One Small Step for the EPA, One Giant Leap for the Environment: A Hybrid Proposal for Regulating Rocket Emissions Due to the Rising Commercial Space Industry

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I. Introduction

When asked what they want to be when they grow up, kids often respond, "An astronaut! I want to go to space!" But this generation of children may not need to become astronauts to go to space—the commercial space industry is rapidly on the rise.

Along with the excitement at the prospect of space exploration, tourism, and commercial enterprise, however, comes a new set of problems for the environmental and legal communities to solve. One such difficulty this boon of progress will pose is the emissions of air pollutants. Simply watching a rocket lift off, with billows of black smoke gathering ominously below, should concern any environmentalist. Some experts have noted the relatively low environmental cost attributed to rocket launches, based on certain exhaust products,[1] but given the nascent nature of private spaceflight and its imminent potential for maturation, the countdown clock on the need to regulate rocket emissions has already begun.[2]

As the industry matures and costs decrease, satellite launches and space tourism will likely become commonplace. Scientists predict that these aggregated rocket emissions could significantly exacerbate changes to the climate and the ozone layer.[3] Neither Congress nor the U.S. Environmental Protection Agency ("EPA") has yet addressed this concern through legislation or regulation. However, in a policy determination letter, the EPA categorized rocket launching as a mobile source activity rather than a stationary source activity under the Clean Air Act ("CAA"), absolving a space company of potential permitting requirements.[4] This conclusion provided the EPA less oversight over the company's emissions and lowered the company's administrative burden. Although the EPA's decision is based on sound logic, it requires clarification so that the burgeoning commercial space industry has certainty in how it can expect to be regulated in the future. For example, aerospace engineers and rocket manufacturers require a regulatory framework that will clarify the parameters within which they must design and build the rockets.[5]

The EPA has clear authority over rockets as aircraft, a subset of mobile sources of emissions, as the policy determination letter suggested. The letter also alluded to the regulation

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1. *See, e.g.*, Darin W. Toohey, *How Do Rocket Emissions Impact Ozone and Climate?*, U. of Colo. at Boulder Atmospheric and Oceanic Sci., http://atoc.colorado.edu/~toohey/basics.html; Prachi Patel-Predd; *A Spaceport for Treehuggers*, Discover Mag. (Nov. 26, 2007), http://discovermagazine.com/2007/dec/a-spaceport-for-tree-huggers (quoting former Virgin Galactic president Will Whitehorn).
2. *See* Federal Aviation Admin., The Annual Compendium of Commercial Space Transportation: 2017 46 (2017), http://commercialspace.pbworks.com/w/file/115291906/2017%20Compendium%20%20-%20Small.pdf; *see also* Bob Granath, *Commercial Spaceflight Opens Unlimited Opportunities*, NASA (Dec. 1, 2015), http://www.nasa.gov/feature/commercial-flight-opens-unlimited-opportunities.
3. *See* Martin Ross et al., *Potential Climate Impact of Black Carbon Emitted by Rockets*, 37 Geophysical Research Letters (Dec. 2010); *see also* Donald E. Gardner et al., National Research Council Committee on Toxicology, Assessment of Exposure-Response Functions for Rocket-Emission Toxicants (1998), https://www.nap.edu/catalog/6205/assessment-of-exposure-response-functions-for-rocket-emission-toxicants.
4. *See* Letter from John S. Seitz, EPA Dir., Off. Quality Planning & Standards, to Pat Ladner, Exec. Dir., AK Aerospace Dev. Corp. (Jan. 12, 2000), https://www.epa.gov/sites/production/files/2015-08/documents/rocket.pdf [hereinafter Letter from John S. Seitz].
5. *See* Larry A. Caddy et al., *Reduced Hazard Chemicals for Solid Rocket Motor Production*, AGARD, Envtl. Aspects of Rocket and Gun Propulsion (Feb. 1, 1995), http://infohouse.p2ric.org/ref/23/22126.pdf.

of rockets launched from being attached to fixed test stands as a part of rocket launch systems (defined as the rocket and its launch facility), which would be regulated as stationary sources. Therefore, given the unique nature of rocket launch systems, which fit both the categories of mobile sources and stationary sources, the EPA should regulate rocket launch systems as hybrid mobile-stationary sources. It is critical that the EPA regulate emissions of rocket activities as accurately and comprehensively as possible to avoid exacerbation of climate change and ozone depletion.

This Note considers the following issues:

I. How will emissions from rockets be regulated under the Clean Air Act?

II. How can Congress amend the Clean Air Act to further clarify the applicability of the statute to rocket launch systems?

Part II discusses the history of public spaceflight, the ascent of the commercial space industry, the mechanics of a rocket launch, and the environmental impact of rocket emissions and airplane emissions. Part III describes the CAA's purpose, its categorization of air pollutants, and its definitions and parameters of mobile and stationary sources of emissions. Part IV analyzes the possibilities of regulating rocket emissions under the CAA's current constraints, based on whether rockets and launch systems properly fall under the definition of mobile sources, stationary sources, or both. Part V proposes amendments to the CAA and EPA regulations to clarify the law's jurisdiction to regulate rockets and launch systems. Part VI concludes the Note with a summary of the environmental implications of the rise of commercial space travel and how to correct the course it is on.

II. The Rise and Implications of the Commercial Space Industry

A. A Brief History of the Space Industry

The Space Age began on October 4, 1957. On that date, the U.S.S.R. successfully launched the first artificial satellite, Sputnik I, and the Soviet Union and the United States began an interstellar competition.[6] Though many associate the Space Race with two world powers pitted against each other, the private sector has been involved since before man walked on the moon.

In the early 1960s, the newly created National Aeronautics and Space Administration ("NASA") began contracting with commercial companies to aid in the rapid creation and implementation of active communication satellites.[7] At that time, there were no existing public policies that governed the execution of private companies' proposals.[8] Among these proposals was NASA's launch of AT&T Bell Telephone Lab's *Telestar* on July 10, 1962, the first successfully launched active communications satellite in the world, as well as government contracts for additional satellites from commercial companies.[9]

With the help of the U.S. government, this movement towards industry-directed spaceflight has grown since the Space Race. Congress passed legislation over several decades in its attempt to deregulate the space industry and encourage access by private companies. However, NASA opposed several proprivatization attempts of the space industry, which was met with pushback via legislation by Congress.[10] These efforts began with the Communications Satellite Act of 1962, which created a corporation, Comsat, to work with foreign governments or businesses on a communications satellite system.[11] The government considered Comsat a public entity, even an agency, rather than a private enterprise.[12]

Despite these congressional efforts, NASA continued to resist commercial competition to the Space Shuttle. Nonetheless, President Reagan signed the Commercial Space Launch Act of 1984 into law, which encouraged the U.S. private sector to work with NASA to develop launch vehicles and promote economic growth.[13]

The private sector began to see a steady increase in interest in space exploration around the turn of the 21st century, and that interest has continued to gain momentum to date. In 2004, President George W. Bush signed the Commercial Space Launch Amendments Act into law, effectively mandating NASA and the Federal Aviation Administration ("FAA") to legalize commercial space travel.[14]

The X PRIZE Foundation, a non-profit that stimulates technological development which is beneficial for humanity by sponsoring competitions with cash prizes as incentives, created the Ansari X Prize in May 1996.[15] The Foundation announced that the Ansari X Prize would provide $10 million to the first non-governmental organization that developed a privately-funded spacecraft that fit the criteria to (1) travel 100 kilometers above Earth, (2) with three people, and (3), twice within two weeks.[16] This ushered in the era of a private space race, as twenty-four teams from around the world competed.[17] On October 4, 2004, a spaceplane called SpaceShipOne, owned by Mojave Aerospace Ventures, completed

6. Steve Garber, *Sputnik and the Dawn of the Space Age*, NASA (Oct. 10, 2007), http://history.nasa.gov/sputnik/.
7. *See* David J. Whalen, *Communications Satellites: Making the Global Village Possible*, NASA, http://history.nasa.gov/satcomhistory.html.
8. *Id.*
9. *Id.*
10. *See generally* Jonathan F. Galloway, *Originating Communications Satellite Systems; The Interactions of Technological Change, Domestic Politics, and Foreign Policy, in* Beyond the Ionosphere (Andrew J. Butrica, ed., 1997), http://history.nasa.gov/SP-4217/ch13.htm.
11. *Id.* at 171–72.
12. *Id.* at 173.
13. Commercial Space Launch Act, Pub. L. No. 98-575, 98 Stat. 3055 (1984).
14. Commercial Space Launch Amendments Act of 2004, Pub. L. No. 108-492, 118 Stat. 3974 (2004). The FAA has licensed 251 launches as of November 11, 2016, and there are currently 11 active launch licenses, the longest of which run through 2021. *Commercial Space Data*, Fed. Aviation Admin., https://www.faa.gov/data_research/commercial_space_data/ [https://perma.cc/7366-HF4H] (last visited Nov. 20, 2016).
15. XPRIZE, *What Is an XPRIZE?*, http://www.xprize.org/about/what-is-an-xprize (last visited Mar. 1, 2018).
16. XPRIZE, *A $10M Competition to Usher in a New Era of Private Space Travel*, http://ansari.xprize.org/ (last visited Mar. 1, 2018).
17. XPRIZE, *Competing Teams*, http://ansari.xprize.org/teams (last visited Nov. 20, 2016).

