commences on the date damages is suffered or the date of identification of the liable launching State. *Id.*

66.*Supra* at 3.

67. International Law Association, *ILA Study Group on Due Diligence in International Law*, *First Report* at 29, March 7, 2014) published at http://www.ila-hq.org/download.cfm/docid/8AC4DFA1-4AB6-4687-A265FF9C0137A699 (last visited Sept. 16, 2014). citing Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area, Seabed Mining Advisory Opinion at ¶ 117 (Seabed Dispute Chamber of the International Tribunal of the Law of the Sea, Case No 17 , 1 February 2011); Jan E. Messerschmidt, *Hackback: Permitting Retaliatory Hacking by Non-State Actors As Proportionate Countermeasures to Transboundary Cyberharm Shearman & Sterling Student Writing Prize in Comparative and International Law, Outstanding Note Aw*, 52 Colum. J. Transnat'l L. 275, 302 - 305 (2013). *See United States Diplomatic and Consular Staff in Tehran (U.S. v. Iran)*, 1980 I.C.J. 3, 61 - 67 (May 24).

68. *See* Mark Allan Gray, *The International Crime of Ecocide*, 26 Cal. W. Int'l L.J. 215, 242 (1996).; Robert Rosenstock and Margo Kaplan*, The Fifty-Third Session of the International Law Commission*, 96 Am. J. Int'l L. 412, 416 (2002)

69.Frans G. von der Dunk*, Beyond What? Beyond Earth Orbit?. . .! The Applicability of the Registration Convention to Private Commercial Manned Sub-Orbital Spaceflight*, 43 Cal. W. Int'l L.J. 269, 327 (2013)

70. Mark Allan Gray, *supra* note 68 at 243.

71. *See* Smita Narula, *The Right to Food: Holding Global Actors Accountable Under International Law*, 44 Colum. J. Transnat'l L. 691, 759 - 765 (2006).

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73. *Id.*, at 3.

74. *Id.*

75. Robert Rosenstock and Margo Kaplan*, supra* note 61 at 416.

76. *Id*.; *See* ILA Study Group *supra* note 67 at 4 and 31.

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78.*Nanosats are go! supra* note 20 at 4.

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81.*Id* at 4.

82. Jeff Foust, *Small satellites, small launchers, big business?* at 4, spacereview.com (Aug. 11, 2014), http://www.thespacereview.com/article/2577/1

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84.Sa'id Mosteshar, *supra* note 15 at 2.

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86.David E. Steitz, *NASA Seeks Proposals For Edison Small Satellite Demonstrations*, NASA News Release 12-042, (Feb. 12, 2012) published at http://www.nasa.gov/home/hqnews/2012/feb/HQ_12-042_Edison_Smallsat.html

87.Jeff Foust, *supra* note 82 at 4.

88.Andoni and Bergamasco*, supra* note 9 at 5 - 6.

89.University of Southampton, Space debris expert warns of increasing CubeSat collision risk, sciencedaily.com (Sept. 30, 2014) http://www.sciencedaily.com/releases/2014/09/140930090447.htm The expert, Dr. Hugh Lewis, presented his concerns at the 65th IAC in Toronto, Canada.

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116.*Id.* SmallSats in orbits of 600 kg or less generally descend into the atmosphere where they are consumed upon entry.

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118. "*Cyber Crime In Space: Hijackers Hijacking A Key Satellite - A Nightmare Scenario*," MessageToEagle.com (Oct. 4, 2012) http://www.messagetoeagle.com/cybercrimeinspace.php. *See* Major Arie J. Schaap, "*Cyber Warfare Operations: Development And Use Under International Law*," 64 Air Force Law Review 121, 162 (2009); John F. Murphy, "*Brave New World: U.S. Responses to the Rise in International Crime*," 50 Villanova Law Review 375, 383 (2005)("With increasing evidence of technological capabilities of terrorists in the use of computers, some commentators have claimed that terrorists now have the capacity for hijacking satellites."); Harper, *supra* note 61, 8 Chicago Journal of International Law at 686("[T] the US fears that terrorist groups will acquire weapons that can hijack US space targets, including satellites)

119.*Cyber Crime In Space: Hijackers Hijacking A Key Satellite - A Nightmare Scenario*," *supra* note 96.

120. *Id*.

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122.John Thomas Didymus, "*Chinese military suspected of hacking two U.S. satellites*" Digital Journal (Oct. 26, 2011)

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133.*See* Cheryl Kemp, *Satellites, Balloons and Solar-Powered Drones to Cover the World in Internet Access,* thewhir.com (June 2, 2014) http://www.thewhir.com/web-hosting-news/satellites-balloons-solar-powered-drones-cover-world-internet-access

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