The Question of Aerospace Vehicles: In Support of Dual Legal Systems for a Dual Purpose Craft

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Abstract *World governments and military contractors have been developing aerospace vehicles (ASVs) for over seventy years. Today, there exists a renewed interest in the development and utilization of this technology. From the Air Force's X37-B spaceplane and DARPA's Hypersonic Technology Vehicle-2 (HTV-2), to Virgin Galactic's SpaceShipTwo, Reaction Engine's SkylonSpaceplane, XCOR's Lynx Mk II and India's Avatar Spaceplane, cutting-edge innovators are pursuing an aircraft capable of traversing the fringes of outer space with unprecedented frequency and efficiency. In order to facilitate the viability of this developing technology, space-faring states—and the international community as a whole—must have a thorough legal discussion concerning the most effective way to regulate these vehicles. This article first provides a brief history of aerospace vehicles—including their most recent developments. Next, it analyzes prominent legal uncertainties surrounding ASVs and their possible use as both aircraft and spacecraft; specifically, the delineation between airspace and outer space, the definition of "launch," and the definition of "spaceobject". Finally, this article argues that dual legal regimes—consisting of both international air law and space law based on a 'Contract-for-Carriage Approach'—would most efficiently regulate the imminent use of this revolutionary technology on a global scale.*

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I. INTRODUCTION

> *"People have been spending their time for fifty years saying, 'well if we just inspire enough and educate enough, the space frontier will be opened.' Our fifty years are up. Steve Jobs did not sit around saying, 'if only we inspire enough people to think computers are important, we'll have a computer revolution;' he just made one. I want us to have a frontier in space. I want to live in a society that has a frontier. If the only way to get that is to build it, then I'm gonna build it."*
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> —*Jeff Greason, CEO and Founder of XCOR Aerospace*[1]

Imagine living in an age where sub-orbital flights become as frequent and affordable as connecting flights out of New York City. Imagine vehicles that burn non-toxic liquid fuels in reliable, piston-pump fed engines, capable of crossing continents or reaching low-earth-orbit in a matter of minutes.[2] Imagine having the option of watching the sun set behind your home planet without needing to be an astronaut or a multi-billionaire. Many would assume these ideas are exactly that: imaginary. However, what once existed only in humanity's collective imagination is now quickly becoming a technologically and commercially viable reality.

World governments and military contractors have been developing aerospace vehicles (ASVs) for over seventy years. The 1970s and 80s saw sub-orbital jet projects such as the North American X-15 and the Rockwell X-30 steadily push the technological envelope forward, promising a future for dual-purpose ASVs. Today, there exists a renewed interest in the development and utilization of such craft. From the United States Air Force's X37-B spaceplane[3] and DARPA's Hypersonic Technology Vehicle-2 (HTV-2),[4] to

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1 Freethink, *Four Flights a Day. Five Days a Week.*,YouTube (October 11, 2016), https://www.youtube.com/watch?v=HvMyVZjZZ7c&list=PLXthoedLVIdKtw2AIEdobDFbRIg-Cocbit&index=2.

2 *Linx Spacecraft*, XCOR Aerospace, http://aerospace.xcor.com/reusable-launch-vehicles/lynx-spacecraft/ (Last visited on November 14, 2016).

3 Brian Weeden, *X-37B Orbital Test Vehicle Fact Sheet*, Secure World Foundation (2012), https://swfound.org/media/1791/swf_x-37b_otv_fact_sheet_updated_2012.pdf (Last visited on September 22, 2016); Leonard David, *Mystery Mission: Air Force's X-37B Space Plane Nears 1 Year in Orbit*, Space.com (May 10, 2016), http://www.space.com/32839-x37b-military-space-plane-one-year-mission-otv4.html (Last visited on September 22, 2016).

4 Jerome Dunn, *Falcon HTV-2 (Archived),* DARPA, http://www.darpa.mil/program/falcon-htv-2 (Last visited on December 2, 2016).

Virgin Galactic's Space Ship Two,[5] Reaction Engine's Skylon Spaceplane,[6] XCOR's Lynx Mk II,[7] and India's Avatar Spaceplane,[8] governments and private entities alike are pursuing an aircraft capable of traversing the fringes of outer space with unprecedented frequency and efficiency. Although the prospect of aerospace vehicles is undeniably exciting, it begs the question of what international legal system would govern a vehicle capable of both intercontinental air transportation and delivering payloads into low-earth-orbit or beyond.

This article will first provide a brief history of aerospace vehicles—including their most recent developments in the United States (U.S.), Europe, and India. Next, it will analyze some prominent legal uncertainties surrounding ASVs and their possible use as both aircraft and spacecraft; specifically, the delineation between airspace and outer space, the definition of "*launch*," and the definition of "*spaceobject*". Finally, this article will argue that dual legal regimes—consisting of both international air and space law—would most efficiently regulate the imminent use of this revolutionary technology on a global scale. This article is by no means the first to advocate for a dual-regime approach. However, in addition to briefly summarizing pre-existing dual-regime approaches, it will advocate for a dual legal regime based on a unique 'Contract-for Carriage Approach'.

II. THE AEROSPACE VEHICLE

A. HISTORY

For the purposes of this article, an aerospace vehicle is any vehicle capable of operating as both an aircraft in flight and a spacecraft "*built to operate in, or place a payload or human beings [in] outer space*".[9] The concept of the aer-

[5] *Our Vehicles: These are the Vehicles that will take you to Space*, VIRGIN GALACTIC, http://www.virgingalactic.com/human-spaceflight/our-vehicles/ (Last visited on December 2, 2016).

[6] *Reaction Engines: The Engine that's Transforming Air & Space Flight*, REACTION ENGINES, https://www.reactionengines.co.uk/sabre/ (Last visited on December 2, 2016).

[7] *Linx Spacecraft, supra* note 3.

[8] Varun Sharma, *ISRO Scramjet Engine Test: Here's what it Signifies for the Space Agency*, THE INDIAN EXPRESS (August 29, 2016), http://indianexpress.com/article/technology/science/isros-scramjet-technology-why-is-it-important-for-the-space-agency-3000387/ (Last visited on March 6, 2017); Tomasz Nowakowski, *India to Launch its Reusable Spaceplane in May*, SPACEFLIGHT INSIDER (April 5, 2016), http://www.spaceflightinsider.com/organizations/isro/india-launch-reusable-spaceplane-may/ (Last visited on March 6, 2017).