the challenge and won the Ansari X Prize.[18] It was the first private spacecraft in history to carry a human into space.[19]

Inspired by SpaceShipOne, famed entrepreneur Richard Branson co-founded Virgin Galactic.[20] Virgin Galactic aimed to build the first commercial spaceline. It sought to launch two flights per day for space tourists by 2011, partnering with Mojave Aerospace Ventures.[21] Although it has not begun commercial flights, as of the beginning of 2017, approximately 700 people have put deposits down to travel on Virgin Galactic's SpaceShipTwo.[22] In August 2016, the Federal Aviation Administration's Office of Commercial Space Transportation granted Virgin Galactic an operator license for SpaceShipTwo.[23] It is currently in flight testing phases.[24] One noteworthy component of spaceplane SpaceShipTwo's design is that it is carried to launch altitude by an aircraft, at which point its rocket engine ignites.[25] When landing, it operates as a normal airplane would on a runway.[26]

Space Exploration Technologies Corporation, or SpaceX, was founded in 2002 by Elon Musk.[27] Musk wanted to lower the cost of space travel and colonize Mars, with the goal of inspiring an interest in space exploration again and increasing NASA's budget.[28] He has certainly achieved his goal of making space the exciting industry it once was, due in part to his fame from other projects, but also due to the overwhelming success that SpaceX has enjoyed. Not only was SpaceX the first privately-funded company to put a rocket into orbit, but in 2016, it famously landed its Falcon 9 rocket upright just six miles away from its launch pad.[29] This feat achieved the dream of a reusable rocket, which the industry had sought after for years.[30] SpaceX completed eighteen launch missions during each 2016 and 2017, and it has completed nine launch missions within 2018 as of May 11, 2018.[31] In March 2017, the private space company made history again by reusing a rocket to launch a commercial satellite.[32] This successful flight heralded the age of more affordable and sustainable spaceflight.[33]

On April 3, 2017, a new commercial enterprise entered the outer space scene: Brand Delta-V.[34] But this company is not launching private rockets; it is a dedicated marketing firm for those space startups.[35] This is yet another indication of the tipping point of the growth of the private space industry.

Twelve men on the moon,[36] five decades, and two Mars-exploring rovers later,[37] the NASA budget was no longer large enough to keep the Space Shuttle Program afloat without sacrificing its priorities, and its last mission landed in 2011.[38] The suspension of the Space Shuttle's activities after the *Challenger* accident afforded the commercial space industry an opportunity to fill the void.[39] The Obama Administration's space policy turned toward public-private partnerships, including looking to industry to develop a commercial spacecraft to shuttle astronauts to and from the International Space Station ("ISS").[40] Just over two years later, NASA's Commercial Orbital Transportation Services ("COTS") program afforded two American aerospace manufacturers, SpaceX and Orbital ATK, the opportunity to resupply the ISS with cargo.[41] Due to the success of the COTS program, which provides inexpensive and efficient commercial transportation,[42] NASA awarded SpaceX and Orbital ATK commercial resupply services contracts through the end of 2016.[43]

The dawn of the Trump Administration has also delivered a focus on space exploration through the private sector.[44] President Trump's first address to a joint session of

18. *See id.*
19. Tim Sharp, *SpaceShipOne: The First Private Spacecraft | The Most Amazing Flying Machines Ever*, Space.com (Oct. 2, 2014), https://www.space.com/16769-spaceshipone-first-private-spacecraft.html.
20. *Id.*
21. Patel-Predd, *supra* note 1.
22. *See* Irene Klotz, *Richard Branson's Passenger Space Firm Granted FAA Operating License*, Reuters (Aug. 1, 2016), https://www.reuters.com/article/space-virgin-gltct/richard-bransons-passenger-space-firm-granted-faa-operating-licence-idINKCN10C36Q; *see also* Sharp, *supra* note 19.
23. *FAA-AST Awards Virgin Galactic Operator License for SpaceshipTwo*, Virgin Galactic (Aug. 1, 2016), http://www.virgingalactic.com/faa-ast-awards-virgin-galactic-operator-license-for-spaceshiptwo/; *see also* Sharp, *supra* note 19.
24. *See generally Update From Mojave: The Next Phase of Flight Test*, Virgin Galactic (Nov. 1, 2016), http://www.virgingalactic.com/update-from-mojave-the-next-phase-of-flight-test; *see also* Sharp, *supra* note 19.
25. *See* Jonathan Amos, *Sir Richard Branson's Virgin Galactic Spaceship Ignites Engine in Flight*, BBC (Apr. 29, 2013), http://www.bbc.com/news/science-environment-22344398.
26. Tariq Malik, *Virgin Galactic's SpaceShipTwo Unity Takes 1st Flight With Mothership*, Space.com (Sept. 9, 2016), https://www.space.com/34025-virgin-galactic-spaceshiptwo-unity-first-mothership-flight.html.
27. *About*, SpaceX, http://www.spacex.com/about (last visited May 15, 2018).
28. *See generally* Elon Musk, *Risky Business*, Inst. of Electrical and Electronics Engineers, http://spectrum.ieee.org/aerospace/space-flight/risky-business.
29. Jeffrey Kluger, *10 Things to Know About SpaceX*, TIME (Dec. 22, 2015), http://time.com/space-x-ten-things-to-know/.
30. *Id.*
31. *Completed Missions*, SpaceX, http://www.spacex.com/missions (last visited Jan. 20, 2017).
32. Kenneth Chang, *SpaceX Launches a Satellite With a Partly Used Rocket*, N.Y. Times (Mar. 30, 2017), https://www.nytimes.com/2017/03/30/science/spacex-launches-a-satellite-with-a-partly-used-rocket.html.
33. *Id.*
34. *Brand Delta-V Becomes the NewSpace Industry's First Marketing Company*, Brand Delta-V (Apr. 3, 2017), http://branddeltav.com/newspace-first-marketing-company/.
35. *Id.*
36. Nat'l Aeronautics & Space Admin., *NASA and Scouting* (Apr. 12, 2011), https://www.nasa.gov/audience/foreducators/informal/features/F_NASA_and_Scouting.html [https://perma.cc/HJ65-BNZ6].
37. Elizabeth Howell, *A Brief History of Mars Missions*, Space (Mar. 17, 2015), http://www.space.com/13558-historic-mars-missions.html.
38. Nat'l Aeronautics & Space Admin., *Space Shuttle Era: Overview*, https://www.nasa.gov/mission_pages/shuttle/flyout/index.html [https://perma.cc/TL4C-TZM6] (last visited May 15, 2018).
39. Joan Lisa Bromberg, NASA and the Space Industry 186 (2000).
40. Joel Achenbach, *NASA Budget for 2011 Eliminates Funds for Manned Lunar Missions*, Wash. Post (Feb. 1, 2010), http://www.washingtonpost.com/wp-dyn/content/article/2010/01/31/AR2010013101058.html; *see also* Andrew Moseman, *Obama's NASA Budget: So Long, Moon Missions; Hello, Private Spaceflight*, Discover Mag. (Feb. 1, 2010) http://blogs.discovermagazine.com/80beats/2010/02/01/obamas-nasa-budget-so-long-moon-missions-hello-private-spaceflight/#.WDDva6IrLow.
41. Nat'l Aeronautics & Space Admin., *Commercial Resupply Services Overview* (July 29, 2016), https://www.nasa.gov/mission_pages/station/structure/launch/overview.html [https://perma.cc/2NT3-HFSD].
42. *Id.*
43. John Yembrick & Josh Byerly, *NASA Awards Space Station Commercial Resupply Services Contracts*, Nat'l Aeronautics & Space Admin. (Dec. 23, 2008), https://www.nasa.gov/offices/c3po/home/CRS-Announcement-Dec-08.html [https://perma.cc/8AM7-W9R5].
44. Eric Berger, *The Trump Administration Has Unleashed a Lunar Gold Rush*, Ars Technica (Mar. 3, 2017), https://arstechnica.com/science/2017/03/the-trump-administration-has-unleashed-a-lunar-gold-rush/l; *see also* Andy Pasztor, *Trump Space Policy Options Emphasize Role of Private Enterprise*, Wall St.

