U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE

The Commercial Space Launch Industry: Small Satellite Opportunities and Challenges

HEARING CHARTER

Tuesday, April 19, 2016
10:00 a.m.
2318 Rayburn House Office Building

Purpose

The Subcommittee on Space will hold a hearing titled *The Commercial Space Launch Industry: Small Satellite Opportunities and Challenges* on Tuesday, April 19, 2016, at 10:00 a.m. in Room 2318 Rayburn House Office Building. The purpose of this hearing is to examine the current state of the small satellite commercial launch industry.

Witnesses

- **Mr. Elliot Pulham,** Chief Executive Officer, Space Foundation
- **Mr. Eric Stallmer,** President, Commercial Spaceflight Federation (CSF)

Background

Origins of the U.S. Commercial Space Launch Industry[1]

> *Between 1963 and 1982, U.S. expendable launch vehicle (ELV) manufacturers produced vehicles only under contract to the National Aeronautics and Space Administration (NASA) or the Department of Defense (DOD). In the early 1970s, when private companies and foreign governments purchased communications satellites, they had to contract with NASA to launch their payloads. Through NASA, launches could be procured on any one of four ELVs: Titan, built by Martin Marietta; Atlas, built by General Dynamics; Delta, built by McDonnell Douglas; and Scout, built by LTV Aerospace Corporation. NASA would purchase a launch vehicle through traditional government procurement practices, and the launch would be conducted by a private-sector contractor under NASA supervision. The U.S. government essentially served as the only provider of space launch services to the Western world. Seeing an opportunity to provide launch services, the European Space Agency developed its own ELV, Ariane, which became the first competitor to NASA for commercial launches. The first Ariane*

[1] *Origins of the Commercial Space Industry*. It can be accessed at: http://www.faa.gov/about/history/milestones/media/Commercial_Space_Industry.pdf (Last Accessed on March 31st, 2016).

launch occurred in 1979, and in 1984, a private company, Arianespace, took over commercial operation of the vehicle.[2]

In the late 1970s, the U.S. government decided to phase out all ELVs, except Scout, in favor of the U.S. space shuttle. The shuttle would take all U.S. government satellites, as well as commercial satellites, into orbit. NASA declared the shuttle, which made its first flight in 1981, operational in 1982, and government funding of ELV production ceased in 1983. It quickly became evident, however, that the flight schedule of the shuttle could not meet all of the U.S. security, civil, and commercial launch requirements.[3] *As the need grew for more launches than NASA could handle, some launch vehicle manufacturers expressed interest in offering commercial launch services. In 1982, the first successful private launch in the United States took place – a test launch of the Space Services' prototype Conestoga rocket. The procedures required to gain approval for that launch, however, proved time-consuming and led to the introduction of legislation to make it easier for companies to pursue commercial launch activities. A bill (HR 1011) introduced in the House by Congressman Daniel Akaka (D-HI) would have designated the Department of Commerce as lead agency, while the Senate bill (S 560), introduced by Ernest "Fritz" Hollings (D-SC), intended to give the lead role to the Federal Aviation Administration (FAA). Others suggested the lead go to the Department of State or NASA. While Congress debated the efficacy of its legislation, on July 4, 1982, President Ronald Reagan issued national security decision directive (NSDD) 42, "National Space Policy," stating that expansion of U.S. private sector involvement in civil space activities was a national goal.*[4]

On May 16, 1983, the President issued NSDD 94, "Commercialization of Expendable Launch Vehicles." This stated the "U.S. Government fully endorses and will facilitate the commercialization of U.S. Expendable Launch Vehicles. The U.S. Government will license, supervise, and/or regulate U.S. commercial ELV operations only to the extent required to meet its national and international obligations and to ensure public safety."

Congress affirmed and expanded these actions through the Commercial Space Launch Act, enacted on October 30, 1984. This legislation addressed three substantive areas: licensing and regulation; liability insurance requirements; and access of private launch companies to government facilities."[5]

[2] For more information on the development of the early commercial launch market, consult the 1992 Vice President's Space Policy Advisory Board's report on "The Future of the U.S. Space Industrial Base." Part one is available here: http://history.nasa.gov/33081.pt1.pdf. Part two is available here: http://history.nasa.gov/33081.pt2.pdf (Last Accessed on March 31st, 2016).

[3] During this time, there was also considerable objection to what was seen as a NASA monopoly on the commercial launch market. For more see the June 20, 1984 paper by Milton Copulos, "The Perils of a NASA Space Monopoly," published by the Heritage Foundation. Retrieved at: http://www.heritage.org/research/reports/1984/06/the-perils-of-a-nasa-space-monopoly (Last Accessed on April 4th, 2016).

[4] For more information on the "National Space Policy" consult NASA's fact sheet "'Presidential Directive on National Space Policy,' February 11, 1988." It can be found through the NASA History Office at: http://www.hq.nasa.gov/office/pao/History/policy88.html.

[5] A copy of the Commercial Space Launch Act (P.L. 98-575) can be found at: https://www.gpo.gov/fdsys/pkg/STATUTE-98/pdf/STATUTE-98-Pg3055.pdf.

State of the Commercial Space Launch Industry Today

Since the passage of the *Commercial Space Launch Act* (P.L. 98-575) in 1984, global commercial space launch services are estimated to account for about $6 billion in annual revenue.[6] Most of this launch activity is presumed captive; that is, the most payload operators have existing agreements with launch service providers or do not otherwise "shop around" for a launch.[7] About a third of this $6 billion represents internationally competed, or commercial, transactions.[8] In 2014, U.S. launch service providers accounted for about $2.4 billion in total revenues or 41percent of global launch services.[9] In 2014, the FAA Office of Commercial Space Transportation licensed launches accounted for $617 million of the $2.4 billion.[10] Globally, the commercial space launch industry revenue is experiencing growth, estimated at 9 percent growth in 2015 as compared to 2014, in part due to higher numbers of European and U.S. launches of commercial satellites.[11]