[9] 51 U.S.C. § 5092(11)(A).

ospace vehicle developed not long after the end of WWII. Innovative pilots, engineers, and military leaders imagined an airplane capable of reaching the fringes of outer space. [10]The first hurdle presented itself in the form of the sound barrier (mach 1). However, Chuck Yeager famously piloted the Bell X-1 to defeat this adversary in 1947. Within seven years, Yeager surpassed both mach-2 and mach-3 in the X-2.[11] By 1959 the United States Air Force and NASA had developed the X-15, an experimental sub-orbital jet that eventually surpassed mach-6.7 (4,000 mph).[12] Around this same time, the United States Air Force began developing scramjet (supersonic combustion ramjet) technology in order to compliment the already existing rocket-powered aircraft designs, hoping that the combination of rockets and scramjet engines would allow an aircraft to break through the atmosphere and traverse the lower reaches of outer space.[13] Military contractors, research institutions, and government agencies alike pursued a feasible space-plane throughout the 1960s, fielding designs intended to help a vehicle reach up to mach-29 using air breathing engines.[14] NASA even began applying scramjet designs for possible commercial transportation applications.[15] At the dawn of the 1970s, NASA's Langley Hypersonic Propulsion Branch was established to experiment with scramjet powered airframes such as the X-24 spaceplane, resulting in documentation by the General Applied Science Laboratory of scramjet performance above mach-7 by 1978.[16]

One of the primary motivating factors behind the development of a space plane in the U.S. was the need for a more efficient, less expensive, and immediately reusable alternative to the space shuttle. Such capabilities "*promised to yield what economists call 'social savings' at exponential levels—that is, the generation of new and unforeseen opportunities for economic activities simply by having access to daily or weekly orbital flight*".[17]One of the proposed alternatives was an aerospace plane capable of taking off vertically using a combination of scramjets and rockets to reach orbital velocity.[18] With the backing of United States agencies like Strategic Air Command, DARPA, the Tactical Air Command, Air Force Space Command, and the Navy, the United States' interest in making a functioning aerospace vehicle

[10] Larry Schweikart, *The Quest for the Orbital Jet: The National Aero-Space Plane Program*, III The Hypersonic Revolution: Studies in the History of Hypersonic Technology (1983-1995) (1998), 13.
[11] *Id*. at 16.
[12] *Id*.
[13] *Id*. at 13.
[14] *Id*. at 14.
[15] *Id*.
[16] *Id*. at 16.
[17] *Id*. at 23.
[18] *Id*. at 18.

culminated in the establishment of the National Aero-Space Plane Program (NASP) in 1984. The purpose of NASP was to spearhead the pursuit of ASV technology.[19] The NASP would pursue this elusive machine in many shapes and forms until the agency's eventual dissolution in the mid-1990s.[20] One of the NASP's primary focuses was an experimental orbital jet, designed by Rockwell International, called the X-30. This truly dual-purpose vehicle would be capable of reaching anywhere on the planet within two hours, or in the alternative, could replace the space shuttle as a fast and efficient means of reaching orbit. However, the X-30 allegedly never flew.[21]

Although the aerospace plane program lost momentum (and public interest) in the mid-90s, the technology did not disappear, in fact, it continued to advance—even after the lights were turned off on the NASP. Air Force Historian Dr. Larry Schweikart wrote,

> the hypersonic hopes of putting a jet into orbit may, as of the late 1990s, merely be in the same formative stages as the dawn of the automobile age in the 1890s, or the emergence of the computer age in the 1960s. When—not if—the first jet eventually does go into orbit, it will have the same revolutionary effect on society and the world.[22]

Recent developments in ASV technology suggest Dr. Schweikart's prediction is closer than ever to becoming a reality.

B. NOTABLE RECENT DEVELOPMENTS

Although the NASP failed to put an aircraft into orbit, both the commercial space industry and government/military developers have recently rekindled their interest in hypersonic aerospace vehicles. The past ten years have seen significant leaps forward in both airframe and propulsion technology, setting the stage for a rapid increase in the development and use of space-capable aircraft in military and commercial theatres on an international scale. Although countless designs and prototypes have been tested in the last decade, two notable examples of potential breakthroughs in ASV propulsion and airframe technology include DARPA's HTV-2, Reaction Engines' Skylon Spaceplane and India's Avatar Spaceplane.

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19 *Id*. at 21.
20 *Id*. at 20-39.
21 *Id*. at 39.
22 *Id*. at 351.

i. Darpa's Htv-2

At 7:45 a.m. on August 11, 2011, a Minotaur IV rocket launched from California's Vandenberg Air Force Base carrying a very unique payload.[23] As the rocket reached orbit, its payload fairings fell away and an arrowhead shaped object separated from the rocket, beginning a hypersonic return to the earth. Over the next nine minutes this craft—created by DARPA and named the HTV-2—hurdled over the Pacific Ocean at more than 13,000 miles per hour (mach-20).[24] As the unmanned aircraft approached this unprecedented velocity, its advanced design allowed the craft to recover from an uncontrolled roll caused by speed-induced shockwaves. However, the HTV-2 was forced to direct itself into the Pacific Ocean after its skin began to peel away under the intense heat and stress of hypersonic speed.[25]In the second of the two test flights administered by DARPA, HTV-2 successfully demonstrated that an aircraft could be controlled at speeds of mach-20 or above, representing a huge leap forward in the development of airframes for hypersonic vehicles.[26] According to DARPA Acting Director, Kaigham J. Gabriel,

> "the initial shockwave disturbances experienced during second flight, from which the vehicle was able to recover and continue controlled flight, exceeded by more than 100 times what the vehicle was designed to withstand . . . that's a major validation that we're advancing our understanding of aerodynamic control for hypersonic flight."[27]

ii. Reaction Engine's Skylon Spaceplane

In addition to significant advances in the development of airframe design, the pursuit of an ASV has also seen recent leaps forward in propulsion. A U.K. company called Reaction Engines is currently developing the Skylon Spaceplane, which is a dual-purpose aerospace vehicle, capable of taking off horizontally (like a conventional jet) and reaching orbit without the aid of external rocket boosters or an assisted air launch (also known as, single-stage-to-orbit, or SSTO).[28] Moving beyond the scramjet technology

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23 *Falcon Hypersonic Technology Vehicle HTV-2*, GlobalSecurity.org, http://www.globalsecurity.org/space/systems/x-41-htv-2.htm (Last visited on October 5, 2016).