Congress included an indication of his goal to have astronauts land on the moon during the 2019 planned orbit mission.[45] Almost immediately after, SpaceX announced that it would transport two private citizens around the moon by the end of 2018.[46] These paying customers will go further into space than any other space tourist has before.[47] Additionally, President Trump signed a NASA budget authorization bill, the agency's first in seven years, on March 21, 2017.[48] The bill, the National Aeronautics and Space Administration Transition Authorization Act of 2017, instructs NASA to promote the private space industry, especially through public-private partnerships.[49]

Although robust space tourism for civilians is not yet underway, companies continue to engage in the commercial space industry through satellite communications. Satellite launches are the quintessence of the commercial space industry in its current form, as it produces billions of dollars in sales of products and services each year.[50] In addition to the anticipated growing number of launches for space tourism, satellite launches are and will likely continue to be a large percentage of the commercial space industry.[51] For example, SpaceX alone plans to deploy at least seventy satellites between the beginning of 2017 and early 2018 on just one contract.[52] The company intends to launch twenty rockets in 2017, in comparison to its eight launches in 2016.[53]

Despite the abundance of commercial satellites that are launched each year,[54] scientific data about their emissions has not been widely reported. However, given the potential payload capacity of each rocket of several hundred satellites,[55] the launch of a single satellite is more efficient than the launch of a single rocket. Therefore, the emissions of a rocket are still relevant as it is the vessel for satellite delivery. Rockets have been launching satellites for years and will continue to do so. The next section will discuss the mechanics of rocket launches.

B. The Mechanics of Rocket Launches and Spaceflight

A launch system is comprised of at least a rocket and a launch pad, if not other structures such as an umbilical tower.[56] Rockets deploy into space from launch facilities, which include a launch pad and its service structures.[57] A launch complex or spaceport may contain several launch facilities.[58] A launch pad has a service structure built on top of it, which allows crew to board and service the rocket from different access points. The service structure also supports the shuttle stack while it is vertically positioned, per Figures 1 and 2.[59] This service structure, also called an umbilical tower or gantry, is generally stationary and facilitates communications and fueling while the rocket is still earthbound.[60]

Figure 1 - The gantry arms are raised to secure the Soyuz rocket onto the launch pad.[61]

Figure 2 - The gantry arms closed around the Soyuz rocket.[62]

J. (Feb. 5, 2017), https://www.wsj.com/articles/trump-space-policy-options-emphasize-role-of-private-enterprise-1486317411.

45. Pasztor, *supra* note 44; James Grebey, *Trump Proposes "American Footprints on Distant Worlds" in Speech*, Inverse (Feb 28, 2017), https://www.inverse.com/article/28494-donald-trump-space-exploration-moon-mars-mission-speech-to-joint-sessioncongress.
46. Christian Davenport & Joel Achenbach, *Elon Musk's SpaceX Plans to Fly Two Private Citizens Around the Moon by Late Next Year*, Wash. Post (Feb. 27, 2017), https://www.washingtonpost.com/news/the-switch/wp/2017/02/27/elon-musks-spacex-plans-to-fly-two-private-citizens-around-the-moon-by-late-next-year/?utm_term=.543c263c1475.
47. *Id.*
48. NASA Transition Authorization Act of 2017, S. 442, Pub. L. No. 115-10; *see also* Sarah Kaplan, *Trump Signs NASA Bill Aimed at Sending People to Mars*, Wash. Post (Mar. 21, 2017), https://www.washingtonpost.com/news/speaking-of-science/wp/2017/03/21/trump-signs-nasa-bill-aimed-at-landing-on-mars/?utm_term=.f635a0cdcd79.
49. *See* NASA Transition Authorization Act of 2017, S. 442, Pub. L. No. 115-10.
50. Whalen, *supra* note 7.
51. *The Annual Compendium of Commercial Space Transportation: 2017*, *supra* note 2.
52. *See* Press Release, Iridium-1 NEXT Mission, (Jan. 2017), http://www.spacex.com/sites/spacex/files/spacex_iridium1_press_kit.pdf.
53. Stephen Clark, *SES 10 Telecom Satellite in Florida for Launch on Reused SpaceX Rocket*, Spaceflight Now (Jan. 17, 2017), https://spaceflightnow.com/2017/01/17/ses-10-telecom-satellite-in-florida-for-launch-on-reused-spacex-rocket/; *see Completed Missions*, *supra* note 31.
54. Ivan Mehta, *IRSO to Launch a Record 104 Satellites on 15 February*, Huffington Post India (Feb. 6, 2017), http://www.huffingtonpost.in/2017/02/06/isro-to-launch-a-record-104-satellites-on-15-february/.
55. *See* Eric Berger, *The US Intelligence Nominee Cannot Believe India Just Launched 104 Satellites*, Ars Technica, (Mar. 2, 2017), https://arstechnica.com/science/2017/03/nominee-for-top-intelligence-post-shocked-by-indian-satellite-launch/ (noting that despite 104 being the record-setting number of satellites launched into space, SpaceX has the capacity to launch more than five times that payload).
56. *See, e.g.*, John Kelly, *NASA Kills "Wounded" Launch System Upgrade at KSC*, Florida Today (Sept. 18, 2002), http://archive.li/3MuRR.
57. *See, e.g.*, *FAQs*, Spaceport America, http://spaceportamerica.com/about-us/faq/ (last visited Apr. 9, 2017).
58. *Id.*
59. *See Fixed Service Structure*, NASA, https://www.nasa.gov/mission_pages/shuttle/launch/fixed-service-structure.html (last visited Apr. 9, 2017).
60. *Id.; see also* David S.F. Portree, *The LUT, the Shuttle, and the Saturn V S-IC Stage (1969)*, Wired (Apr. 13, 2012), https://www.wired.com/2012/04/the-lut-the-shuttle-and-the-saturn-v-s-ic-stage-1969/.
61. Mike, *Soyuz TMA-08M to Launch From Baikonur to ISS* Today, Wired4Space (Mar. 28, 2013), http://www.wired4space.com/category/rockets/soyuz.
62. Jerry Wright, ed., *Gantry Arms Secure Soyuz*, NASA (Mar. 23, 2014), https://www.nasa.gov/content/gantry-arms-secure-soyuz.

Figure 3 - The gantry retracts as Apollo 11 launches.[63]

Because rockets take off vertically, they are still attached to the pad to provide stability for several seconds after engine ignition.[64] Once the engines have built up to their full-thrust capacity, the launch pad's connections to the rocket, either through hold-down arms or explosive bolts, are released.[65] Subsequently, the rocket may lift off, free from support or restraint from the launch pad.[66]

Black carbon particles, or soot,[67] which is the dark gray smoke seen coming out of tailpipes and trucks' exhaust stacks, begins discharging when the rocket engines have ignited, while still attached to the launch pad. The rocket continues to emit soot once the gantry has retracted and it is no longer attached to the launch facility, and when the rocket is in flight.[68] Rockets reach at least 200 km, or 125 miles, above the Earth's surface,[69] traveling through the atmospheric layer known as the thermosphere.[70]

There are launch methods other than the traditional launch pad approach described above. Some rockets are launched using flame trenches,[71] while others, like the Virgin Galactic SpaceShipTwo, are dropped at launch altitude by aircraft.[72] Flame trenches can be used in addition to fixed structures on launch pads or in place of them.[73] A flame trench, a pit constructed with bricks, is used to deflect the fire and rocket exhaust during launch so that the rocket does not get damaged.[74] As mentioned in an earlier section, SpaceShipTwo functions similarly to an airplane after it reenters the stratosphere.[75] To launch, an aircraft carries it to launch altitude and its engines ignite to blast off from a suspended state.[76]

C. Environmental Impacts of Rocket Emissions

Each rocket launch may be *de minimis* in environmental costs. But given the aforementioned rapid rise of the commercial space industry, disaggregated statistics of each launch are not accurately representative of the effects the industry might have once many rockets are launched.[77] The emissions that rockets give off are based on the type of propellant used, but generally include water, nitric oxide, carbon dioxide (CO_2), and soot made up of black carbon particles.[78]