NASA's Relationship with the Commercial Space Launch Industry

NASA's Launch Services Program

The Launch Services Program (LSP) was established at Kennedy Space Center for NASA's acquisition and program management of expendable launch vehicle (ELV) missions. The principal objectives of the LSP are to provide safe, reliable, cost-effective and on schedule launch services for NASA and NASA-sponsored payloads seeking launch on ELVs.[12] The Launch Services Program is responsible for NASA oversight of the launch service including launch vehicle engineering and manufacturing, launch operations and countdown management, and providing added quality and mission assurance in lieu of the requirement for the launch service provider to obtain a commercial launch license. Since 1990, NASA has purchased ELV launch services directly from commercial providers for its missions. In September 2010, NASA's Launch Services (NLS) contract was extended by the agency for 10 years, through 2020, with the award of four indefinite delivery/indefinite quantity contracts to United Launch Alliance (ULA), Space Exploration Technologies (SpaceX), Orbital Sciences Corporation (now Orbital ATK), and Lockheed Martin Space Systems.[13]

Part of LSP's duties include managing the Venture Class Launch Services (VCLS) contracts. NASA's Venture class missions are small- to medium-sized missions that can be designed, built,

[6] Federal Aviation Administration, "The Annual Compendium of Commercial Space Transportation: 2016." January 2016. Retrieved at https://www.faa.gov/about/office_org/headquarters_offices/ast/media/2016_Compendium.pdf.
[7] Ibid., 1.
[8] Ibid., 1.
[9] Ibid., 9.
[10] Ibid., 1.
[11] Satellite Industry Association, "2015 State of the Satellite Industry Report." September 2015. Retrieved at: http://www.sia.org/wp-content/uploads/2015/06/Mktg15-SSIR-2015-FINAL-Compressed.pdf (Last Accessed on April 5th, 2016).
[12] NASA fact sheet, "NASA's Launch Services Program." Retrieved at: http://www.nasa.gov/sites/default/files/files/LSP_factsheet_Nov2011.pdf
[13] NASA fact sheet, "NASA's Launch Services Program." Retrieved at: http://www.nasa.gov/sites/default/files/files/LSP_factsheet_Nov2011.pdf.

and launched in a short period of time. NASA explains the VCLS contract as "a Firm-Fixed Price contract for a dedicated launch service for U-Class satellites with NASA having sole responsibility for the payload on the launch vehicle. NASA's LSP supports the CubeSat Launch Initiative (CSLI) by providing launch opportunities for CubeSats that are currently on the manifest back log."[14]

For example, in October 2015, the LSP awarded multiple VCLS contracts to provide small satellites (also called SmallSats, CubeSats, microsats and nanosatellites) access to low-Earth orbit. The launch-provider companies and the value of their NASA contracts are listed below:

- Firefly Space Systems Inc. of Cedar Park, Texas, $5.5 million
- Rocket Lab USA Inc. of Los Angeles, California, $6.9 million
- Virgin Galactic LLC of Long Beach, California, $4.7 million

According to NASA, "LSP is attempting to foster commercial launch services dedicated to transporting smaller payloads into orbit as an alternative to the rideshare approach and to promote the continued development of the U.S. commercial space transportation industry… VCLS is intended to help open the door for future dedicated opportunities to launch CubeSats and other small satellites and science missions."[15]

Commercial Crew and Cargo

Commercial Crew- Currently, the Russian Space Agency, Roscosmos, provides crew transportation to the International Space Station (ISS). This contract is worth $490 million through 2018.[16] However, NASA is funding U.S. private sector development of crew transportation capabilities to the ISS on domestic launches that can then be procured on a fixed price contract after certification by NASA.[17] NASA hopes to demonstrate this capability in 2017.

NASA awarded contracts to two of the final competitors in the Commercial Crew Program, the Boeing Company (Boeing) and SpaceX. The final phase of the program, Commercial Crew Transportation Capability (CCtCap) provides significant government funding to finalize designs, test various elements, and certify each of the crew systems. The firm-fixed price contract guarantees each company at least two flights to the ISS and as many as six for a total of 12

[14] Found at the Federal Business Opportunities website. Retrieved at: https://www.fbo.gov/index?s=opportunity&mode=form&id=2831d4142a7bb8fd6323b9971add63bc&tab=core&_cview=1 (Last Accessed on April 5th, 2016).
[15] NASA Press Release, "NASA Awards Venture Class Launch Services Contracts for CubeSat Satellites." October 14, 2015. Retrieved at: http://www.nasa.gov/press-release/nasa-awards-venture-class-launch-services-contracts-for-cubesat-satellites.
[16] NASA Press Release, "NASA Notifies Congress about Space Station Contract Modification with Russia," August 5, 2015. Retrieved at: https://www.nasa.gov/sites/default/files/atoms/files/soyuz_seat_modification_letter.pdf
[17] NASA provided $49 million in 2010 for CCDev1, $315 million in 2011 for CCDev2, $1.167 billion for CCiCap in 2012, $29.582 million for CPC in 2012, and $6.8 billion for CCtCap in 2014 for a total of $8.361 billion. See supra 13.

possible flights. The potential contract value is $4.2 billion for Boeing and $2.6 billion for SpaceX.[18]

Commercial Cargo- NASA began funding commercial space transportation services to the ISS in 2006 by funding multiple companies to develop systems for transporting cargo to the ISS with an eye towards eventually having multiple carriers compete for the resupply contract. This was accomplished through the Commercial Orbital Transportation Services (COTS) and Cargo Resupply Services (CRS) programs. NASA purchases cargo transportation to the ISS under the CRS contracts with Orbital ATK and SpaceX and under the CRS2 contract with Orbital ATK, Sierra Nevada, and SpaceX.[19]

In 2008, NASA signed two CRS contracts. The original SpaceX contract was valued at $1.6 billion for 12 missions and the Orbital Sciences contract was valued at $1.9 billion for 8 missions. Through contract extensions, NASA has since awarded SpaceX eight additional and Orbital-ATK two additional space station cargo-supply missions. While the SpaceX contract includes a down-mass capability (returns cargo to Earth), Orbital ATK's Cygnus spacecraft (like the European Space Agency's ATV or the Japanese Space Agency's HTV) has no down-mass capability (by design). In January, 2016, NASA awarded the CRS-2 contracts to SpaceX, Orbital ATK, and Sierra Nevada Corporation. The CRS-2 awardees are to each fly at least six cargo missions, between 2019 and 2024.[20]

Commercial Launch Market Demand

The Federal Aviation Administration's Commercial Space Transportation Forecast is published every year by the FAA's Commercial Space Transportation (AST) office and the Commercial Space Transportation Advisory Committee (COMSTAC). In the April 2015 publication, COMSTAC predicts a "healthy" demand for commercial launch services to geostationary orbit. It projects that the number of commercial launches to geostationary orbit will be 17 launches in 2015 and 18 launches in 2017. The report only forecasts up to 2017 for commercial geostationary launches due to realignment of issuance dates of the report.