24 *Id.*

25 Tariq Malik, *Death of DARPA's Superfast Hypersonic Glider Explained,* Space.com, http://www.space.com/15388-darpa-hypersonic-glider-demise-explained.html (Last visited on October 5, 2016).

26 *Superfast Military Aircraft Hit Mach 20 Before Ocean Crash,* Space.com, http://www.space.com/12670-superfast-hypersonic-military-aircraft-darpa-htv2.html (Last visited on October 5, 2016).

27 Malik, s*upra* note 26.

28 *SABRE: How it Works*, ReactionEngines.co.uk, https://www.reactionengines.co.uk/sabre-engine/ (2015).

of the 70s and 80s, Reaction Engines is utilizing its dual-mode Synergetic Air-Breathing Rocket Engine (SABRE) to propel the Skylon to mach-25 and beyond.[29] This rocket engine is designed to cool incoming air from 1,000 degrees Celsius to negative 10 degrees Celsius in as little as 1/100 of a second, providing an oxidizing agent for the liquid hydrogen propellant in lieu of conventional liquid hydrogen.[30] The Skylon would ideally operate in "*air breathing mode*" until reaching mach-5—eliminating the need for over 250 tons of liquid oxygen.[31] At this point, the SABRE would switch to a "*conventional rocket mode*", using on-board liquid oxygen and liquid hydrogen to propel the vehicle towards mach-25 and into orbit.[32] This technology has attracted many international investors within the European Space Agency,[33] and has even garnered affirmative support from the United States Air Force under a cooperative research and development agreement.[34]

iii. India's Avatar Spaceplane

United States and European entities are not the only big players pursuing a functional aerospace vehicle. The Indian Space Research Organization (ISRO)—one of the fastest growing space agencies in the world—is currently developing its own dual-purpose ASV with fantastic success. On August 28, 2016, ISRO's Advanced Technology Vehicle (ATV) successfully lifted from the Satish Dhawan Space Center in Sriharikota.[35] Equipped with two experimental scramjet engines, the ATV surpassed six times the speed of sound, making India one of only four nations to reach mach-6 in the history of flight.[36] According to the ISRO, "*the successful technology demonstration of air-breathing scramjet engines in flight by ISRO . . . is a modest yet important milestone in its endeavor to design and develop advanced air-breathing engines[,] including engines for ISRO's future space transportation system.*"[37] The ISRO is currently testing its scramjet engines for use on its Avatar Spaceplane, an ASV (similar to the Skylon) that will use a

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29 *Id.*

30 Peter B. de Selding, *AFRL Gives Seal of Approval to British Air-breathing SABRE Engine Design*, SpaceNews.com (2015), http://spacenews.com/afrl-gives-seal-of-approval-to-british-air-breathing-engine-design/ (Last visited on September 28, 2016).

31 *SABRE: How it Works, supra* note 29.

32 *Id.*

33 Peter B. de Selding, *Europe's Next-gen Rocket Design Competition Had Surprise Bidder*, SpaceNews.com (2012), http://spacenews.com/europes-next-gen-rocket-design-competition-included-surprise-finalist/ (Last visited on September 28, 2016).

34 *Id.*

35 Sharma, *supra* note 9.

36 *Id.*

37 Stephen Clark, *India Tests Scramjet Demonstrator over Bay of Bengal*, Spaceflight Now (August 30, 2016), https://spaceflightnow.com/2016/08/30/india-tests-scramjet-demonstrator-over-bay-of-bengal/ (Last visited on March 6, 2017).

combination of ramjet, scramjet and cryogenic engines to propel the Avatar to the edge of space.[38] The Avatar will take off horizontally from an airstrip using turbo-ramjet engines until it reaches cruising altitude.[39] Next, its scramjet system would accelerate the vehicle up to mach-8, at which point an oxygen collection system would condense atmospheric oxygen into liquid oxygen for use in its final, rocket powered flight phase.[40] If the Avatar performs as planned, ISRO could potentially deliver up to 1,000 kilogram payloads into low-earth-orbit for as little as $67 per kilo.[41] This capability would make India incredibly competitive in the international launch market, potentially changing the way humans reach space.

In fact, many new and promising aerospace vehicles can be found with a simple google search. For example, Virgin Galactic's second SpaceShipTwo recently completed its first successful free-flight—the first SpaceShipTwo experiencing a devastating accident in 2014[42]—while XCOR Aerospace's Lynx Mark II may begin carrying passengers to the fringes of space within a year.[43] Although advances in ASV technology do not always receive front-page media attention, the future will undeniably see a massive increase in the use of space-faring aircraft. In order to facilitate the viability of this developing technology across the globe, space-faring states and the international community as a whole must have a thorough legal discussion concerning the most effective way to regulate these vehicles.

III. LEGAL UNCERTAINTIES SURROUNDING AEROSPACE VEHICLES

At the peak of the NASP era, aerospace scholars and government/military experts attempted to navigate the legal uncertainties of an ASV. However, despite various special colloquiums, reports, and hearings, very little was

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38 Sharma, *supra* note 9.

39 Mark Williams Pontin, *India's space Ambitions Soar*, MIT Technology Review (July 30, 2007), https://www.technologyreview.com/s/408323/indias-space-ambitions-soar/ (Last visited on March 6, 2016).

40 *Id.*

41 *Id.*

42 Amy Thompson, *SpaceShipTwo Completes its First Successful Free-Flight*, Inverse (December 3, 2016), https://www.inverse.com/article/24684-virgin-galactic-s-vss-unity-completes-first-successful-free-flight. Virgin Galactic's first SpaceShipTwo crashed in October, 2014 due to pilot error, *see* Tariq Malik, *Deadly SpaceShipTwo Crash Caused by Co-Pilot Error: NTSB*, Space.com (July 28, 2015), http://www.space.com/30073-virgin-galactic-spaceshiptwo-crash-pilot-error.html.