Scientists predict that 1,000 launches per year of suborbital rockets would produce a "layer of black carbon particles in the northern stratosphere that could cause potentially significant changes in the global atmospheric circulation and distributions of ozone and temperature."[79] These scientists stated that there are plans for several hundred to thousands of suborbital spaceflights per year by 2021,[80] so these environmental changes are well within reach. Rocket emissions will exacerbate global warming because, as compared to intermittent ejections of black carbon into the air like volcanic eruptions, their "continuous nature . . . means that the rocket stratospheric [black carbon] layer becomes a constant . . . feature of the Earth's atmosphere for as long as the launches continue."[81] When spaceflight becomes consistent, the soot

63. Ralph Morse, The LIFE Picture Collection/Getty Images, Time, http://time.com/3880305/apollo-11-photos-of-what-liftoff-looked-like/ (last visited Mar. 6, 2017).
64. Portree, *supra* note 60.
65. *See, e.g.*, *id.*
66. *Id.*
67. For the purposes of this Note, black carbon will be interchangeable with soot. As explained in Section I.C., black carbon is particulate matter, which is a type of air pollutant.
68. *See* Don Pettit, *The Tyranny of the Rocket Equation*, Nat'l Aeronautics & Space Admin. (May 1, 2012), https://www.nasa.gov/mission_pages/station/expeditions/expedition30/tryanny.html.
69. *Why Can't an Airplane Just Fly Into Space? Why Do We Need Rockets?*, Nat'l Aeronautics & Space Admin., https://spaceplace.nasa.gov/review/dr-marc-technology/rockets.html (last visited Apr. 8, 2017) [hereinafter *Why Can't an Airplane Just Fly Into Space?*].
70. *Thermosphere—Overview*, UCAR Center for Science Education, https://scied.ucar.edu/shortcontent/thermosphere-overview (last visited Apr. 8, 2017). Conversely, airplanes can only fly to about 12 km, or 7.5 miles, above the Earth's surface, a height which is within the layer of atmosphere called the stratosphere. *Why Can't an Airplane Just Fly Into Space?*, *supra* note 69; *see also The Stratosphere—Overview*, UCAR Center for Science Education, https://scied.ucar.edu/shortcontent/stratosphere-overview (last visited Apr. 9, 2017).
71. *Flame Trench-Deflector System*, Nat'l Aeronautics & Space Admin., https://www.nasa.gov/mission_pages/shuttle/launch/Flame-trench-deflector.html [https://perma.cc/3XTP-CDK7] (last visited Apr. 9, 2017); *see also* Linda Herridge, *New Flame Trench Will Support New Era at Launch Pad 39B*, Nat'l Aeronautics & Space Admin. (June 24, 2013), https://www.nasa.gov/exploration/systems/ground/pad_b_flame_trench.html.
72. Amos, *supra* note 25.
73. *Cf.* Linda Herridge, *supra* note 71*; Flame Trench-Deflector System*, *supra* note 71; *see also* Letter from John S. Seitz, *supra* note 4.
74. Linda Herridge, *supra* note 71*; Flame Trench-Deflector System*, *supra* note 71.
75. *See* Amos, *supra* note 25.
76. *See id.*
77. An issue not addressed in this Note is the virulence of the type of rocket fuel used: solid or liquid. Solid rocket fuels are more durable and more easily stored, and solid propellant motors are the simplest rocket designs, but liquid rocket fuel is less harmful to the environment. *See* Martin Ross et al., *Limits on the Space Launch Market Related to Stratospheric Ozone Depletion*, 7 Int'l J. Space Politics & Pol. 50–82 (2009).
78. *See* Toohey, *supra* note 1.
79. Ross et al., *supra* note 3; *see also* Andrew Rosenblum, *Space Tourism's Black Carbon Problem*, Popular Science (May 16, 2013), http://www.popsci.com/science/article/2013-05/space-tourism-experiment-geo-engineering.
80. Ross et al., *supra* note 3, at 77.
81. *Id.*

from steady launches will intensify the rise in temperature, implicating climate change.[82]

Although there is a dearth of research in the field of rocket emissions and these scientists did not research rocket emissions of all air pollutants, they did note that, based on assumptions their research made, there were "expected future increases" in greenhouse gases based on rocket emissions as well.[83] Greenhouse gases ("GHG") include water vapor, CO_2, and other gases that prevent heat from escaping from the atmosphere, causing the global temperature to rise.[84]

The study also showed the global impact that rocket launch emissions would have on ozone distribution, which would change up to 6%.[85] Ozone layer loss is caused by water as well as soot.[86] With the amount of expected increase in unregulated rocket activity, ozone depletion could reach precarious conditions by around 2050.[87]

Commercial space enterprise Virgin Galactic has estimated that the per-passenger CO_2 emissions of a spaceflight will be equivalent to about 60% of the per-passenger round-trip commercial flight from London to New York.[88] However, this does not take into account that there are other emissions of environmental concern (i.e. black carbon), or that a commercial flight holds significantly more passengers than a spaceflight currently does.[89] Because Virgin Galactic did not discuss how it reached this statistic, it is likely that rocket emissions are greater than the company represents.

Emissions from rocket launches and spaceflight are inevitable, but the launch complexes from which rockets takeoff have their own sources of pollution, which may also pose a need for regulation.[90]

D. Environmental Impacts of Airplane Emissions

Airplanes generate emissions in the form of CO_2, water vapor, particulate matter, and other pollutants.[91] Aircraft[92] comprise 12% of GHG emissions from the U.S. transportation sector and 3% of total U.S. GHG emissions.[93] To date, there is still no clear, direct regulation of aircraft GHG emissions.[94] The next section, however, will describe how the EPA can regulate other pollutants emitted by airplanes.

III. The Legal Framework of Aircraft and Rocket Emission Regulation

Space law, like the law of the sea, falls within the common heritage of mankind—a principle that deems outer space to be shared property of all countries.[95] However, given that rockets are launching from, and emitting air pollutants within, the borders of the U.S., this Note will assume that environmental regulation of the U.S.'s private space industry will be subject to EPA jurisdiction and that the Clean Air Act will apply, as will be discussed in Part III.

A. The Clean Air Act

The Clean Air Act ("CAA") was the first federal law in the U.S. to control air pollution and, through its iterations, is extremely comprehensive.[96] Congress's intent in creating the statute was to prevent air pollution,[97] and as experts learned more about air pollution's environmental and health effects, Congress passed subsequent amendments to update and modernize the law.

The CAA directs the EPA to control air pollution through the regulation of ambient air.[98] Regulation of ambient air has the goal of protecting and enhancing air quality to promote public health and welfare.[99] The EPA does so through several