For non-geostationary orbit (NGSO) launches, the report predicts a global average of 13.1 launches per year over the next ten years. It forecasts a peak of 19 launches in 2016 due to completion of the Iridium constellation. Once complete, launches will decline to 10-11 per year.[21]

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[18] NASA fact sheet, "NASA's Commercial Crew Program." Retrieved at: https://www.nasa.gov/sites/default/files/files/CCtCapFactSheet.pdf (Last Accessed on April 4th, 2016).

[19] NASA's FY 2017 Budget Estimate. Retrieved at: http://www.nasa.gov/sites/default/files/atoms/files/fy_2017_budget_estimates.pdf (Last Accessed on April 4th, 2016).

[20] NASA Press Release, "NASA Awards International Space Station Cargo Transportation Contracts." January 14, 2016. Retrieved at: http://www.nasa.gov/press-release/nasa-awards-international-space-station-cargo-transport-contracts (Last Accessed on March, 15th, 2016).

[21] Federal Aviation Administration, "2015 Commercial Space Transportation Forecasts." April, 2015. Retrieved at: https://www.faa.gov/about/office_org/headquarters_offices/ast/media/Commercial_Space_Transportation_Forecasts_2015.pdf (Last Accessed on March 31st, 2016).

The report takes into account an expected jump in small satellite constellations to be launched in the coming years. "From 2015 – 2018 the report forecasts a number of small commercial satellites to be launched as Iridium, ORBCOMM, Planet Labs, and Skybox all deploy their constellations."[22]

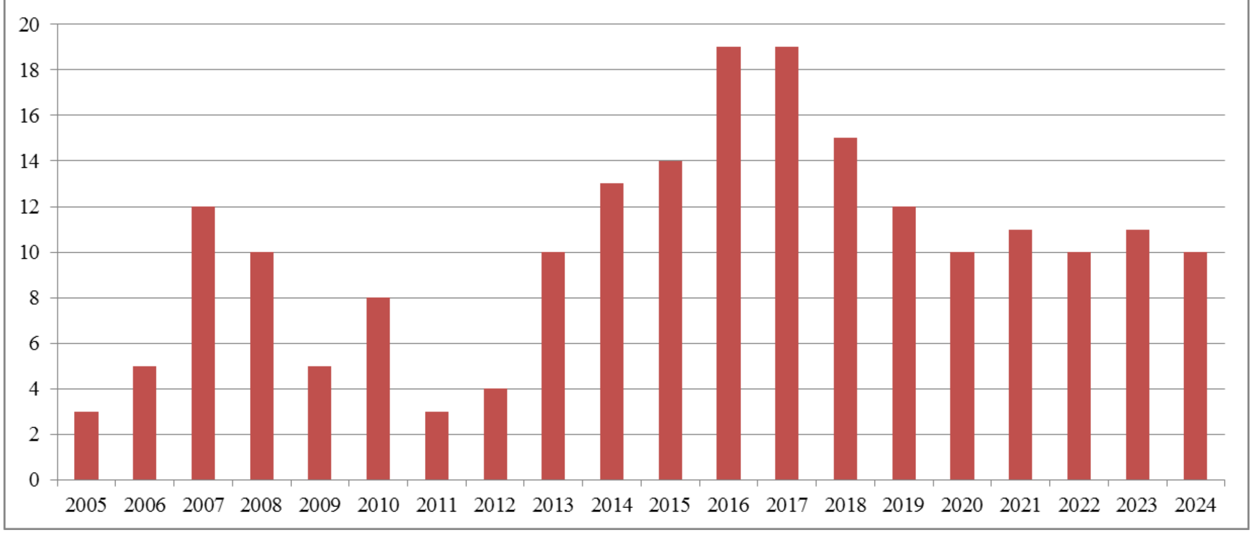

Table 1: NGSO Launch History and Projected Plans

Source: FAA, "2015 Commercial Space Transportation Forecasts."

<u>Commercial Telecommunications and Earth Observation Services Demand</u>

Launch service revenue derived from private sector customers is dominated by commercial telecommunication satellites, but there are an increasing number of commercial Earth observation satellites purchasing launch services. To put the respective size of the telecommunication and Earth observation services sector in perspective: mobile, fixed, and consumer telecommunication satellite servicing revenues account for 98.5 percent of global satellite services ($121.3 billion), with the remaining 1.5 percent derived from commercial Earth observation ($1.6 billion).[23]

According to the Satellite Industry Association's "2015 State of the Satellite Industry Report," Earth observation services grew by 9 percent and mobile satellite services grew by 25 percent in 2014.[24] The major growth in mobile satellite services, according to the report, is due to an increase in data services for aviation customers. Overall, satellite services reported a growth of 4 percent in 2014. In the same year, the launch industry grew by 9 percent as a result of more European and U.S. commercial satellite launches than in 2013.[25]

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[22] Ibid., 3

[23] Satellite Industry Association, "2015 State of the Satellite Industry Report." September 2015. Retrieved at: http://www.sia.org/wp-content/uploads/2015/06/Mktg15-SSIR-2015-FINAL-Compressed.pdf (Last Accessed on April 5, 2016), 11.

[24] Ibid., 13.