43 Mike Wall, *Private Lynx Space Plane Could Take Off in Early 2017*, Space.com (April 5, 2016), http://www.space.com/32463-xcor-lynx-space-plane-2017.html; *Our Hero: XCOR Lynx*, xcor.com (2016), http://spaceexpeditions.xcor.com/spacecraft/.

decided concerning how an ASV would fit into existing frameworks of air or space law. Could an ASV operate under the current air or space law regimes? Should it? Or, should a completely new regime be created to regulate a vehicle that has not officially come into existence yet? In the quarter-century since, the same uncertainties and questions remain largely unaddressed. Because fully addressing the depth and breadth of these questions would require an entire collection of detailed studies, this article will briefly address three of the main recurring issues surrounding the regulation of ASVs: the delineation between air space and outer space, the definition of "*launch*," and the definition of "*space object*".

A. THE DELINEATION BETWEEN AIR SPACE AND OUTER SPACE

When pursuing an appropriate legal regime for ASVs, experts have often proposed to create a regulatory framework based on an ASV's location. This means that either air law or space law would apply depending on whether the vehicle is operating in airspace or outer space. This method would hold promise, save that one of the earliest and most debated questions arising since the dawn of the space era concerns the delineation between airspace and outer space.[44] Despite endless debate and a seemingly infinite plethora of possible clarifications for this elusive boundary, no official legal definition has been adopted by the international community.[45] However, this question is extremely relevant when deciding how to regulate a vehicle capable of traversing both realms. Several proposed methods of defining this boundary include the Von Karman Line method, the Lowest Possible Orbit method, and the Earth Entry Interface method.[46]

i. Von Karman Line Method

Possibly the most famous delineation method proposed is the Von Karman Line: established by the (non-governmental) Federation Aeronautique Internationale (FAI) at 275,000 feet above the surface of the earth. This specific height is significant because it is roughly where the force of aerodynamic lift gives way to centrifugal force.[47] However, this method has not been adopted by any state government and has been criticized by the United

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44 Theodore W. Goodman, *To the End of the Earth: A Study of the Boundary Between Earth and Space*, 36(1) Journal of Space Law 87 (2010).

45 *Id.* at 88.

46 *Id.* at 91-94.

47 Stanley B. Rosenfield, *Where Air Space Ends and Outer Space Begins*, 7(2) Journal of Space Law 137, 140 (1979).

States Department of Defense as possibly limiting the development of future high-altitude aircraft.[48]

ii. Lowest Possible Orbit Method

A more regularly applied understanding of the boundary between air and space is the Lowest Possible Orbit Method, placing the beginning of space at the lowest possible orbit of a satellite.[49] Article II(1) of the Registration Convention states, "*When a space object is launched into earth orbit or beyond, the launching State shall register the space object by means of an entry in an appropriate registry which it shall maintain* . . .".[50] The information required upon registration includes the space object's "*basic orbital parameters*", such as perigee, apogee, inclination, and nodal period.[51] Renowned scholar, Bin Cheng, writes that the language used in Articles II and IV of the Registration Convention supports the lowest possible orbit method:

> this article really serves to confirm that 'objects launched into earth orbit or beyond' are in fact 'space objects,' and thereby implies that outer space does begin where satellites are capable of completing a full or whole orbit around the earth, since it is calling any object that is capable of going into any earth orbit, even one with the lowest possible perigee a 'space object.'[52]

Cheng suggests that a height as low as 96 kilometers likely constitutes outer space, gaining surety with altitude until surpassing the "*definite*" point of 130 kilometers.[53] Many scholars believe that the Lowest Possible Orbit method is steadily becoming an international custom, evidenced by growing state practice.[54] According to Vladimir Kopal, "*this meaning has in fact been attributed to outer space by all space faring nations and has been also tacitly recognized by other nations.*"[55] However, the Lowest Possible Orbit

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48 Goodman, *supra* note 45, at 99.

49 *Id.* at 93.

50 Convention on the Registration of Objects Launched into Outer Space, Art. II(1), January 14, 1975, 28 U.S.T. 695, 1023 U.N.T.S. 15.

51 *Id.* at Art. IV(1).

52 Bin Cheng, *"Space Objects," "Astronauts" and Related Expressions*, 34 Proc. Colloq. L. Outer Space 17, 19 (1991).

53 *Id.* at 20.

54 Vladimir Kopal, *Issues Involved in Defining Outer space, Space Object and Space Debris*, 34 Proc. Colloq. L. Outer Space 38, 40 (1991); *see also*, Carl Q. Christol, *Air and Space Transit; International Law and Space Law: Clarification of Law and Policy*, 34 Proc. Colloq. L. Outer Space 28, 29 (1991); Cheng, *supra* note 53, at 20; Goodman, *supra* note 45, at 93.

55 Kopal,*supra* note 55, at 40.

method has also received criticism due to its arbitrary nature.[56] Technology will almost inevitably allow future satellites to successfully orbit the earth at lower perigees, thus changing the definition—to the military's distaste—of where national sovereignty ends and space begins.[57]

iii. Earth Entry Interface Method

Some of the most logical of the proposed delineation methods center around the Earth Entry Interface, or "*the point at which a space craft returning to Earth is considered to be reentering the Earth's atmosphere*".[58] Defined at approximately 400,000 feet (120 kilometers), this is the altitude at which an object reentering the atmosphere will begin to encounter atmospheric resistance.[59] The Earth Entry Interface is fairly promising given that it is globally consistent and "*as the name implies, marks a change in the physics of the space flight*."[60]

Despite potentially promising means for defining the limits of outer space, space-faring super powers like the United States have openly discouraged adopting concrete definitions, voicing concerns that a universal boundary would result in undesirable/unforeseeable restraints on the military's use of outer space.[61] Space-faring nations fear the consequences of deciding once-and-for-all where their national sovereign airspace ends.[62] Consequently, it is highly unlikely that an official definition will ever surface from the international community, which makes it especially difficult to create a legal regime for ASVs based on their location alone.