82. Press Release, Am. Geophysical Union, Soot From Space Tourism Could Spur Climate Change (Oct. 22, 2010), https://news.agu.org/press-release/soot-from-space-tourism-rockets-could-spur-climate-change/; *see* Ross et al., *supra* note 3.
83. Ross et al., *supra* note 3.
84. *Overview of Greenhouse Gases*, U.S. Envtl. Protection Agency, https://www.epa.gov/ghgemissions/overview-greenhouse-gases [https://perma.cc/8XNK-CM9R] (last visited Apr. 9, 2017) (noting that carbon dioxide is a GHG); *see also Climate Roles of H_2O, CH_4, and CO*, NASA Jet Propulsion Laboratory, https://tes.jpl.nasa.gov/mission/climateroles/ [https://perma.cc/7ZEU-9UD8] (last visited Apr. 9, 2017) (noting that water vapor is the most important GHG).
85. This percentage is limited to the "high-mid latitudes and polar regions" whereas the impact on other parts of the globe would not be as significant. Ross et al., *supra* note 3, at 5.
86. *See id.* at 8; M.N. Ross et al., *Ozone Depletion Caused by NO and H_2O Emissions From Hydrazine-Fueled Rockets*, J. Geophysical Res. (Nov. 2004).
87. *See Rocket Launches May Need Regulation to Prevent Ozone Depletion, Says New Study*, CU Boulder Today (Mar. 31, 2009), https://www.colorado.edu/today/2009/03/31/rocket-launches-may-need-regulation-prevent-ozone-depletion-says-new-study.
88. Leo Hickman, *It's Not Rocket Science: Leaving the Planet Costs the Earth*, The Guardian (May 11, 2009), https://www.theguardian.com/environment/blog/2009/may/11/travel-and-transport-carbon-emissions.
89. *See generally id.*
90. The launch sites themselves are sources of environmental havoc, causing air pollution that leads to area water contamination and unhealthy local animals. For example, scientists note that rockets launching from NASA's Kennedy Space Center in Florida emit "thousands of pounds of metals and other chemicals into the air." They settle into the water and cause liver damage in crocodiles that live near the launch complex due to higher rates of iron and other metals in their environments. Lindsey Konkel, *NASA Shuttle Launches Leave Legacy of Pollution in Florida Refuge*, MintPress News (May 20, 2014), http://www.mintpressnews.com/nasa-shuttle-launches-leave-legacy-of-pollution-in-florida-refuge/191127/. Additionally, launches have contaminated the soil beneath the Kennedy Space Center launch pads with a chemical used to clean rocket engines. Despite stopping the practice in the 1970s, NASA would dump the contaminant directly into the ground. More recently, however, the ground beneath the launch pad is laden with other solvents, flame retardants, and metals, which NASA has made efforts to eradicate. Rebecca Boyle, *With Shuttle Launches Over, Cleanup of Launch Zone Chemicals Will Take Decades and Millions of Dollars,* Popular Sci. (Aug. 1, 2011), http://www.popsci.com/technology/article/2011-08/space-shuttles-and-rocket-launches-caused-1-billion-toxic-pollution.
91. Fed. Aviation Admin. Office of Env't and Energy, Aviation Emissions, Impacts & Mitigation: A Primer 2 (2015), https://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/Primer_Jan2015.pdf.
92. This statistic only accounts for the current definition of aircraft, which excludes rockets.
93. *Regulations for Greenhouse Gas Emissions From Aircraft*, U.S. Envtl. Protection Agency, https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-aircraft [https://perma.cc/LKH5-SRKY] (last visited Apr. 8, 2017).
94. *Id.*
95. *See* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies art. 1–2, Dec. 5, 1979, 18 U.S.T. 2410, 610 U.N.T.S. 205.
96. *Evolution of the Clean Air Act*, U.S. Envtl. Protection Agency, https://www.epa.gov/clean-air-act-overview/evolution-clean-air-act [https://perma.cc/JLV5-MNLB] (last visited Apr. 9, 2017).
97. *See generally* 42 U.S.C. § 7401 (2012).
98. *Id.*
99. 42 U.S.C. § 7401(b)(1).

approaches. Among others, these include the regulation of criteria pollutants, hazardous air pollutants, and GHG emissions through mobile sources and stationary sources.

The EPA regulates six types of criteria pollutants, one of which is particulate matter.[100] Particulate matter includes soot and other small suspended particles in the air. Hazardous air pollutants are any air pollutant which is not considered a criteria pollutant.[101]

The CAA largely covers two categories of emitters: mobile sources and stationary sources.[102] Title II of the CAA governs mobile sources. The CAA defines mobile sources as on-road motor vehicle engines and off-road vehicles and engines, which include cars, trucks, buses, recreational vehicles and engines, generators, farm and construction machines, lawn and garden equipment, marine engines and locomotives, aircraft, and composition of the fuel used to operate mobile sources.[103]

The CAA defines stationary sources as "facilities such as factories and chemical plants, which must install pollution control equipment" and cap their emissions.[104] Title V of the CAA further specifies regulations for "major" stationary sources, which are "any stationary source (or any group of stationary sources that are located on one or more contiguous or adjacent properties, and are under common control of the same person (or persons under common control)) belonging to a single major industrial grouping."[105] Major sources require permits under Title V of the CAA, which more stringently limits emissions.[106] Area sources are all stationary sources which are not deemed to be major sources.[107] The Title V permitting requirements mandate all major sources to be granted permits before operation.[108] A major source is a source that (1) companies or agencies can group together "contiguous or adjacent" stationary sources if they are under the same "Major Group," and (2) discharges at least ten tons of emissions per year of a single hazardous air pollutant, or 100 tons per year for any air pollutant.[109] The regulation includes a list of potential major stationary sources but also adds a catch-all "any other stationary source category. Which . . . is being regulated under section 111 or 112 of the Act."[110]

New Source Performance Standards ("NSPS") govern the amount of emissions that new stationary sources may generate.[111] NSPS set the benchmark for certain emissions, including particulate matter.[112] Black carbon, which is a component of particulate matter, is regulated by NSPS.[113]

B. Clean Air Act Provisions Regarding Aircraft

Part B of Title II deals entirely and exclusively with aircraft emissions. The EPA's authority to regulate aircraft emissions comes from section 231(a)(2)(A), which states, "The Administrator shall, from time to time, issue proposed emissions standards applicable to the emission of any air pollutant from any class or classes of aircraft engines which in his judgment causes, or contributes to, air pollution which may reasonably be anticipated to endanger public health or welfare."[114] The definition of terms in this section of the CAA come from section 101 of the Federal Aviation Act of 1958 ("Aviation Act").[115] In the Aviation Act, "Aircraft means a device that is used or intended to be used for flight in the air."[116] The same section of the Act states that "[r]ocket means an aircraft propelled by ejected expanding gases generated in the engine from self-contained propellants and not dependent on the intake of outside substances. It includes any part which becomes separated during the operation."[117]

Aircraft emit particulate matter comprised of black carbon, also found in soot from rocket exhausts, as well as GHG emissions. To mitigate the damages of black carbon, the EPA has a number of programs and regulations in place, including the reduction of diesel fuel.[118] Black carbon is a "significant portion of particulate matter . . . which is an air pollutant."[119]

Although the EPA has implemented programs to limit emissions of black soot, whether the CAA provides the EPA with the authority to regulate GHG emissions has been a topic of intense debate. Based on the Supreme Court's decision in *Massachusetts v. EPA*, the Court held that the CAA's definition of pollutants does include GHGs, providing the EPA with the authority to regulate aircraft GHG emissions.[120] It was not until the end of 2016 that the EPA finalized its findings that certain aircraft engines contribute to climate change under section 231(a) of the CAA.[121] The EPA is preparing for a future rulemaking to implement GHG standards for aviation.[122] To do this, EPA must follow CAA standards to measure ninety percent of the aircraft's emissions and their effect up to 3,000 feet above Earth's surface.[123]

100. Criteria pollutants are a subset of hazardous air pollutants that are extremely prevalent in the air. *See* 42 U.S.C. § 7408.
101. 42 U.S.C. § 7412.
102. 42 U.S.C. §§ 7401 et seq. (2012).
103. *See* 42 U.S.C. § 7521 (2012).
104. *Air Enforcement*, U.S. Envtl. Protection Agency, https://www.epa.gov/enforcement/air-enforcement [https://perma.cc/9RN2-YFVV] (last visited Apr. 8, 2017); *see* § 7411.
105. 40 C.F.R. § 70.2 (2016).
106. *See* 42 U.S.C. § 7479(1) (2012).
107. *Id.* at § 7412(a)(2).
108. *Id.* at § 7661.
109. 40 C.F.R. § 70.2 (2016).
110. *Id.*
111. *See generally* 40 C.F.R. §§ 60.1–60.6.
112. *See* 40 C.F.R. § 60; *see also* 40 C.F.R. § 60.42.
113. *Air Enforcement*, *supra* note 104 ("[n]ewly constructed sources . . . must follow these standards to control excess emissions of . . . particulate matter.").
114. 42 U.S.C. § 7571(a)(2)(A).
115. 40 C.F.R. § 87.1; 14 C.F.R. § 1.1 (2016).
116. 14 C.F.R. § 1.1.
117. *Id.*
118. *See generally Mitigating Black Carbon*, U.S. Envtl. Protection Agency, https://www3.epa.gov/airquality/blackcarbon/mitigation.html [https://perma.cc/47RX-6GDD] (last visited Jan. 24, 2017).
119. *Black Carbon Research*, U.S. Envtl. Protection Agency, https://www.epa.gov/air-research/black-carbon-research (last visited Jan. 24, 2017).
120. Nathan Richardson, *Aviation, Carbon, and the Clean Air Act* (July 2012), Resources for the Future 7, http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-12-22.pdf (citing *Massachusetts v. EPA*, 549 U.S. 497, 528–29 (2007)).
121. U.S. Envtl. Protection Agency, *supra* note 93.
122. *Id.*
123. Fed. Aviation Admin. Office of Env't and Energy, *supra* note 91.