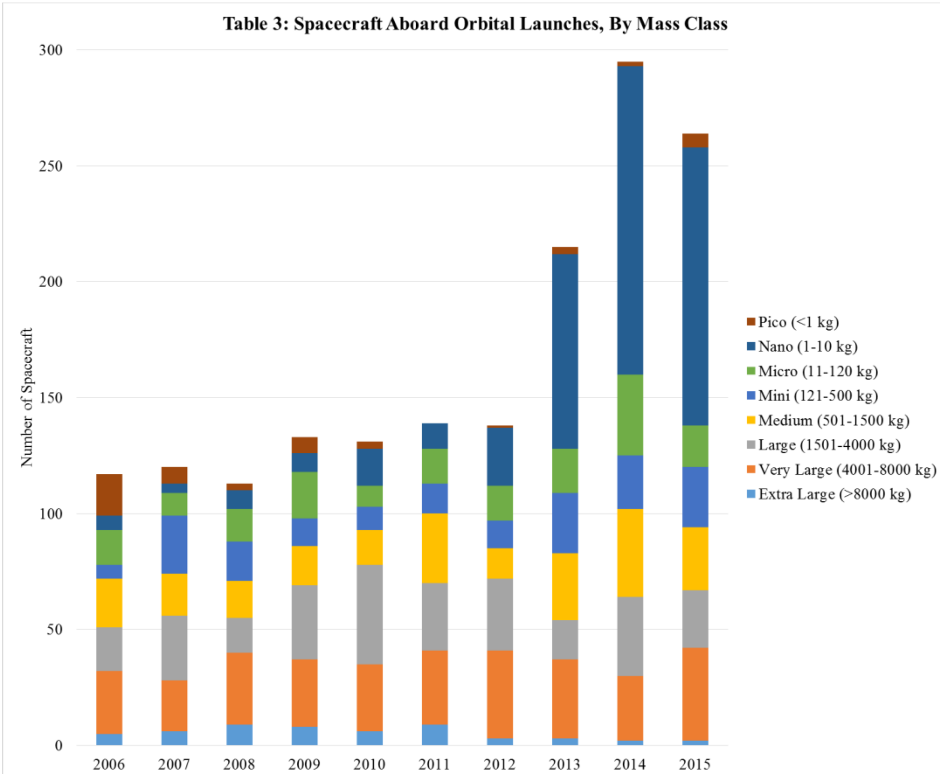
[25] Ibid., 9.

Table 2: Global Revenue for Satellite Services ($billion)					
Year	Consumer[26]	Fixed Satellite[27]	Mobile Satellite[28]	Earth Observation	Total
2014	$100.90	$17.10	$3.30	$1.60	$122.90
2013	$98.10	$16.40	$2.60	$1.50	$118.60
2012	$93.30	$16.40	$2.40	$1.30	$113.50

Small Satellite Demand

Technological advances in computer hardware and sensors allow satellite manufactures to put more capabilities in smaller spacecraft. Small satellites are generally considered those that weigh less than 500 kilograms. Due to their size and low mass, it is much easier to build and launch small satellites than larger satellites. The drawback of small satellites is that they usually do not have the same capabilities as larger satellites. Also, due to the relatively low orbit at which they are deployed, small satellites encounter more atmospheric drag and do not stay in orbit for as long as satellites in higher--like geosynchronous--orbits. On the other hand, constellations of small satellites can be launched more frequently and their hardware can be updated more often. Some estimates have suggested that over the past decade $2.5 billion has been invested in small satellite development.[29] Table 3 shows the significant increase of small satellites launched over the past three years.

[26] Satellite TV, Satellite, Radio, and Satellite Broadband.
[27] Transponder Agreements and Managed Services.
[28] Voice and Data.
[29] Clay Dillow, "Here's why small satellites are so big right now." *Fortune*, August 4, 2015. Retrieved at: http://fortune.com/2015/08/04/small-satellites-newspace/ (Last Accessed on April 1, 2016).



Source: Eurospace LEAT data, courtesy of the Space Foundation

In June 2015, the Science and Technology Policy Institute, a Federally Funded Research and Development Center (FFRDC), published a study sponsored by the National Aeronautics and Space Administration (NASA) and Office of the Director of National Intelligence (ODNI) study titled *Global Trends in Outer Space*. According to this study, small satellite demand for launch services has been increasing and is forecasted to increase significantly over the next few years.

> *Small satellites are not a fundamentally new concept—even the first artificial satellite, Sputnik-1, fits most definitions of a modern small satellite. However, the high cost of launch into space and importance of operational missions has, over time, driven the production of larger, more capable, longer lived, and rigorously reliable satellites. While these satellites are highly capable, they have high production costs. Recently, there has been interest in developing small, low-mass satellites, which have more limited capabilities but cost less to produce.*
>
> *While small satellites have lower component, launch, and development costs, they have significantly less power and functionality on a single platform. Because of these characteristics, small satellites often have higher mission and component risk tolerances and lower lifetime expectations. The lower costs make it simpler to build additional platforms—whether for a constellation or for replacements.*
>
> *The lower cost of smaller satellites is allowing new entities to build, launch, operate, and support satellites, especially in low Earth orbit. In turn, the greater number of interested parties results in a more competitive market for goods and services, driving down costs further. The result has been a spike in the number of small satellites below 50 kilograms in the last few years, which has been projected to increase significantly over the next few*

years based on mission plans and launch manifests. From 2013 to 2014 alone, the number of microsatellites launched in the range of 1–50 kilograms increased 72 percent. Large communication microsatellite constellations have been announced by SpaceX and OneWeb, consisting of 4,025 and 648 satellites, respectively (SpaceWorks Enterprise, Inc. (SEI) 2015). This growth is in sync with an increase in the available market of component and payload suppliers and developers, as well as for launch and satellite service providers for launch, launch integration, ground-station construction or management, and so forth. However, the long-term viability of this market of parts, a sustained demand for missions, and commercial returns on investment are all interlinked claims that remain to be observed.[30]

Commercial Launch Market Supply

Current U.S. Orbital Launch Service Providers

Orbital ATK- The Dulles, Virginia-based Orbital ATK offers three different launch vehicles: the Antares, Minotaur and Pegasus rockets. It is currently developing a medium- to heavy-class rocket that uses solid propulsion.[31]

SpaceX- Space Exploration Technologies (SpaceX) is a Hawthorne, California-based company that offers the Falcon 9 launch vehicle. SpaceX's heavy-lift vehicle, the Falcon Heavy, is scheduled to launch later this fall.[32]

ULA- United Launch Alliance, a joint venture of Lockheed Martin Space Systems and Boeing Defense, Space and Security, is headquartered in Centennial, Colorado and currently operates three different launch vehicles (Atlas V, Delta II and Delta IV). ULA's next launch vehicle, the Vulcan, is currently under development to replace the Atlas V.[33]

U.S. Small Satellite Launch Services

Several new launch vehicles are being developed specifically to address what some believe is latent demand among small satellite operators. [34] These rockets are designed to launch payloads

[30] Bhavya Lal, et al. "Global Trends in Space." Science & Technology Policy Institute, June 2015. Retrieved at: https://www.ida.org/idamedia/Corporate/Files/Publications/STPIPubs/2015/p5242v2.ashx (Last Accessed on April 5, 2016).

[31] Mike Gruss, "Orbital Developing Rocket to Compete With SpaceX, ULA." *SpaceNews*, January 14, 2016. Retrieved at: http://spacenews.com/orbital-developing-rocket-to-compete-with-spacex-ula/ (Last Accessed on March 31, 2016).