B. THE DEFINITION OF "LAUNCH"

Although the idea of regulating an ASV based on its location remains open to discussion, there is also a movement suggesting ASVs should be regulated in accordance with their primary function/purpose. Absent a defined boundary between air and space, it is unclear whether an ASV would fall under existing air or space law, seeing as many ASV designs will not "*launch*," per se, but take-off horizontally and operate as an aircraft for varying portions of a mission. Nearly every United Nations (U.N.) space treaty includes the terms "*launch*" or "*launching*" in key Articles relating to the definition and

[56] Goodman, *supra* note 45, at 93.
[57] *Id.*
[58] *Id.* at 95.
[59] *Columbia Accident Investigation Board: Report Synopsis*, SPACEFLIGHTNOW.COM, http://spaceflightnow.com/columbia/report/011synopsis.html (Last visited on January 18, 2010).
[60] Goodman, *supra* note 45, at 95.
[61] *Id.* at 100.
[62] *Id.* at 101.

regulation of space objects.[63] This has led experts like Stephen Gorove to ask:

Would such a vehicle have to be "*launched*" to be regarded as a "*space object*?" Should the fact of launching make a difference? Is the meaning of "*launch*" crucial? Should the aerospace plane be regarded as a space object throughout its flight, or more precisely, should the Liability Convention's provision be applicable to the flight of the aerospace plane in the airspace or in the outer space?[64]

Article I of the Liability Convention establishes that, in order for there to be liability for damage caused by a space object, there must be a "*launching state*".[65] Article I defines a "*launching state*" as the state which launches the object, procures the launch, from whose territory an object is launched, or from whose facility an object is launched. However, the term "*launching*" is not defined other than that "*launching*" includes "*attempted launching*".[66] Absent a clear definition of "*launch*," some scholars suggest that the best policy choice would be to apply air law to an ASV if it is used primarily for point-to-point transportation on earth, and apply space law only when the vehicle enters outer space.[67] However, this approach would require a defined boundary between air and space.

On the other hand, had the drafters of the Liability Convention meant for the manner of a "*launch*" to hold significance, perhaps they would have defined it clearly. If "*the manner in which the object ascends*" does not hold legal significance, terms such as "*take-off*" or "*lift-off*" could potentially have the same effect.[68] Even absent a clear definition of "*launch*," treaties like the Liability Convention may well apply to an ASV, especially considering they applied to the Space Shuttle.[69] Despite flying and landing like a conventional aircraft upon re-entry, the Shuttle's primary function/purpose was to

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63 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, Arts. VII, VIII, X, January 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter,"Outer Space Treaty"]; Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space, Art.1-6, April 22, 1968, 19 U.S.T. 7570, 672 U.N.T.S. 119 [hereinafter, "Rescue Agreement"]; Convention on International Liability for Damage Caused by Space Objects, Arts. I-XII, XIV, XV, XVII, XXI, March 29, 1972, 24 U.S.T. 2389, 961 U.N.T.S. 187 [hereinafter, "Liability Convention"]; Registration Convention, Arts. I, II, IV, V.

64 Stephen Gorove, *Toward a Clarification of the Term 'Space Object' - An International Legal and Policy Imperative?*, 21(1) Journal of Space Law 11, 17 (1993).

65 Liability Convention, Art. I.

66 *Id.*

67 Goodman, *supra* note 45.

68 *Id.*

69 Stephen Gorove, *Legal and Policy Issues of the Aerospace Plane*, 16(2) Journal of Space Law 147, 152 (1988).

conduct missions in earth orbit, reinforcing its place within the framework of space law despite functioning partially as an aircraft.[70] It is argued that, "*any recognized definition of launch inherently incorporates an intention to place the launch vehicle, crew, flight participants, or payload from earth into a suborbital trajectory, earth orbit , or otherwise in space.*"[71] Stephen Gorove writes:

> What appears important, however, is that the act of launching in the sense of lift off or take off or its "*attempt*" must in fact take place before an object may be regarded as a space object, assuming of course that the purpose of the intended activity was to put the object in orbit around the earth or beyond and there was a realistic expectancy of achieving it.[72]

However, applying space law to a vehicle simply because it "*launches*," "*lifts-off*," or "*takes-off*" would potentially be "*unwise*" if the vehicle's primary purpose—requiring passage through only the lowest fringes of outer space—was point-to-point Earth transportation.[73]

This idea is reinforced by Articles I & II of the Liability Convention, which hold a launching state liable for damage caused by both "*launching*" and "*attempted launching*".[74] In other words, even if an object is launched and falls back to Earth before reaching outer space, the launching state is held liable for any damages. The vehicle's location or mode of flight is irrelevant under this Convention when approached from the standpoint of its mission's purpose, that is, conducting activities in outer space.

C. THE DEFINITION OF "SPACE OBJECT"

Also involving the question of an object's purpose is perhaps the most important uncertainty surrounding aerospace vehicles: would an ASV constitute a "*space object*"? If an ASV is purely an aircraft designed to speed up point-to-point transportation, international air law could potentially regulate what amounts to little more than an improved version of current commercial air transportation. However, when dealing with a truly dual-purpose ASV—capable of both conventional air transportation and executing missions in outer space—one must determine whether such a machine would

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70 *Id*. at 149.

71 Sarah M. Langston, *Suborbital Flights: A Comparative Analysis of National and International Law*, 21 JOURNAL OF SPACE LAW 299, 319 (2011).

72 Goodman, *supra* note 45.

73 *Id*. at 101.

74 Liability Convention, Arts. I, II.

fall under the dominion of space law treaties like the Outer Space Treaty, Liability Convention, and Registration Convention. Central to this determination is whether an ASV would constitute a "*space object*". However, there is no detailed definition for this term. Both the Liability Convention and the Registration Convention define a "*space object*" as: "*The Term 'space object' includes component parts of a space object as well as its launch vehicle and parts thereof[.]*".[75] As evidenced by this circular language, there is no officially recognized definition of a "*space object*". Nonetheless, Bin Cheng proposes that a "*spaceobject*" simply equates with an "*object launched into outer space*",[76]

On [the above] assumption, the various treaties drafted by the United Nations appear superficially to be fairly consistent, inasmuch as the term "space object" figures in all of them. Thus the Astronauts Agreement in both its Title and Paragraph 1 of its Preamble speaks of "objects launched into outer space", while its Article 5 repeatedly uses the term "space object". The Liability Convention too adheres most faithfully to the term "space object," and includes it in its Title.[77]

Many experts agree with this assertion. For example, Vladimir Kopal writes, "*in the doctrine of space law, the term 'space object' has been used for all man-made instrumentalities launched into outer space and moving in orbits around the Earth or on other trajectories, in opposition to natural bodies moving in the universe – stars, planets, asteroids, and meteoroids.*"[78]

The Registration Convention uses the terms "*space object*" and "*objects launched into outer space*" interchangeably in Articles I to VI. However, Article II only requires "*space objects launched into earth orbit or beyond*" to be registered.[79] Does this mean some objects launched into outer space are not necessarily space objects? More than likely, the purpose of this distinction is simply to exclude from the registration requirement any "*space objects*" not "*launched into earth orbit or beyond*".[80] Although it is tempting to extract a distinction between the two terms from the language of Article II, nothing in the Registration Convention as a whole indicates an affirmative intent to differentiate between the two terms. Therefore, when

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75 Registration Convention, Art. I; Liability Convention, Art. I.