Specifically related to the CAA's jurisdiction over rockets, the EPA's Office of Quality Planning and Standards issued a policy determination letter in January 2000. The letter responded to a corporation's question about hazardous air pollutant emissions from rocket engine testing launches.[124] In little more than a page, the EPA deemed rocket launches to be mobile source activities, therefore exempting the company from acquiring a Title V permit.[125] It also suggests that if a rocket were attached to a fixed test stand, it may be considered a stationary source.[126] However, the EPA did not have to reach that issue, so it did not provide a conclusion.[127]

IV. The Legality of Regulating Rocket Emissions

The issue presented is whether the CAA in its current form regulates rockets and launch systems and, if so, how. This section will focus on "source" regulations. The EPA can regulate rocket emissions in a variety of ways under the CAA. The current structure of the CAA should govern rockets because it regulates emissions from both mobile and stationary sources. Based on the EPA policy determination letter and the similarities of rockets to currently-regulated entities such as aircraft, rockets should fall within the CAA's purview of mobile sources.[128] However, given the nature of launch systems as a whole, there are strong arguments for the EPA to regulate launch systems as stationary sources. Because neither the mobile source nor the stationary source definitions align with rocket launch systems perfectly, the EPA should create a nuanced approach by regulating rockets through a hybrid mobile-stationary source regulatory scheme. This section will present the two alternatives to the proposed solution.

Rockets generate emissions including black carbon, CO_2, and other substances, depending on the rocket's propellant and engine type.[129] These emissions can be categorized in various ways within the CAA, specifically as criteria pollutants, greenhouse gases, or hazardous air pollutants.[130] But regardless of which type of pollutant the emissions are termed, the law has accounted for all possible components of rocket emissions, and therefore, the EPA has a duty to regulate rocket engines.[131]

The next question posed is whether a rocket should be considered a mobile or stationary source under the CAA in order to more accurately regulate its emissions. Based on the response in its policy determination letter, the EPA deems rockets as mobile sources in a conclusory manner, failing to take into consideration the nature of launch systems as a whole. With the inevitable growth of private space companies, the EPA can expect to receive many more questions from industry on this topic,[132] and answering it before the need is pressing is imperative to stymie environmental aggravation.

A. The Case for Mobile Sources

The intention of the CAA was to control air pollution in the U.S., and the most energy expended in the duration of a rocket's flightpath is at launch,[133] which occurs within U.S. airspace. The most energy is expended at launch, not once it has reached outer space, which is international or common property. The legislative history of the statute elucidates the mission of passing this law, which was an effort to maintain public health as well as environmental health.[134] Therefore, if most of the pollution discharged from a rocket occurs when it is still in the air (i.e. before it is in space), the intention of the statute's authors would be that those emissions would be covered under the CAA

124. Letter from John S. Seitz, *supra* note 4.
125. *Id.*
126. *See id.*
127. *See id.*
128. *See id.*
129. *See* Toohey, *supra* note 1.
130. *Criteria Air Pollutants*, U.S. Envtl. Protection Agency, https://www.epa.gov/criteria-air-pollutants [https://perma.cc/SJU4-XE3U] (last visited Feb 26, 2018); *Overview of Greenhouse Gas Emissions*, U.S. Envtl. Protection Agency, https://www.epa.gov/ghgemissions/overview-greenhous-gases [https://perma.cc/8YKR-23P9] (last visited Feb. 26, 2018); *What are Hazardous Air Pollutants?*, U.S. Envtl. Protection Agency, https://www.epa.gov/haps/what-are-hazardous-air-pollutants [https://perma.cc/49SL-L259] (last visited Feb. 26, 2018).
131. The three types of possible pollutant rockets may emit are criteria pollutants, greenhouse gases, or hazardous air pollutants.

First, because black carbon has a "strong warming potential," it is imperative that the EPA takes steps to prevent additional damage from new sources like the private space industry so that it does not contribute to global warming. *Mitigating Black Carbon, supra* note 118. Emissions of certain rockets contain black carbon, a component of particulate matter, and the EPA has the authority to regulate particulate matter under its jurisdiction of criteria pollutants. Therefore, the EPA has a duty to and should regulate rocket engines that emit soot as a criteria pollutant. *Particulate Matter (PM) Basics*, U.S. Envtl. Protection Agency, https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#reducing [https://perma.cc/B6AE-W87A] (last visited May 18, 2018).

Second, rocket emissions contain carbon dioxide and water vapor, both GHGs. *Overview of Greenhouse Gases*, U.S. Envtl. Protection Agency, https://www.epa.gov/ghgemissions/overview-greenhouse-gases (last visited Apr. 9, 2017) (noting that carbon dioxide is a GHG); *see also Climate Roles of H_2O, CH_4, and CO*, NASA Jet Propulsion Laboratory, https://tes.jpl.nasa.gov/mission/climateroles/ (last visited Apr. 9, 2017) (noting that water vapor is the most important GHG). The next section will describe why rockets are considered aircraft under the CAA. *See infra* note 116. Considering any future EPA rulemaking which will finalize regulations of GHG emissions from aircraft, rockets emissions of GHGs should be covered by the CAA, so the EPA should regulate those rocket engines which emit carbon dioxide and water vapor. *Regulations for Greenhouse Gas Emissions from Aircraft*, U.S. Envtl. Protection Agency, https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-aircraft (last visited May 16, 2018).

Third, some rockets' emissions contain pollutants other than particulate matter and greenhouse gases. *See, e.g.*, *National Emission Standards for Hazardous Air Pollutants (NESHAP)*, U.S. Envtl. Protection Agency, https://www.epa.gov/stationary-sources-air-pollution/national-emission-standards-hazardous-air-pollutants-neshap-9 (last visited May 16, 2018) (hereinafter *NESHAP*); *see also* Nina Rastogi, *Dirty Rockets*, Slate (Nov. 17, 2009), http://www.slate.com/articles/health_and_science/the_green_lantern/2009/11/dirty_rockets.html. Although soot is a common emission, and other rocket emissions such as CO_2 and water vapor are categorized as GHGs, if a rocket engine is not the type which emits black carbon, the rocket's harmful emissions will fall within the catch-all definition of hazardous air pollutants. *NESHAP.*

Regardless of which definition of pollutant a specific launch system's emissions fall under, the CAA has comprehensive jurisdiction over the pollutants that any rocket will emit.
132. *See generally* Federal Aviation Admin., *supra* note 2, at 2.
133. *See* Pettit, *supra* note 68.
134. *See generally Implementation and Enforcement of Clean Air Act*, *Hearings Before the Subcomm. on Oversight and Investigations of the H. Commerce Comm.*, 104th Cong. 3 (1995).

as aircraft as well. The EPA can choose to regulate aircraft engine emissions as it sees fit, and should include rockets in its decision to do so.[135]

Moreover, the EPA should regulate rockets as mobile sources because of their inherent purpose: to move. A mobile source, governed by Title II of the CAA, can be either an on-road or non-road vehicle.[136] Because rockets are not on-road sources, (i.e. motor vehicles), Title II is applicable based on the broader scope of non-road vehicles. One category of such non-road vehicles is aircraft.[137]

The CAA allows for the EPA's sweeping authority of aircraft engines but does not elucidate what the parameters of aircraft are. In the Federal Aviation Act, from which the EPA takes its definition, aircraft is defined as "a device that is used or intended to be used for flight in the air."[138] Rockets must traverse the air to reach space.[139] Using that definition, the EPA should currently consider rockets mobile sources under the CAA, specifically aircraft, based on their flight through the air to reach the stratosphere and beyond. Additionally, in light of the construction of the statute, "used or intended to be used" is almost a catch-all term and should include any vehicle in the air.[140] Furthermore, EPA regulations point specifically to the Federal Aviation Act for its own definition of aircraft. Although neither the CAA nor EPA regulations mention rockets, the same section of the Federal Aviation Act specifically defines rockets to mean "an aircraft." Therefore, the EPA should defer to the FAA's inclusion of rocket within the category of aircraft and regulate rockets as mobile sources under the CAA.

The statute also implicates the futurity of aircraft. Using the language "intended to be used" puts a prospective lens on the applicability of the statute.[141] Because of the future-looking construction of the definition, including inventions and designs without the requirement for actual implementation, the statute includes technologies that may not yet be created, but still have the purpose of being a vehicle in the air. There are several types of rockets in existence today, some of which are new designs (like the reusable Falcon 9), and even more are awaiting development in this nascent commercial space industry.[142] Therefore, the EPA should regulate rockets not just currently in use but also those that are in preliminary stages of development that could one day be deployed.