[32] Peter B. de Selding, "SpaceX says reusable stage could cut prices 30 percent, plans November Falcon Heavy debut," *SpaceNews*, March 10, 2016. Retrieved at: http://spacenews.com/spacex-says-reusable-stage-could-cut-prices-by-30-plans-first-falcon-heavy-in-november (Last Accessed on April 15, 2016).

[33] Mike Gruss, "ULA's Vulcan Rocket To be Rolled out in Stages." *SpaceNews*, April 13, 2015. Retrieved at: http://spacenews.com/ulas-vulcan-rocket-to-be-rolled-out-in-stages/ (Last Accessed on March 31, 2016).

[34] Federal Aviation Administration, "The Annual Compendium of Commercial Space Transportation: 2016" January 2016. Retrieved at https://www.faa.gov/about/office_org/headquarters_offices/ast/media/2016_Compendium.pdf (Last Accessed April 5, 2016). Federal Aviation Administration, "2015 Commercial Space Transportation Forecasts." April, 2015. Retrieved at:

with masses under 500 kg (1,102 lb) to low Earth orbit (LEO). Though the price per kilogram may remain high relative to larger launch vehicles, presumably there will be additional value in scheduling; small satellite operators, especially those with constellations of many satellites, can have greater control over the orbits their satellites are placed rather than simply being a "piggyback", rideshare secondary payload for a larger satellite. New launch vehicles are in various stages of development, like the Electron by Rocket Lab and LauncherOne from Virgin Galactic.[35]

Foreign Launch Service Providers

China- The China Great Wall Industry Corporation (CGWIC) aggressively pursues international clients via package deals that include satellite manufacturing and launch. However, these CGWIC launch contracts are not internationally competed. China conducted 19 launches in 2015.[36] Also in 2015, China introduced two new small-class launch vehicles, the Long March 6 and the Long March 11.[37] The country continues to develop the Long March 5 and Long March 7, both of which are expected to be launched in 2016 from a new launch site on Hainan Island.[38] Finally, China's human spaceflight program continues development, while the Chinese National Space Agency (CNSA) carries out robotic missions to the Moon. These activities point to an expansion of China into the international commercial launch market.[39]

India- The Indian Space Research Organization (ISRO) and its commercial arm, Antrix Corp., are expanding India's domestic launch capabilities and seeking new commercial opportunities. ISRO's Polar Satellite Launch Vehicle (PSLV) has completed 25 operational missions and India has funded 15 more launches to be completed before 2020.[40] In February of this year, ISRO Chairman, A.S. Kiran Kuman, said that ISRO plans to "largely privatize" the PSLV by 2020 and to increase its launch rate from 12 to 18 per year.[41] India has also developed its Geosynchronous Satellite Launch Vehicle (GSLV) and intends to launch a GSLV Mark-3 (also known as the LMV3) with its new, Indian-made Cryogenic CE-20 engine on the upper stage in December of

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https://www.faa.gov/about/office_org/headquarters_offices/ast/media/Commercial_Space_Transportation_Forecasts_2015.pdf (Last Accessed on March 31, 2016).

[35] Federal Aviation Administration, "The Annual compendium of Commercial Space Transportation: 2016." January 2016. Retrieved at https://www.faa.gov/about/office_org/headquarters_offices/ast/media/2016_Compendium.pdf (Last Accessed April 5, 2016), 2.

[36] Deganit Paikowsky, et al. "Space 2015: A Year In Review." Tel Aviv University, March 2016. Retrieved at: https://pdfs.semanticscholar.org/54cb/99e00456e952a07d8e9eee6e9ab05830b3f2.pdf (Last Accessed on April 5, 2016).

[37] Marcia Smith, "China Debuts Second New Small Rocket, Long March 11." *Space Policy Online.com*, September 25, 2015. Retrieved at: http://www.spacepolicyonline.com/news/china-debuts-second-new-small-rocket-long-march-11 (Last Accessed, March 31, 2016).

[38] Bradley Perrett, "Long March 7 Is Delayed Again, Due To Fly In 2016." *Aviation Week*, March 25, 2015. Retrieved at: http://aviationweek.com/space/long-march-7-delayed-again-due-fly-2016 (Last Accessed on March 31, 2016).

[39] Federal Aviation Administration, "The Annual Compendium of Commercial Space Transportation: 2016".

[40] Peter B. de Selding, "India Oks Budget for Building, Launching 15 PSLV Rockets by 2020." *SpaceNews*, May 22, 2015. Retrieved at: http://spacenews.com/india-to-build-and-launch-15-pslv-rockets-by-2020/ (Last Accessed on March 29, 2016).

[41] Srinivas Laxman, "Plan to largely privatize PSLV operations by 2020: ISRO chief." *The Times of India*, February 15, 2016. Retrieved at: http://timesofindia.indiatimes.com/india/Plan-to-largely-privatize-PSLV-operations-by-2020-Isro-chief/articleshow/50990145.cms (Last Accessed on March 29, 2016).

2016.[42] On the GSLV Mark-3's maiden voyage in 2014, it demonstrated re-entry and recovery of an experimental crew capsule.[43]

Russia- On January 1, 2016, Russia's Federal Space Agency Roscosmos was dissolved and all of its responsibilities transferred to the Roscosmos state corporation.[44] Roscosmos' two main launch vehicles, the Soyuz and Proton, launch regularly. The Proton had 8 launches in 2015.[45] The Soyuz had 17 launches in 2015.[46] Among its capabilities, the Soyuz is currently used to bring astronauts and cosmonauts to the International Space Station. The Soyuz rocket also launches from the European Space Agency's Guiana Space Center in South America. The Proton launch vehicle is used for both Russian government and commercial satellites launches. Russia intends to phase out the Proton rocket by 2025 and replace it with the Angara A5, which completed a successful first test flight in 2014.[47] Russia is also planning to phase out its Dnepr launch vehicle, which was based on decommissioned Russian intercontinental ballistic missiles, and its Zenit medium-class rocket.[48,49]

European Space Agency (ESA)- In addition to the Soyuz, ESA uses the Ariane 5 launch vehicle and the Vega small launch vehicle. The French-based company Airbus Defense and Space is the Ariane 5's prime contractor. The Italian Space Agency, in cooperation with ESA developed the Vega launch vehicle that is used to launch small satellites. In August 2015, ESA committed over $3 billion to upgrade both the Arianne and Vega launch vehicles. The Ariane 6 and the Vega-C are expected to debut in 2020 and 2018, respectively.[50]

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[42] K.S. Jayaraman, "India's heavy-lift rocket on track for December debut following engine test." *SpaceNews***,** February 22, 2016. Retrieved at: http://spacenews.com/indias-heavy-lift-rocket-on-track-for-december-debut-following-engine-test/ (Last Accessed on March 29, 2016).