76 Cheng, *supra* note 53, at 17; referencing The Outer Space Treaty, Arts. VII, VIII; Liability Convention, Art. I; Rescue Agreement, Art. 5.

77 *Id.*

78 Kopal, *supra* note 55, at 40.

79 Registration Convention. Art. II.

80 Cheng, *supra* note 53, at 18.

attempting to define "*space object*", we are left with its apparent interchangeable twin: "*objects launched into outer space*".[81]

One may ask whether an ASV would fall under the registration requirement if it simply skirts the edge or only briefly enters orbit to deliver a payload? A straightforward reading of Article II would suggest that registration is not required. Though, on the other hand, nowhere does the Registration Convention expressly state that an object must be intended to "*complete*" an orbit before the registration requirement activates.[82] However, this question was arguably answered within weeks of the Outer Space Treaty's entry into force when the Soviet Union began testing their Fractional Orbital Bombardment System (FOBS).[83] Although some considered this a direct violation of the Treaty, the United States quickly confirmed that the use of an FOBS would not amount to a Treaty violation because a missile launched into space "*was not placed 'in orbit' until there was an orbit (i.e., at least one complete circle of the globe) and a FOBS—as any very long-range intercontinental missile—would be fired back to a target on earth before completing an orbit.*"[84]

Nonetheless, when looking at the language from the U.N. space treaties alone, one is often left with more questions than answers concerning not only what constitutes a "*space object*" but also what constitutes a "*launch*" and what sort of objects require registration. Despite ambiguity arising from decades-old international space policy (based on even older technology), some States are beginning to draft national space legislation that defines a vehicle based solely on its primary purpose.[85] However, a truly dual-purpose ASV would potentially have a primary purpose of both speeding up international transportation and providing a fast/efficient means of delivering payloads to orbit, raising the question as to which legal regime should take precedent when dealing with this new technology.

IV. AIR LAW APPROACH

Assuming the scope of ASV activities consisted of international carriage for reward, their use for the purpose of point-to-point transportation would

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[81] *Id.* at 19.
[82] *Id.*
[83] Rahmond L. Garthoff, *Banning the Bomb in Outer Space*, 5 INTERNATIONAL SECURITY 25, 38 (1980).
[84] *Id.*
[85] Langston, *supra* note 72, at 321, 330-31.

potentially have a sufficient regulatory home in conventional air law.[86] This legal regime already enjoys the benefits of well-established case law, endless scholarly interpretation, in-depth expert analysis, and nearly universal application from North America and Europe to Asia. However, applying air law would require a presumption that ASVs act only as enhanced versions of conventional passenger aircraft, ignoring arguably the most crucial service ASVs are hoped to provide, that is, efficient space travel. Despite providing a clear liability and regulatory framework for point-to-point international transportation, "*Warsaw and supplementary Conventions currently does not apply to space objects nor does it apply to space related activities.*"[87] Air law is simply incapable of addressing questions of liability, registration, and proper conduct concerning an ASV's space-faring potential. It is this author's position that such a legal shortcoming would not only stunt the growth of ASV related development and commerce, but also have potentially negative impacts on the security of the space environment. Under-regulating space-capable ASVs would demonstrate a disregard for the obligations enumerated under Article 9 of the Outer Space Treaty.[88] Even when many experts were considering ASV technology for commercial air transportation purposes only, there remained skepticism as to the sufficiency of air law to deal with the possible scope of ASV capability:

> if future technological developments were to create an aerospace vehicle capable of moving freely in the air like an aircraft and also moving at will in outer space, the whole range of variables distinguishing air law from space law and the applicability of these laws to given situations may have to be re-examined.[89]

In light of recent technological developments paving the way for ASVs to reach orbit, it becomes apparent that conventional air law alone is hardly the most effective fit for these vehicles.

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86 The Convention for the Unification of Certain Rules Relating to International Carriage by Air, Art. I, October 12, 1929, ICAO Doc. 7838, 9201, 137 L.N.T.S. 11 (1933), 49 Stat 3000 (1929) [hereinafter, "Warsaw Convention"]; The Convention for the Unification of Certain Rules for International Carriage by Air, Art. I, May 28, 1999, ICAO Doc 9740 [hereinafter, "Montreal Convention"].

87 Langston, *supra* note 72, at 312.

88 Outer Space Treaty. Art. IX. This article imposes an obligation that all States party to the Treaty conduct all their space activities in "*due regard*" to the interests of other States.

89 Gorove, *supra* note 65, at 149 (citing The Space Shuttle and the Law 2-3 (S. Gorove ed. 1980)).

V. SPACE LAW APPROACH

In much the same way, regulating dual-purpose ASVs exclusively under conventional space law would likely yield similarly lopsided results. Although the U.N. space treaty regime[90] enjoys the benefit of nearly universal application, with established parameters for liability, registration, and conduct for States and their space-faring objects, there are no space treaty provisions addressing anything close to international commercial transportation. This leads to effective elimination of one of the primary motivating factors for states/companies to develop ASV technology. Neither air law, nor space law alone is sufficient in scope to satisfy the needs of a dual-purpose ASV. The conversation needs to untangle its antlers from the decades-old gridlock of ambiguous definitions, take a step back, and approach this question from a big-picture perspective.

VI. IN SUPPORT OF DUAL LEGAL REGIMES FOR A DUAL-PURPOSE VEHICLE

As previously discussed, there is great uncertainty as to which legal regime should govern ASVs. Basing this determination on a vehicle's location, method of leaving the ground, and even its identity as an aircraft or spacecraft has yielded few—if any—definitive results and a host of unanswered questions. Short of accomplishing the highly difficult—if not impossible—task of creating a completely new legal regime, it would seem neither conventional air law nor space law alone has the sufficient scope to regulate the breadth of possible ASV activity or capability. Therefore, it is this author's contention that a dual legal regime—consisting of both international air law and space law—would most effectively regulate ASVs, regardless of their origin, point of development, or intended purpose.