Rockets should be viewed as a mobile source because of their inherent nature: they are built to move, similar to airplanes, commercial trucks, and buses. Like airplanes, rockets are transportation devices, either for people or for cargo. Rockets are similar to commercial trucks and buses, which are considered mobile sources under the CAA, because they emit particulate matter, including smoke and soot, while in transit.[143] Since a rocket emits particulate matter while in transit, it can also be deemed a mobile source.[144] Additionally, given that the EPA uses an altitude measurement of 3,000 feet[145] to evaluate air quality impact under the CAA, this metric seems appropriate to determine whether a rocket is mobile or stationary. Because the most energy during a rocket's journey is expended during the launch process,[146] the 3,000-foot height standard is important because a rocket would be responsible for a vast amount of particulate matter in the air given its behavior up to that altitude, at a similar height to an airplane.

Based on examples of specific commercial rockets, it is clear that rockets are aircraft and should be regulated as such. Virgin Galactic's SpaceShipTwo does not utilize a fixed service structure, but rather is attached to an already-regulated aircraft.[147] This spaceplane can clearly meet the definition of aircraft in the CAA, so the EPA should regulate its harmful emissions.

Thus, the EPA's policy determination holds true: a rocket should be considered a mobile source. Rockets should be included as another form of aircraft, as their similarities were described above. They would therefore be subject to the same emissions standards as aviation. Though aircraft do not have to undergo the stringent Title V permitting application requirements that stationary sources do, there is a certification and compliance process for which the EPA has oversight and will enforce.[148]

If the EPA does not choose to prospectively enforce rocket emissions, citizen suits may be filed against private space companies based on their understanding of the CAA's jurisdiction, alleging that the EPA has shirked its duty. Litigation will then have to make its way through the courts while additional private sector rocket emissions continue to amass. Because rockets fit within the CAA's definition of aircraft, the EPA should affirmatively rather than defensively enforce solely off of this basis, and the agency could avoid litigation costs.

The next section will explore a potential counterargument: whether to regulate launch systems as a whole, including rockets, as stationary sources.

B. Considering the Alternative: Stationary Sources

A potentially strong counterargument is that the EPA made a rash determination that rockets are mobile sources. Its letter did not account for the fact that rockets are affixed

135. *See* John Krois, *Onwards and Upwards: Space Tourism's Climate Costs and Solutions*, Field Reports, Columbia Enviro. L. (Nov. 18 2011), http://www.columbiaenvironmentallaw.org/onwards-and-upwards-space-tourisms-climate-costs-and-solutions-2/.
136. *See generally* 42 U.S.C. § 7521 (2012).
137. 42 U.S.C. § 7571(a)(2)(A).
138. 14 C.F.R. § 1.1 (2016).
139. Because neither the CAA nor the Federal Aviation Act defines "air," this analysis assumes that air is considered the layers of the atmosphere from the Earth's surface to the stratosphere.
140. 14 C.F.R. § 1.1.
141. *Id.*
142. *See, e.g.*, Kluger, *supra* note 29.
143. *See Particle Pollution*, Ctr. for Disease Control and Prevention, https://www.cdc.gov/air/particulate_matter.html [https://perma.cc/7A9J-9RWR] (last visited May 16, 2018).
144. *See* Toohey, *supra* note 1 (discussing particles or particulate matters emitted by rockets, impacting ozone and climate).
145. Fed. Aviation Admin. Office of Env't and Energy, *supra* note 91.
146. Pettit, *supra* note 68.
147. Virgin Atlantic, *supra* note 23.
148. *Compliance Reporting for Aircraft*, U.S. Envtl. Protection Agency, https://www.epa.gov/vehicle-and-engine-certification/compliance-reporting-aircraft (last visited Jan. 24, 2017).

to launch pads and generally fastened to additional fixed service structures or umbilical towers in addition to being a part of a larger launch facilities.[149] Further, the letter indicates that the specific rocket in question was not attached to a fixed test stand, so it would not be a stationary source.[150] But the EPA did not address whether those rockets which *are* attached to fixed test stands (or stationary service structures, or other fixed infrastructure) may be considered stationary sources.[151] Additionally, because the letter only addressed one particular type of rocket, the subject of the EPA's analysis for the larger determination of rockets was too narrow and limited.[152] This section will thus address why the implication of the EPA's letter may be correct, but why it is likely not, and how the EPA should proceed with regulation of rockets and launch systems.

A stationary source, as defined in Title I of the CAA, is "any building, structure, facility, or installation which emits or may emit any air pollutant."[153] Rockets are connected to their launch facilities not just during assembly but also after ignition of their engines.[154] Therefore, launch systems as a whole, including rockets, could be governed by the CAA's definition of stationary sources as a "structure."

Black carbon emissions begin, as evidenced by the plumes of smoke that collect before liftoff, while the rocket is still affixed to the ground, connected to the fixed service structure and umbilical structure.[155] Notably, because the most energy expended during a rocket's entire voyage to space is to deploy it off of the ground, its state at that time—stationary, not mobile—is vital.[156] Rockets spend the majority of their lifespans not being used as a mobile transportation device but rather on the ground, immobile, or attached to a structure on the ground (albeit not producing discharge).

Some may argue that launch systems should be considered as one entity, including the rocket and its emissions, and be categorized as a stationary source because of their similarities with factories. Airplanes travel through air, and rockets were made to travel through air and space, with only about eight and a half minutes of their long journeys spent in the air, until they reach outer space.[157] Airplanes are intended to conduct entire trips in the air, but rockets begin their flight on the ground and end trips in space with only a minimal percentage of its transit in the air.[158]

Conversely, a rocket connected to its launch site has more similarities to a factory than to an airplane. Once the rocket is assembled onto the launch pad, the emissions from the service structure, the umbilical structure, and the rocket itself function like a factory. The launch system is affixed to a specific location on the ground, and people can enter and exit the rocket through the service structure as if it were a building, not a vehicle. Additionally, the majority of a rocket's life while in use will be its assembly and deployment on the ground like a static building rather than in a state of movement. Given the physical launch site as well as the negligible period of time a rocket in motion in the atmosphere, a launch system should be considered a stationary source.[159] In space, emissions are not destructive to public and environmental health the same way they are when launch systems are stationary structures.

The following considerations should occur when a determination has been made as to which type of source should be applied to a particular launch system. If a launch system is considered a stationary source, it may require a permit under Title V of the CAA.[160] Many launch systems may be deemed as major sources because they may have several launch facilities at one launch complex,[161] which would compel them to count the activities from all of the launch pads, including the buildings in which the operational work and interim repair are conducted. Launch systems would also be considered major sources because their air emissions would include not just lift-off but the assembly and maintenance before the launch.[162] For instance, based on the pollutants that Kennedy Space Center is emitting, the Florida state government has committed to regulating air emissions of those pollutants.[163] This is an indication that the pollutants must be significant enough that the State chooses not to ignore its potentially harmful results.

Even if a launch system is not a major stationary source, it will likely still fall within the definition of an area source, should the launch system be considered one entity.[164] If so, certain non-major sources are subject to Title V permitting depending on the character of their facility.[165] One of the emissions of these non-major sources is the production of black carbon.[166] If launch systems were to be regulated as an entity with the rocket attached, it is possible that the amount of their black carbon emissions would be tantamount to these pollutants and would require a Title V permit, regardless of how much tonnage of pollutants were emitted. If the launch

149. Letter from John S. Seitz, *supra* note 4; *see, e.g.*, *Space Shuttle: Launch Complex 39*, Nat'l Aeronautics & Space Admin., https://www.nasa.gov/mission_pages/shuttle/launch/launch-complex39-toc.html [https://perma.cc/45ZJ-H525] (last visited Jan. 24, 2017); *Space Shuttle: Fixed Service Structure*, Nat'l Aeronautics & Space Admin., https://www.nasa.gov/mission_pages/shuttle/launch/fixed-service-structure.html [https://perma.cc/98MR-25N7] (last visited Jan. 24, 2017).
150. Letter from John S. Seitz, *supra* note 4.
151. *See id.*
152. *See id.*
153. 42 U.S.C. § 7411(a)(3) (2012).
154. Portree, *supra* note 60.
155. *See id.*
156. *See* Pettit, *supra* note 68.
157. *See* Mike Leinbach, *Ask the Mission Team—Question and Answer Session*, Nat'l Aeronautics & Space Admin. (Nov. 23, 2007), https://www.nasa.gov/mission_pages/shuttle/shuttlemissions/sts121/launch/qa-leinbach.html [https://perma.cc/A33N-LYAG].
158. *See id.*
159. *See id.*
160. 40 C.F.R. § 70.2 (2016).
161. *Id.* (defining a "Major Source" as ". . . any group of stationary sources located on one or more contiguous or adjacent properties . . .").
162. *Id.*
163. *See Environmental Program at KSC: Permitting & Compliance—Overview*, John F. Kennedy Space Ctr., https://environmental.ksc.nasa.gov/PermittingCompliance/PermittingComplianceOverview (last visited Jan. 23, 2017).
164. *Area Source Standards*, U.S. Envtl. Protection Agency, https://www3.epa.gov/airtoxics/area/arearules.html (last visited Mar. 15, 2018).
165. *See Who Has to Obtain a Title V Permit?*, U.S. Envtl. Protection Agency, https://www.epa.gov/title-v-operating-permits/who-has-obtain-title-v-permit (last visited Jan. 23, 2017).
166. *Id.*

system is an area source but not emitting black carbon, it will be governed by NSPS.[167]

The EPA policy determination letter distinguishes between launch facilities that have rocket engines that are launching from fixed test stands versus those that are "directed through an acoustical energy diversion structure (flame trench) during the early stages of rocket liftoff," which the EPA concluded was a mobile source.[168] Extrapolating from the EPA's analysis, it would logically follow that those rocket launch facilities that *do* include fixed stands would indeed be considered major stationary sources that would require a Title V permit if their emissions meet the minimum requirement.