[43] K.S. Jayaraman, "India Tests GSLV-3 Rocket and Crew Capsule with Suborbital Launch." *SpaceNews*, December 18, 2014. Retrieved at: http://spacenews.com/india-tests-gslv-3-rocket-and-crew-capsule-with-suborbital-launch/ (Last Accessed on March 29, 2016).

[44] Avanesh Pandey, "Russia's Federal Space Agency Dissolved, Responsibilities To Be Transferred To State Corporation." *International Business Times***,** December 28, 2015. Retrieved at: http://www.ibtimes.com/russias-federal-space-agency-dissolved-responsibilities-be-transferred-state-2240831 (Last Accessed on March 29, 2016).

[45] Federal Aviation Administration, "The Annual Compendium of Commercial Space Transportation: 2016"

[46] Federal Aviation Administration, "The Annual Compendium of Commercial Space Transportation: 2016"

[47] Warren Ferster, "Russia Aims To Retire Proton in 2025 as Angara Takes Over." *SpaceNews*, March 17, 2015. Retrieved at: http://spacenews.com/russia-aims-to-retire-proton-in-2025-as-angara-takes-over/ (Last Accessed on March 30, 2016).

[48] Doug Messier, "IMF: Ukraine Space Sector Possibly Suffered 80 Percent Revenue Loss." *Parabolic Arc*, February 15, 2016. Retrieved at: http://www.parabolicarc.com/2016/02/16/ukraine-space-sector/ (Last Accessed on April 4, 2016).

[49] Ibid.

[50] Peter B. de Selding, "ESA Inks $3.8 Billion in Contracts for Ariane 6, Vega-C and Spaceport Upgrades." *SpaceNews*, August 12, 2015. Retrieved at: http://spacenews.com/esa-inks-3-8-billion-in-contracts-for-ariane-6-vega-c-and-spaceport-upgrades/ (Last Accessed on March 30, 2016).

Table 4: Orbital Launch Vehicles by Lifting Capability					
Vehicle	**Provider**	**Country**	**kg to LEO**	**kg to GTO**	**First launch**
Cab-3A	CubeCab	USA	5	N/A	2017*
Lynx Mark III	XCOR Aerospace	USA	10	N/A	2018*
GOLauncher-2	Generation Orbit	USA	45	N/A	2017*
Electron	Rocket Lab	USA	150	N/A	2016*
SOAR	Swiss Space Systems	Switzerland	250	N/A	2018*
LauncherOne	Virgin Galactic	USA	400	N/A	2017*
Firefly	Firefly Space Ststems	USA	400	N/A	2017*
Pegasus	Orbital ATK	USA	450	N/A	1994
Minotaur I	Orbital ATK	USA	580	N/A	2000
Long March 11	PLA	China	700	N/A	2015
Minotaur IV	Orbital ATK	USA	1,600	N/A	2010
Vega	Arianespace	France	1,963	N/A	2012
Rokot	VKS/Eurockot	Russia	2,150	N/A	1990
XS-1	DARPA	USA	2,267	N/A	2018*
Stratolaunch	Startolaunch Systems	USA	3,000	N/A	2016*
Dnepr	ISC Kosmotras	Russia	3,200	N/A	1999
Minotaur V	Orbital ATK	USA	N/A	532	2013
PSLV	ISRO/Antrix	India	3,250	1,425	1993
Detla II	ULA	USA	3,470	N/A	1998
Angara 1.2	Roscosmos	Russia	3,800	N/A	2014
GSLV	ISRO/Antrix	India	5,000	2,500	2001
Antares	Orbital ATK	USA	7,000	N/A	2013
Soyuz FG	VKS/Roscosmos	Russia	7,800	N/A	2001
GSLV Mark-3 (LMV3)	ISRO/Antrix	India	8,000	4,000	2016*
Delta IV (Medium)	ULA	USA	12,900	6,160	2002
Falcon 9	SpaceX	USA	13,150	4,850	2010
Long March 7	PLA	China	13,500	N/A	2017*
Minotaur-C	Orbital ATK	USA	14,580	N/A	2016*
Long March 6	PLA	Russia	15,000	N/A	2015
Vulcan	ULA	USA	18,510	8,900	2019*
Atlas V	ULA/LMCLS	USA	18,814	8,900	2002
Ariane 5	Arianespace	France	21,000	9,500	1996
Ariane 6	Arianespace	France	21,000	11,000	2020*
Proton M	VKS/Roscosmos/ILS	Russia	23,000	6,920	2001
Angara A5	Roscosmos	Russia	24,500	7,500	2014
Long March 5	PLA	China	25,000	14,000	2016*
Delta IV Heavy	ULA	USA	28,370	13,810	2004
Falcon Heavy	SpaceX	USA	53,000	21,200	2016*
Blue Origin Vehicle	Blue Origin	USA	Undisclosed	Undisclosed	2020*

Data taken from FAA 2016 Compendium and respective launch service provider's website. Numbers reflect maximum lifting capabilities.