A. THE INTENT APPROACH

In his written submission for the 34th Colloquium on the Law of Outer Space, Carl Christol advocated for an innovative approach to regulating ASVs consisting of both air and space law regimes that depended exclusively on the "*purpose and effects of the hybrid vehicle*":

> This new perspective will emphasize the relevance of criteria able to allocate to a functioning aerospace plane a regime of either air law or space law. The allocative criteria are two in number. First, it will be

[90] Outer Space Treaty, s*upra* note 64.

> necessary to identify the intended purpose or purposes of the hybrid vehicle. The second aspect to be examined is the effect or the effects of hybrid vehicular activity. Further, reference can be made, as needed in appropriate cases, to both purposes and effects. In practice this will mean that if the purposes and effects of the hybrid vehicle relate to air travel, it will be an aircraft. If its purpose (based on the owner's intent) is to enter into orbit then it would be subject to the regime of space law.[91]

This approach regulates each individual ASV based on its owner's intent: vehicles intended for space travel are placed under the space law regime, while vehicles intended for point-to-point transportation are placed under the air law regime.[92] The Federal Aviation Administration (FAA) has already applied a similar approach when applying either space law or air law to a vehicle based on the purpose of its mission. For example, in 2013 the FAA determined that Paragon Space Development Corporation's use of its World View commercial space tourism vehicle (a high-altitude balloon capable of reaching an altitude of 30 kilometers) fell under the jurisdiction of Title 51 of the United States Code[93] as a vehicle "*built to operate in outer space*" and launched "*in a suborbital trajectory*".[94] While expressly stating no intention to address whether the altitude of 30 kilometers constitutes outer space, the FAA recognizes that water and blood would boil at World View's maximum operating altitude, requiring the vehicle to be space-qualified in much the same way as components of the International Space Station.[95] However, the FAA emphasized that, if the balloon were not operating "*at an altitude where it needs to be built to operate in outer space*", domestic aviation law would apply.[96] The FAA analogized this approach to how Virgin Galactic's WhiteKnightTwo carrier aircraft and its detachable SpaceShipTwo suborbital rocket fall under space law only when the rocket is actually launched from its carrier in a suborbital trajectory.[97] However, the carrier and rocket combo fall under the jurisdiction of domestic aviation law when the mission

[91] Christol, *supra* note 55, at 30.

[92] *Id.*

[93] 51 U.S.C. §§ 50902(7)(A), (11)(A) (2010).

[94] Letter from Mark W. Bury, Assistance Chief Counsel for Int'l Law, Fed. Aviation Admin., to Pamela L. Meredith, Attorney at Law, Zuckert, Scoutt & Rasenberger, LLP (September 26, 2013) (on file with the Federal Aviation Administration), *available at*https://www.faa.gov/about/office_org/headquarters_offices/agc/pol_adjudication/agc200/interpretations/data/interps/2013/meredithzuckertscoutt&rasenberger%20-%20(2013)%20legal%20interpretation.pdf.

[95] *Id.*

[96] *Id.*

[97] *Id.*

does not include SpaceShipTwo's ignition.[98] Similarly, aviation law applies to some aircrafts (F-104s & MiGs) that are capable of surpassing 30 kilometers, seeing as these aircrafts "*are not designed, tested, or built to operate in outer space for any period of time, let alone for the length of time that Paragon intends to operate its vehicle*".[99]

Applying such an approach to all ASVs would arguably enjoy the benefits of already developed legal concepts, avoid the harrowing notion of developing a new regime from scratch, fill the legal vacuum created by singularly applying air or space law, and accommodate future ASV evolutions.[100] However, what determines an owner's intent for each mission? Could not the subjective nature of intent potentially limit the enforceability of this dual legal regime? Christol argues that intent can be implied based on where an ASV goes and what is does. However, he does not address how one determines an ASV operator's intent. Furthermore, what legal regime would apply when an ASV mission inevitably fails prior to reaching its destination or accomplishing its mission objective? Finally, how would one classify a truly dual-purpose ASV under this approach? Neither space law nor air law alone sufficiently covers a vehicle intended for both air and space related purposes.

B. THE CONTRACT-FOR-CARRIAGE APPROACH

i. Overview

Although the intent approach to implementing a dual-legal regime holds promise, applying an ambiguous standard to determine the purpose—and thus, the applicable legal regime—of an ASV would likely prove unreliable at best, even when considering a vehicle's conduct. The magic of truly dual-purpose ASVs is their potential for both highly efficient point-to-point transportation and delivering payloads into earth-orbit and beyond. Applying an insufficient or unduly ambiguous legal framework to this class of vehicles will inevitably slow their development and use in commerce. Therefore, it is essential that ASVs have the opportunity to operate at their maximum potential in both air and space related industries. The only way to efficiently accomplish this objective is by allocating each ASV mission to the legal regime that best regulates the activities at hand. Therefore, this author proposes implementing a dual legal approach for ASVs based on a Contract-for-Carriage Approach. This entails allocating either air law or space law to an ASV on a mission-by-mission basis, determined by the content of its

[98] *Id.*
[99] *Id.*
[100] Christol, *supra* note 55.

contract for use/carriage. Nearly every international commercial flight is conducted under contracts for carriage and regulated by International conventions, like the Warsaw Convention, the Hague Protocol, and the Montreal Convention.[101] Likewise, any legitimate government agency or private space-launch company delivers payloads to earth-orbit under similar contracts for carriage.[102] For the purposes of allocating missions to the appropriate legal regime, a contract for the carriage of passengers from London to New York can hardly be mistaken for a contract to deliver military satellites into orbit, and vice versa.

ii. Questions

However, what happens when an ASV conducts a mission involving both air and space related objectives? If a vehicle is capable of both delivering payloads to orbit and delivering passengers across the planet, could it not potentially conduct both activities under the same contract for carriage? In an attempt to address this same question from the intent approach, Christol writes,

> In the case where there is both an aviation purpose and an outer space purpose the authorizing State (in the case of a space launch a launching state) would be responsible for the effects of the subsequent activities. To be taken into account in measuring the responsibility of the operators of the different types of vehicles are subjective considerations consisting of the purposes for which the vehicle is to be used and the objectively measured effects of such use. The objective performance of a hybrid vehicle when joined with the subjective purpose of the mission of such a vehicle can provide a valid theoretical basis for the law of international aerospace activity.[103]

As evidenced by the above excerpt, tackling the question of simultaneous dual-purpose missions is potentially complicated, revealing the difficult nature of reconciling two separate legal regimes with a class of vehicles that will inevitably blend the realms of air and space forever. For the purposes of the Contract-for-Carriage Approach, this author suggests allocating either air or space law to a specific ASV mission in a tiered system. Seeing as the

[101] Warsaw Convention, Montreal Convention, *supra* note 87.