This counterargument framing launch systems as stationary sources likely fails because rockets and airplanes are analogous, so the most apt analogy that can be made for launch systems as stationary sources is to compare them to airports, as both launch systems and airports serve as docking stations for their respective vehicles. Airplanes, however, are usually connected to the larger airport facility through jet bridges, or passenger boarding bridges.[169] Jet bridges, like gantries or umbilical towers, are movable portals that connect the vehicle to a service structure. Yet airplanes are not considered in the emissions of airports as a whole, and though airports have stationary sources within them (e.g. fuel tanks), airports are not considered stationary sources under the CAA.[170] Therefore, rocket emissions cannot be considered as part of launch system's emissions, and the whole structure's emissions may not be regulated together as a stationary source under the CAA.

C. *Mobile and Stationary Sources Working in Tandem*

As illustrated by the above analyses, categorizing rockets as mobile sources is too limited given their unique and idiosyncratic relationship to launch systems. Furthermore, categorizing launch systems as stationary sources ignores the rocket's true vehicular nature. Even if rockets are regulated as mobile sources, the counterargument may still hold because the two regulatory schemes are focused on different subsets of the same category: rockets which launch on their own versus rockets which launch as part of a system. Therefore, launch systems where a rocket is affixed to a stationary structure can still be regulated as stationary sources. In fact, having both regulatory schemes may allow for more stringent regulation of the space industry emission and could bolster the argument overall. Because no part of the infrastructure would be exempt from regulation, there would be greater certainty for industry, and ultimately better control of pollution impacting the environment.

Emissions from the space industry were not a concern during the Space Race or the environmental revolution, despite the overlap of the two eras during their most intense periods.[171] But now, given the bright, reignited future of the space industry, the EPA should exercise its authority to regulate rockets as mobile sources, following the existing emissions standards set for aircraft, and launch systems as stationary sources, following Title V permits for major sources and the NSPS for area sources. The next section will determine how Congress could amend the CAA to clarify its jurisdiction over emissions of rocket launch systems.

V. Proposed Solution to Clarify the EPA's Jurisdiction of Rocket Emissions

This Note's proposed solution to remedy exacerbation of climate change and stratospheric ozone depletion is for the EPA to affirmatively regulate rocket emissions through a hybrid mobile-stationary source regulatory scheme.

This solution assumes that rockets will utilize stationary structures on launch sites, such as the gantries described in Section I(B). If a rocket launches on its own, then it would be simply regulated as a mobile source under the EPA's jurisdiction of aircraft. Those rockets would not require the additional regulation under the hybrid mobile-stationary model. That said, the EPA should designate rockets as mobile sources as well as clarifying that their launch facilities should be regulated as stationary sources.

This solution can be enacted through legislative or regulatory action. The simpler path forward would be through agency regulation, given the relative ease of navigating administrative bureaucracy as compared to current congressional gridlock. As such, all it would take is for the EPA to undertake a notice and comment rulemaking procedure to promulgate a rule to regulate rocket launch systems as hybrid mobile-stationary sources under the CAA.

In practice, it would allow the EPA to consider the components of launch systems both separately and together for the purposes of measuring emissions and enforcing limits. The components would be considered separately because the rocket component of the launch system would still be regulated as a mobile source. However, the rocket and launch facility would be considered together to allow for the launch system to be considered a single entity as a stationary source. Therefore, the rocket's discharge while affixed to the launch site would count toward the launch system's emissions.

Should the EPA Administrator choose not to promulgate rules through her authority under the CAA, a congressional

167. *New Source Performance Standards and Permitting Requirements*, U.S. Envtl. Protection Agency, https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-industry/new-source-performance-standards-and (last visited May 16, 2018).

168. Letter from John S. Seitz, *supra* note 4.

169. X-Treme Sports Ent., *How the Movable Jet Bridge Connects Passenger Termination to an Airplane*, YouTube (Mar. 18, 2017), https://www.youtube.com/watch?v=qym9FpMAMt8.

170. *See* Konstantinos Zografos et al., Modelling and Managing Airport Performance § 6.2.4.2 (2013).

171. *See, e.g.*, *Evolution of the Clean Air Act*, *supra* note 96 (indicating the Clean Air Act's passage date to be in 1963 and first amendments to be passed in 1970); *see also NASA Glenn's Historical Timeline*, Nat'l Aeronautics & Space Admin. (Apr. 7, 2008), https://www.nasa.gov/centers/glenn/about/history/timeline.html (last updated July 31, 2015) (stating the NASA founding date to be in 1958 and the first moon landing to be in 1969).

amendment to the CAA rather than an administrative band-aid would ensure that future administrations would not be able to easily dismantle the regulatory scheme. Because industry is relying on regulations for clarification of their path forward, it is helpful to prevent an unraveling of law and policy to ensure the private sector can rely on the government's parameters rather than be preempted by them. The private sector would likely be a focus and, optimistically, boom under such administrations. For this reason, it is more necessary than ever to safeguard environmental protections from being disassembled, or at least slow their demise.

In order to regulate rocket launch systems as a hybrid mobile-stationary source, the EPA must first clarify its jurisdiction of rockets as both mobile sources and stationary sources. Congress can bolster the EPA's jurisdiction of regulating rockets as mobile sources by explicitly including rockets within Title II, Section B of the CAA, governing aircraft emission standards. Given that some rockets are hybrid aircraft, such as the Virgin SpaceShipTwo, a viable solution would be to ensure that rocket engines are explicitly governed by the CAA's mobile source category within the Title II, Section B's aircraft emission standards language. Congress should also include launch systems under the CAA's definition of stationary sources so that should they discharge enough pollutants, the EPA could also regulate them as major stationary sources. Practically, this would allow the EPA to regulate a launch system as one entity as it would allow the rocket and launch site to be viewed and regulated as contiguous or adjacent sources.

VI. Conclusion

The rise of the commercial space industry will pose additional, significant challenges to the fight against climate change and ozone depletion, based on scientific evidence regarding the detrimental effects of black carbon, water vapor, and CO_2 emissions from rocket launches. To mitigate this inevitable damage, the EPA should begin regulating rocket emissions through a hybrid model of rocket launch systems as both mobile sources and stationary sources. The EPA's authority to regulate rockets as aircraft under mobile sources is already inherent in the current language of the CAA. In order to clarify and bolster its jurisdiction, legislative action or agency regulation must follow. Because of its efficiency as compared to legislation, the EPA should promulgate a rule to determine its jurisdiction over rocket emissions as a hybrid mobile-stationary source scheme, based upon a combination of its regulation of rockets as mobile sources and launch systems as stationary sources. Alternatively, Congress should amend the organic statute of its power to control air pollution by first, explicitly including rockets in its definition of mobile sources, and second, including rocket launch systems in its definition of stationary sources.

With private spaceflight companies planning to launch vehicles with test astronauts by late 2018 and a goal to have a colony on Mars within 15 years, the future is here.[172] However, in order to continue journeying into the final frontier, this place from which we launch—our own planet, mother Earth—must stay healthy enough for research to continue and exploration to progress. Even as we leave to discover new worlds, we must also have a home to return to.

172. *See* Stefanie Waldek, *How to Become a Space Tourist: 8 Companies (Almost) Ready to Launch*, Popular Science (last visited May 16, 2018); *see generally* Todd Jaquit, *Predicting 2017: A Look at Humanity's Future in Space*, Futurism (Jan. 10, 2017), https://futurism.com/predicting-2017-a-look-at-humanitys-future-in-space/; Musk, *supra* note 28.