Reusable Vehicles

A majority of launch costs is vehicle hardware. For some launch providers, the first-stage engine alone makes up to 65 percent of the total launch cost.[51] To drive down launch costs, many companies are looking at ways to reuse launch vehicle components, rather than discarding them after launch. Some estimates say that reusing such launch components could reduce costs by a factor of 100.[52] With the possibility of dramatically reducing launch costs, some launch companies are investing in reusable launch vehicle technologies. The Space Transportation System (Space Shuttle) was partially reusable as well; however, inspection, maintenance, and refurbishment of reusable components for a human-rated launch system proved to be more far expensive than originally planned.[53]

SpaceX and Blue Origin have demonstrated the ability to land and recover the first stage of a launch vehicle. SpaceX has landed and recovered their first stage after delivering its second stage to an intended orbit.[54] Blue Origin has landed and recovered their first stage after delivered a suborbital payload. The goal of recovering the first stage of a launch vehicle is to refurbish and reuse the first stage for future launches. ULA has proposed a method to detach the engine of a launch vehicle after the first stage and float it back to the Earth with parachutes where a helicopter can then catch the hardware.[55] Airbus has proposed a similar method where the engine, avionics, and propulsion bay of the first stage detach and glide back to Earth with winglets and land on a runway.[56]

Key National Policy Issues

Use of Excess ICBM Motors

Since 1998, national policy is that excess U.S. intercontinental ballistic missiles or their components should not be used for commercial launch services. The 2013 National Space Transportation Policy states: "Excess U.S. ballistic missiles [or their components] shall either be retained for government use or destroyed," and that departments and agencies may use them on a

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[51] Doug Cameron, "How to Catch a Rocket With a Helicopter." *The Wall Street Journal*, April 14, 2015. Retrieved at: http://www.wsj.com/articles/how-to-catch-a-rocket-with-a-helicopter-1429055300 (Last Accessed on March 31, 2016).

[52] Jessica Orwig, "Elon Musk's rocket landing could make space travel costs cheaper than a penthouse in NYC." *Business Insider*, December 22, 2015 (Last Accessed on March 31, 2016). Retrieved at: http://www.businessinsider.com/how-reusable-rocket-tech-will-revolutionize-spaceflight (Last Accessed on March 31, 2016).

[53] "Space Transportation: The Content and Uses of Shuttle Cost Estimates" GAO Report NSAID-93-115 (January 28th, 1993). Retrieved at: http://www.gao.gov/products/NSIAD-93-115 (Last Accessed on March 31, 2016).

[54] Jeff Foust, "Blue Origin Refiles New Shepard suborbital vehicle." *SpaceNews*, January 23, 2016. Retrieved at: http://spacenews.com/blue-origin-reflies-new-shepard-suborbital-vehicle/ (Last Accessed on March 31, 2016).

[55] Justin Ray, "ULA unveils its future with the Vulcan rocket family." *Spaceflight Now*, April 13, 2015. Retrieved at: http://spaceflightnow.com/2015/04/13/ula-unveils-its-future-with-the-vulcan-rocket-family/ (Last Accessed on April 4, 2016).

[56] Peter B. de Selding, "Meet Adeline, Airbus' Answer To SpaceX Reusability." *SpaceNews*, June 5, 2015. Retrieved at: http://spacenews.com/meet-adeline-airbus-response-to-reusable-spacex-rocket/ (Last Accessed on April 4, 2016).

"case-by-case" basis. The policy also directs that agencies should only use ICBMs in a way that "limits the impact on the U.S. space transportation industry."[57]

According to Federal law, departments and agencies may use such excess ballistic missile assets, including rocket motors, to launch payloads into orbit on a case-by-case basis with the approval of the Secretary of Defense and notification to Congress that: (1) the use would result in cost-savings to the Federal Government when compared to the cost of acquiring space transportation services from United States commercial providers; (2) meets all mission requirements for the agency, including performance, schedule, and risk; and (3) is consistent with the international obligations of the United States.[58] Federal law also requires the Federal Government to acquire space transportation services from United States commercial providers whenever such services are required in the course of its activities, subject to a number of exceptions.[59] Launch vehicles derived from excess ballistic missiles are subject to this requirement and can only be acquired if an exception is determined.

There are examples of companies that use excess ICBM assets. In 1997, for example, the U.S. Air Force awarded its Orbital/Suborbital Program (OSP) contract to Orbital Sciences Corporation (now Orbital ATK), which helped the company develop its Minotaur line of launch vehicles that use decommissioned ICBM rocket motors in combination with commercially built upper-stage motors. Orbital ATK continues to develop and use such launch vehicles. In 2013, NASA launched the Lunar Atmosphere and Dust Environment Explorer (LADEE) to the Moon on a Minotaur V. In total, the Minotaur family has launched 25 variants since 2000, all successfully.[60] In July 2015, the Air Force awarded Orbital ATK a $23.6 million contract to launch a small satellite aboard a Minotaur IV rocket in 2017.[61] The Aerospace Industry Association claims that using ICBMs as launch vehicles is only marginally cheaper than using other vehicles on the market.[62] This is due to costs associated with storing, maintaining and converting the missiles to usable launch vehicles.[63]

Indian Launch Services

[57] The National Space Transportation Policy, November 21, 2013. Retrieved at: http://www.nasa.gov/sites/default/files/files/national_space_transportation_policy_11212013.pdf (Last Accessed on April 4, 2016).
[58] 51 U.S.C. §50134 (2016)
[59] 51 U.S.C. §50131 (2016)
[60] Minotaur Fact Sheet, Orbital ATK. Retrieved at: https://www.orbitalatk.com/flight-systems/space-launch-vehicles/minotaur/ (Last accessed on April 15, 2016)
[61] Mike Gruss, "U.S. Air Force's ORS-5 Satellite To Launch on Minotaur 4." *SpaceNews*, July 9, 2015. Retrieved at: http://spacenews.com/u-s-air-forces-ors-5-satellite-to-launch-on-minotaur-4/ (Last Accessed on April 4th, 2016).
[62] Aerospace Industries Association, "America's Space Propulsion Industrial Base is at Risk." Retrieved at: http://www.aia-aerospace.org/assets/AIA_Space_Propulsion_Industrial_Base_Issue_Paper.pdf (Last Accessed on April 4th, 2016).
[63] Aerospace Industries Association, "America's Space Propulsion Industrial Base is at Risk." Retrieved at: http://www.aia-aerospace.org/assets/AIA_Space_Propulsion_Industrial_Base_Issue_Paper.pdf (Last Accessed on April 4th, 2016).