[102] Kelsey D. Atherton, *Air Force Turns to SpaceX and Orbital ATK to Build New Rockets for Military Satellite Launches*, Popular Science (2016), http://www.popsci.com/air-force-turns-towards-silicon-valley-to-launch-satellites; Charley Riley, *SpaceX Just Landed a Coveted $83 Million Military Contract*, CNN Money (2016), http://money.cnn.com/2016/04/28/news/spacex-military-contract-elon-musk/.

[103] Christol, *supra* note 55, at 30.

hypothetical delivery of both a payload to orbit and passengers to the ground cannot be executed simultaneously, the Contract-for-Carriage Approach would apply both air law and space law consecutively as it corresponds with the order of objectives outlined in the contract for carriage.

The next obvious question under this approach is what happens when an ASV collides with an orbiting satellite while conducting the international carriage of passengers? Article III of the Liability Convention creates a fault-based liability regime "*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 a space object of another launching State . . .*".[104] Although this language covers collisions between two "*space objects*",[105] what happens in the event of a collision between a space object in orbit (like a satellite) and an ASV conducting activities as an aircraft? The Warsaw/Hague/Montreal regime could potentially cover an ASV operator's liability for the death or injury of passengers.[106] However, the air law regime does not address damage to space objects. Could the fault-based liability regime implemented under Article III of the Liability Convention then apply to both the ASV and the satellite?[107] This author argues in the affirmative.

For example, if an ASV carrying passengers collides (due to its fault) with a satellite in orbit, the ASV's operator would be liable for damage to the space object under the Liability Convention, and further liable for the death/injury of its passengers under conventional air law. On the other hand, if a collision occurs due to the space object operator's fault, it could be held liable for damages incurred upon the ASV. The ASV's operator could then limit its liability—under Article 21 of the Montreal Convention—for damages exceeding 100,000 Special Drawing Rights that are "*solely due to the negligence or other wrongful act or omission of a third party*".[108] From a public policy perspective this approach would help protect the operators of orbiting space objects, while also helping to ensure responsible mission planning on the part of ASV operators.

Furthermore, the very nature of this subject begs the question of whether passengers on sub-orbital or even orbital commercial flights would/should attain astronaut status for the purposes of the Outer Space Treaty[109] and

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[104] Liability Convention, Art. III.
[105] *Id.*
[106] Montreal Convention, Art. 17; Hague Protocol, Art.17; Warsaw Convention, Art. 17.
[107] Liability Convention, *supra* note 64.
[108] Montreal Convention, Art. 21(2)(b).
[109] Outer Space Treaty, Art. V.

the Rescue Agreement?[110] However, as previously admitted, addressing every issue involving ASVs and their potential uses would require much larger work. The purpose of this article is simply to provide an introduction to contemporary developments in ASV technology, outline several of the basic legal uncertainties traditionally surrounding their use, and provide the beginnings of an argument for the application of dual legal regimes based on a Contract-for-Carriage Approach. Naturally, interface problems will arise when applying two legal regimes simultaneously. However, this is to be expected when entering a largely unexplored legal and technological territory.

iii. Potential for Universal Application

One of the most utilitarian aspects of the Contract-for-Carriage Approach is its potential for global application via the nearly universal acceptance of uniform international air law—like the Montreal Convention[111]—and international space law encapsulated in the U.N. space treaties.[112] For example, the United States, Great Britain, France, Australia, Brazil, India, Nigeria, and China (only to name a few)are all parties to the Montreal Convention,[113] the Outer Space Treaty, and the Liability Convention.[114] The Contract-for-Carriage Approach simply applies pre-existing principles and legal-frameworks from these already accepted institutions, ensuring that the legal system put in place for the operation of ASV technology is understandable, efficient, and practical for both governments and private actors, regardless of whether they hail from traditional space giants or developing countries. This approach would also serve to help jumpstart the ASV technologies of countries who do not yet have concrete domestic space laws. Instead of re-inventing the wheel, why not start from a place where this is already familiar and acceptable to the international community as a whole? A legal approach to ASVs should be comprehensive, taking into account the incredible progress made in the global west, east, north and south. After all, this is the generation that will set foot on Mars, cross the globe in under an hour, and begin space missions from airport runways.

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[110] Rescue Agreement, Art. 1-4.

[111] Montreal Convention, *supra* note 87.

[112] U.N. space treaties, *supra* note 64.

[113] *Convention for the Unification of Certain Rules for International Carriage by Air done at Montreal on 28 May 1999*, ICAO, http://www.icao.int/secretariat/legal/List%20of%20Parties/Mtl99_EN.pdf (Last visited on March 7, 2017).

[114] *Status of International Agreements relating to activities in outer space as at 1 January 2016*, United Nations Office for Outer Space Affairs, http://www.unoosa.org/documents/pdf/spacelaw/treatystatus/AC105_C2_2016_CRP03E.pdf (Last visited on March 7, 2017).

VII. CONCLUSION

Admittedly, a dual legal regime for ASVs—based on a Contract-for-Carriage Approach—depends on several presumptions both circumstantial and legal. Nonetheless, this regime is pragmatic in that the international community need not create an entirely new legal regime for activities which can be easily regulated by already existing concepts and frameworks. No, it does not answer every possible question or scenario. However, it does provide an efficient and familiar place to start. The law itself does not necessarily answer every question or solve every possible riddle. However, it is designed to adapt to new situations and scenarios as they materialize. It would seem that governments have, for the most part, plateaued

in their attempts to spearhead humanity's cosmic ambitions. Therefore, the future of mankind's exploration of space is now—more than ever—in the hands of individuals and private entities. In light of this quickly developing reality, it is incredibly important that space-faring nations create positive legal frameworks for the benefit of developing technologies like aerospace vehicles. This author believes that the collective concept of space technology and exploration should not merely elicit thoughts of the Apollo launches in the 60s, or the space-plane programs of the 80s, but also of tomorrow: its hopes, dreams, technologies, and laws.