The United States has a long-standing policy of not supporting the development or acquisition of space transportation systems in non-Missile Technology Control Regime (MTCR) countries.[64] The Missile Technology Control Regime is an informal and voluntary association of countries which share the goals of non-proliferation of unmanned delivery systems capable of delivering weapons of mass destruction, and which seek to coordinate national export licensing efforts aimed at preventing their proliferation.[65] The MTCR was originally established in 1987 by Canada, France, Germany, Italy, Japan, the United Kingdom and the United States. Since that time, the number of MTCR partners has increased to a total of thirty-four countries, all of which have equal standing within the Regime. India is a not a member of the MTCR. However, U.S. policy is to support India's entry to the MTCR.[66] India formally submitted an application in June 2015, with active support from the United States. [67] This submission is still under consideration. [68] According to *Foreign Policy:*

> *India has applied for MTCR membership as a part of its efforts to integrate itself with the global non-proliferation community….the efforts began right after its nuclear tests in 1998, when India expressed its support for the basic objectives of the NPT—marking a complete turnaround from the approach it had previously demonstrated. The United States, one of the founding designers of the existing global non-proliferation architecture, realized that while India would not join the NPT, it could play a crucial role in strengthening other non-proliferation and export control bodies. This was the premise of the India-U.S. nuclear initiative which began in 2005, and over the years, the importance of integrating India with the global non-proliferation architecture has now been realized by many other governments, including Australia, Canada, France, Germany, Japan, Russia, South Korea and the United Kingdom.*[69]

On July 20, 2009, the United States and India signed a Technology Safeguards Agreement which changed U.S. Government (USG) policy to permit the launch of civil or non-commercial satellites containing U.S. ITAR-controlled components on Indian space launch vehicles.[70] However, this agreement did not include permission to launch commercial satellites. On a case-by-case basis, U.S. companies must receive a license to export satellites to India for launch that waives the non-MTCR compliant acquisition of launch services policy prohibition. In 2015, Spire Inc. of San Francisco, California, was the first company to have its cubesats to launch from

[64] The National Space Transportation Policy, November 21, 2013. Retrieved at: http://www.nasa.gov/sites/default/files/files/national_space_transportation_policy_11212013.pdf (Last Accessed on April 4th, 2016).

[65] The Missile Technology Control Regime Retrieved at: http://www.mtcr.info/english/ (Last Accessed on April 18th, 2016)

[66] Tom Kington, "Italy Blocks Indian Application to MTCR." *DefenseNews*, October 17, 2015. Retrieved at: http://www.defensenews.com/story/defense/policy-budget/warfare/2015/10/17/italy-blocks-indian-application-mtcr-uav-missile-technology-control-regime/74019832/ (Last Accessed on April 6th, 2016).

[67] Ibid.

[68] Ibid.

[69] Arka Biswas, "India and the Missle Regime." *ForeignPolicy,* September 18, 2015. Retrieved at: http://foreignpolicy.com/2015/09/18/india-and-the-missile-regime/ (Last Accessed on April 6, 2016).

[70] DDTC guidance governing the export of satellites to India for launch is provided under "Licensing Satellite Components for Launch from India (August 8th, 2009). Retrieved at: https://www.pmddtc.state.gov/licensing/documents/WebNotice_IndiaLaunch-updated.pdf (Last Accessed on April 6th, 2016).

India.[71] Skybox Imaging of Mountain View, California, owned by Google's Alphabet , has contracted for multiple commercial imaging satellites to launch on the PSLV.[72] PlanetiQ of Boulder, Colorado, has contracted for a late 2016 launch, and Airbus Defence and Space of Europe has launched commercial Spot 6 and Spot 7 Earth observation satellites, both with U.S. components, on PSLV rockets.[73,74]

According to the United States Trade Representative (USTR), some satellite operators and manufactures are asking for increased access to Indian launch services due to what they see as a shortage of U.S. launch capacity.[75] Others, including the Commercial Space Transportation Advisory Committee (COMSTAC), have warned against increasing access because "India's state-owned and controlled launch providers whose pricing structures and related costs are not able to be confirmed as market-based hold the potential to distort the conditions of competition."[76]

Hosted Payload/Ride Share Challenges

A hosted payload is a module that connects to a commercial satellite. The module shares the host satellite's power supply but operates on its own, independent of the host. Commercial satellites launch regularly and the modular design of hosted payloads in principle makes them easy to install. Some in the U.S. space industry see hosted payloads as an efficient method of launching Federal Government payloads, such as the Space Based Surveillance follow-on mission, but raise concerns that the DoD and other government agencies have resisted committing to hosted payloads.[77,78]

Another option for launching small payloads exists in the form of rideshares. Sometimes, launch service providers will have extra room in a launch vehicle and open up the space for secondary payloads. These slots are often filled by small payload that ride along with the primary payload

[71] Spire Inc. press release, "First of Many: Beginning of First Ever Commercial Weather Network Satellites to Reach Orbit." September 28, 2015. Retrieved at: https://spire.com/insights/news/first-commercial-weather-satellite-network/ (Last Accessed on April 6, 2016).
[72] Peter B. de Selding, "PSLV Rocket Launches India's 1st Astronomy Satellite, 4 Spire Cubesats." *SpaceNews*, September 28, 2015. Retrieved at: http://spacenews.com/pslv-rocket-launches-indias-1st-astronomy-satellite/ (Last Accessed on April 6, 2016).
[73] Peter B. de Selding, "PSLV Rocket Launches India's 1st Astronomy Satellite, 4 Spire Cubesats." *SpaceNews*, September 28, 2015. Retrieved at: http://spacenews.com/pslv-rocket-launches-indias-1st-astronomy-satellite/ (Last Accessed on April 6, 2016).
[74] Jeff Foust, "PlanetiQ Selects India's PSLV to Launch its First Satellites." *SpaceNews*, December 3, 2015. Retrieved at: http://spacenews.com/planetiq-selects-indias-pslv-to-launch-its-first-satellites/ (Last Accessed on April 6, 2016).
[75] Jeff Foust, "U.S. Considers Making it Easier To Launch from India." *SpaceNews*, October 23, 2015. Retrieved at: http://spacenews.com/u-s-considers-making-it-easier-to-launch-from-india/ (Last Accessed on March 31st, 2016).
[76] COMSTAC Observations, Findings, and Recommendations to the Associate Administrator for Commercial Space Transportation (January 29, 2016).
[77] Mike Gruss, "Hosted Payload Hopefuls Eye Air Force's SBSS Follow-on System." *SpaceNews*, October 21, 2015. Retrieved at: http://spacenews.com/hosted-payload-hopefuls-eye-air-forces-sbss-follow-on-system/ (Last Accessed on March 31, 2016).
[78] Kay Sears, "What's Holding Back the Adoption of Hosted Payloads?" *SatCom Frontier*, March 8, 2016. Retrieved at: http://www.intelsatgeneral.com/blog/whats-holding-back-the-adoption-of-hosted-payloads/ (Last Accessed on March 31, 2016).

but are deployed separately. Rideshares are subject to launch delays encountered by the primary payload and are bound to whichever orbit the primary payload chooses.